Improving Public Transportation to Boston Logan International Airport

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ABSTRACT
Boston Logan International Airport is the largest airport in New England and the 19th busiest airport in the United States, serving 29.3 million passengers (arrivals and departures) in 2012. There are approximately 36,900 inbound air passenger trips and 9,000 inbound employee trips to Logan Airport daily. As a result of the limited parking supply at Logan Airport (parking is capped at 20,938 spaces by the Department of Environmental Protection's parking freeze), physical capacity constraints, limited roadway capacity and congestion on airport roadways, it is critical to improve public transportation to Logan Airport to increase the transit mode share.

This study evaluates how public transportation to Logan Airport can be improved with particular consideration of travel demand market segments, the user friendliness of the services, the needs and jurisdiction of stakeholder agencies (Massport, the MBTA and MassDOT), existing transportation and land use plans within the study area and user and agency costs.

A review of existing travel demand to Logan Airport and the operation of existing transit services is provided, leading to an assessment of potential improvements. The major potential areas of improvement analyzed in this paper are airport signage, wayfinding and curbside layout, Massport public transportation services (such as the airport shuttles and Logan Express bus service), potential new vehicle technologies for the Silver Line, operational improvements to the Silver Line, infrastructure improvements at D Street and the South Boston Transitway, and future transit connections to Worcester and Chelsea.

The main areas where Massport, MassDOT and the MBTA should invest their resources in the short-term to improve public transportation to Logan Airport are:

- Decreasing the running time of the Silver Line through operational improvements and infrastructure upgrades at D Street and the Transitway
- Providing free outbound trips for the Silver Line, Blue Line and Logan Express
- Improving the ease of transferring to transit at Logan Airport
- Introducing new transit services to Chelsea and Worcester

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Executive Summary

Boston Logan International Airport is the largest airport in New England and the 19th busiest airport in the United States, serving 29.3 million passengers (arrivals and departures) in 2012. There are approximately 36,900 inbound air passenger trips and 9,000 inbound employee trips to Logan Airport daily. As a result of the limited parking supply at Logan Airport (parking is capped at 20,938 spaces by the Department of Environmental Protection's parking freeze), physical capacity constraints, limited roadway capacity and congestion on airport roadways, it is critical to improve public transportation modes to Logan Airport to increase the transit mode share. Even if Massport's goal of attaining a 35.2% HOV mode split at the 37.5 million annual passenger level is achieved, vehicle volumes on airport roadways will increase by approximately 27% and demand for parking will exceed capacity. This indicates the need for a much more aggressive HOV target, such as 44%, in order to capture most of the growth in employee and passenger travel to Logan Airport by HOV modes. This study has focused on evaluating and recommending strategies to improve public transportation to Logan Airport.

Existing Access Patterns

A review of existing ground access demand and performance of existing services revealed the following:

- Employees represent a sizable market segment and their arrival and departure times are staggered throughout the day, indicating the need for transit services that provide coverage in the early morning and late evening
- Air passenger and employee trip origins are distributed throughout Logan Airport's catchment area, highlighting the need for an integrated system of complementary transit services that can serve both local and regional trips
- The Blue Line is faster than the Silver Line for passengers traveling from Logan Airport to destinations on the Blue Line, Green Line or Orange Line, indicating the desirability of both increasing the Silver Line's operating speed and enhancing the Blue Line by improving the shuttle connection at Logan Airport, facilitating the ease of transferring to the shuttle at the airport terminals and long-range improvements such as Blue Line extensions to Charles Street and to Lynn

Massport Data Collection

The following recommendations are made for Massport in order to improve its data collection program:

- Install Automatic Passenger Counters (APC) on Silver Line buses in order to collect ridership data more effectively
- When completing the Environmental Data Report, distinguish between entrances at Airport Station on the Airport-side and on the community side. Only entrances on the Airport side should be counted; the existing survey includes entrances on the community side, which contribute a significant number of non-airport related trips to the totals
- Improve the Logan Airport Employee Survey by conducting it every 2 years (instead of the present schedule of every 5 years) and including employers in the survey in order to learn about and document their policies and subsidies (for parking, transit, carpooling, etc.) more comprehensively.

- Improve the methodology of the employee survey to avoid modally-biased results (i.e. handing out surveys on a particular transportation mode) and consider the use of a web-based survey accessed through individual web links.

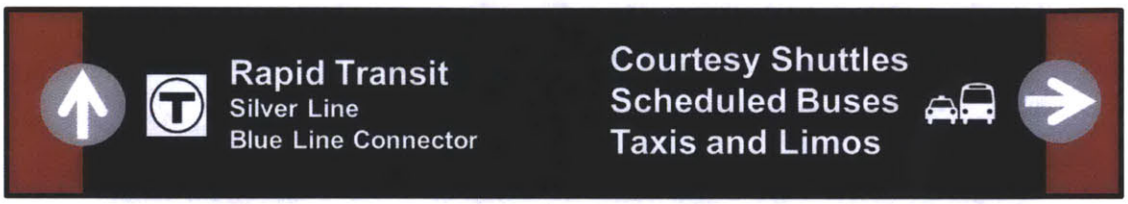
Signage and Wayfinding

A critical element of a passenger's journey is the transfer between the airport terminal and the public transportation mode. To improve the ease of transferring to transit at Logan Airport, Massport should implement the following changes:

- Create a Rapid Transit Zone in a central location at each terminal curb for the Silver Line and shuttle to Airport Station. Logan Express services should be adjacent to this zone
- Re-brand the airport shuttle service as the "Blue Line Connector" or the "Blue Line Express" so that it is more recognizable to users
- Present the Airport Station Shuttle ("Blue Line Connector") more prominently on the MBTA system map
- Provide a free ticket to enter Airport Station on the airport shuttles, to provide symmetry with the existing free Silver Line program
- Improve the comfort of waiting areas and consider potential waiting areas inside the terminal with seating and a clear view of the transit mode through a window
- Improve signage and terminology to provide a logical and comprehensible sequence of information to unfamiliar users. Some sample signage is shown below.

Primary Signage: Intended for when users first enter the arrivals hall

Secondary Signage: Potentially placed above the terminal doors



Tertiary Signage: Placed at the terminal curb

There are also opportunities to reconfigure the layout of the curb at Airport Station in order to improve the signage and increase the directness of the transfer from the station to the shuttle loading area. Further, improved signage at South Station would improve passenger wayfinding.

Airport Shuttles

The existing Airport Shuttle service connecting the airport terminals with Airport Station on the Blue Line is convenient, reliable and well-run. A shared shuttle service that serves both Airport Station and the new Consolidated Rental Car Facility (Conrac) is not recommended, because transit users traveling to the Airport will have to wait while the bus travels to Conrac and while Conrac passengers board. This will increase the travel time for transit passengers and decrease the convenience of the existing service. Providing access to the upper terminal level for Conrac shuttles, as under consideration by Massport, can improve customer service for passengers flying out of Logan and reduce congestion at the lower level.

Logan Express

The number of employees using the Logan Express services has been steadily increasing, while the number of air passenger trips has declined, as shown in **Figure ES-1**. In 2011, the split between passenger trips and employee trips was 55% to 45%. Effective employee subsidies for parking and tickets for Logan Express services are likely causes of the increasing share of employee trips.

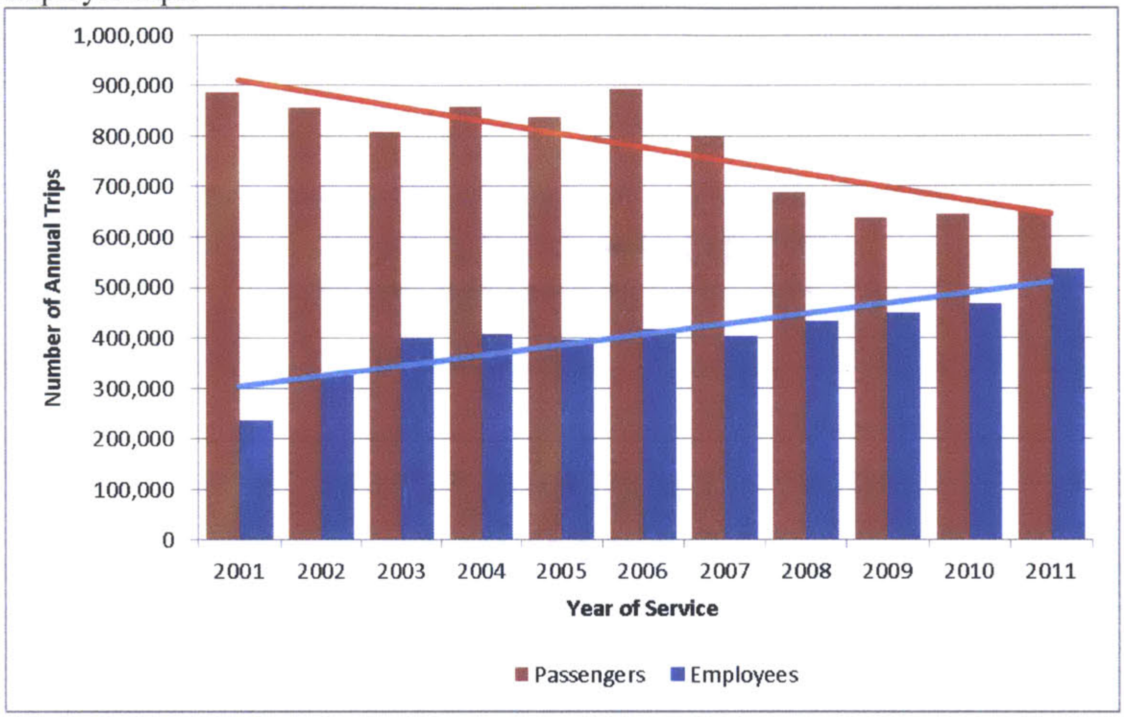


Figure ES-1: Number of Annual Passenger and Employee Logan Express Trips, 2001 to 2011

A review of average load factors indicated that most buses have surplus capacity, suggesting that over-crowding is not the cause of declining air passenger volumes. Rather, the cost of parking and Logan Express tickets are the likely cause of the declining number of air passengers. To reverse this trend and encourage new ridership, free outbound Logan Express trips are recommended. Massport should study the extent to which the inbound fare should be increased to offset the cost of providing free outbound boardings.

A review of the ridership figures indicates that ridership on the Peabody route is low enough to warrant experimenting with the use of smaller vans or shuttles at increased frequencies (instead of coach buses). If there is a positive ridership response to increased frequency, then increasing frequency should be considered for other routes such as Braintree or Woburn.

Future Silver Line Vehicle Technology
A review of available bus propulsion technologies led to the following conclusions and recommendations for the Silver Line vehicles:

- There is no proven alternative to the dual mode technology that is currently available for the Silver Line vehicles
- The MBTA should proceed with the midlife rebuild of the existing dual mode fleet to ensure that the buses are fit to continue service for the next 5+ years
- Battery electric propulsion technology currently shows promise for future procurement options for the Silver Line; Massport should purchase a few of the currently available vehicles for testing
- The feasibility of pure electric operation of hybrid vehicles on the Silver Line route is still questionable, and should be further tested
- Design for eventual new Silver Line vehicles should include lower profile buses to provide additional flexibility for the buses to fit on the upper level of the Airport terminals

Silver Line Operational Improvements
A review of AVL data for the Silver Line revealed that the longest portions of the trip are the surface portion between World Trade Center and Logan Airport, and travel on airport roadways. The section of the trip between World Trade Center and the Ted Williams Tunnel is characterized by circuitous routing and multiple stops (see figure **ES-2**) for the at-grade intersection with D Street, the technology transition and Silver Line Way.

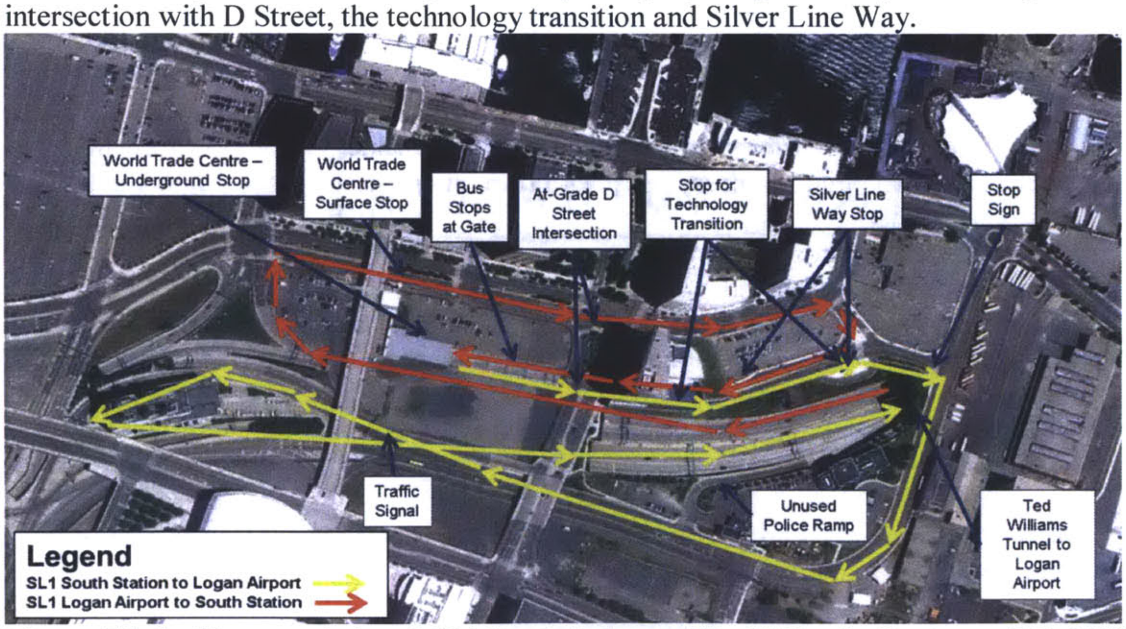


Figure ES-2: Characteristics of SL1 Route between World Trade Center and Ted Williams Tunnel

To improve the quality of the Silver Line, the following strategies are recommended:

Shorter Term:

- Study and implement Transit Signal Priority (TSP) to reduce Silver Line delay at the intersection of D Street and the Transitway. TSP will not be a viable long-term solution, however, as a result of growing congestion in the surrounding roadway network. As congestion increases, queues on Congress Street may even increase the travel time for the Silver Line return trip as it travels through this corridor
- Initiate planning and design of grade separation of the South Boston Transitway at D Street
- Allow Silver Line buses to use the South Boston Emergency Access Ramp on the trip from South Station to Logan Airport, after making any necessary adjustments to the ramp and I-90 to ensure safe merging conditions, adequate sight distance, etc.
- Continue the fare-free boardings of the Silver Line at all Logan Airport terminals, as the program has reduced dwell times and resulted in a ridership increase
- Decrease headways to 8 minutes immediately in order to reduce crowding under existing conditions. Eight minute headways should be attainable using the existing SL1 fleet size, and additional buses could be retrofit with luggage racks and reallocated to the SL1 from the SL2 or short-turn shuttle route
- Consider further decreasing headways to 5 minutes and launching an aggressive marketing campaign to attract new riders to the service. If there are not enough buses available, consider reallocating buses from the SL2 and short-turn shuttle route to the SL1 until more buses are available. Buses must be retrofit to have the luggage racks before being used on the SL1.
- Run additional Silver Line buses during the Government Center closure to serve passengers who would transfer from the Green Line to the Blue Line at Government Center under normal circumstances. Consider also running buses via the Sumner and Callahan Tunnels between Logan Airport and Haymarket Station, which is accessible to both Orange Line and Green Line passengers
- Instruct SL1 operators to stop only once for the technology transition at Silver Line Way (instead of stopping once underneath the John Hancock building and then again at Silver Line Way) in order to reduce the number of stops for passengers
- Re-configure the platform at South Station so that the SL1 bus only stops at the first stop and leaves without excessive dwell on the platform. Platooning of SL1 and SL2 buses can be introduced to limit boarding and alighting time of non-Airport passengers on the SL1
- Fix the real-time "next bus arrival time" displays for the Silver Line at Logan Airport, as have been observed to malfunction

Recommendations Contingent upon the Availability of a Suitable Vehicle Technology:

- Use a new vehicle technology which does not require a technology transition between the Transitway and surface streets to reduce passenger delay
- Eliminate Silver Line Way stop for Silver Line 1 (in the meantime, buses must stop at Silver Line Way for the technology transition so passenger boarding and alighting should continue)

Longer Term:

- Grade separate D Street and the South Boston Transitway
- Consider a tunnel connection that directly links the westbound I-90 with the Transitway so that buses returning from Logan Airport do not need to use surface streets

Potential Future Transit Services

- Worcester is a major population center in Massachusetts with fairly inconvenient existing transit connections to Logan Airport. To better serve this market, consider extending some Framingham Logan Express buses to Worcester to test the demand. At first, buses could be run hourly. Monitor whether new riders use the service, or whether passengers presently boarding at Framingham simply shift to Worcester. If a significant level of new demand is attracted to the service, Massport should consider introducing a new Logan Express route that serves Worcester exclusively.
- MassDOT is presently studying a Silver Line 6 service to Chelsea. Preliminary modeling suggests that an alignment connecting South Station, Airport Station, the Chelsea Commuter Rail station (via the Grand Junction corridor) and Bellingham Square would result in 8,700-8,800 passengers per day. MassDOT should ensure that this corridor is preserved for the implementation of BRT and not encroached upon by the construction of bridges or other new infrastructure.

Topics for Future Study

The following topics related to public transportation access to Logan Airport are recommended for future study:

- The restructuring of the Logan Airport taxi service in order to reduce empty taxi trips to and from the Airport and excessive taxi queues
- The impacts and benefits of shifting all private vehicle travel to the upper level of the Logan Airport terminals so that the lower level can be used exclusively by commercial and transit vehicles
- The implementation of tolls on airport roadways or on highways leading to Logan Airport to discourage private vehicle travel and finance public transportation improvements
- Opportunities to include an express service to Logan Airport in the plans for the South Station Bus Terminal Expansion
- The use of an Urban Ring type alignment for Silver Line 6 from Sullivan Square across Everett and Chelsea to Airport Station and then connecting to Broadway and Ruggles Station (instead of using South Station and the South Boston Transitway)
- The possibility of reducing demand for ground transportation to Logan Airport by attracting air passengers taking short-haul flights to high-speed rail, coach buses or other regional airports.
- The possibility of further enhancing Silver Line and Blue Line access to Logan by considering:
    - Silver Line Phase III: the extension of the Silver Line tunnel from South Station to Chinatown and Boylston Street Station
    - Blue Line extension from Government Center to Charles Street Station (Blue Line / Red Line connector) and from Wonderland to Lynn

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Appendices

1 Ground Access to Logan Airport: Context and Trends

The broad question for this study is "How can public transportation to Boston Logan International Airport be improved?" The specific tasks in this study are to:

- Review existing transit travel trends at Logan Airport
- Assess the performance of existing transit services
- Evaluate and recommend strategies to improve transit access to Logan Airport, considering cost, feasibility, operations and physical constraints.

The guiding principles listed below define the desirable outcomes that the study recommendations aim to achieve:

- Improve the quality of existing transit services to the airport
- Increase the transit mode share to the airport through use of strategic investments
- Improve and facilitate employee access to the airport
- Improve airport curb operations and reduce transit travel times through the terminals
- Increase user understanding of transit services and ease of use
- Improve quality of transit services in terms of wait times, passenger comfort, efficiency of transfers and convenience

Many of these goals are inter-related (i.e. minimizing the travel time will likely increase transit ridership) and also allow for the development of both short-term and long-term improvements.

1.1 Development of Public Transportation to Logan Airport

Boston Logan International Airport, shown below in **Figure 1-1**, is the largest airport in New England and the 19th busiest airport in the United States. Logan Airport has 6 runways and served 29.3 million passengers in 2012 (both arrivals and departures). The airport serves destinations in the United States, Canada, Mexico, the Caribbean, Europe and Asia.

The focus of this report is ground transportation access to the airport. Logan Airport requires a comprehensive and well-managed transportation system in order to efficiently serve passenger trips, employee trips, transfer of air freight and deliveries to the airport. In 2012, 29.3 million passengers passed through the airport (arrivals and departures). Accounting for an estimated 8% of passengers connecting between flights[1], this corresponds to approximately 36,900 inbound and 36,900 outbound daily passenger trips. There are approximately 14,685 employees[2] at the airport which results in approximately 9,000 inbound and 9,000 outbound employee trips per day.

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[1] L. Dantas, Massport, personal communication, February 20, 2013

[2] ACRP Synthesis Report 36, page 12

Figure 1-1: Boston Logan International Airport

To accommodate this magnitude of trips, Logan Airport has direct pick-up and drop-off by Silver Line bus rapid transit, free and frequent shuttles to Airport Station on the MBTA Blue Line, Logan Express buses which serve Framingham, Peabody, Woburn and Braintree, other charter buses to locations within Massachusetts and nearby states, 20,938 on-airport parking spaces, rental car spaces, taxi and limousine service at each terminal and pick-up and drop-off zones and a cell phone lot for private vehicles.

The original Airport Station on the Blue Line opened in 1952. The MBTA originally ran buses connecting the airport terminals to Airport Station; users would pay a fare when boarding the bus at the airport. In 1978 Massport assumed responsibility for running shuttles between the airport and Airport Station, and made this shuttle service free, to improve user understanding and reduce boarding times. Massport later introduced branch shuttle service during the peak hours, in which one shuttle serves Terminals A and B, and another serves Terminals C and E to further reduce access time to the terminals. The MBTA re-constructed Airport Station in the early 2000's, with the new station opening for service in 2004. The new station included wider stairs and escalators and monitors with flight arrival and departure times[3] and a direct level transfer from the Blue Line platform to the shuttle bus waiting area.

A recent and significant improvement to public transit access to Logan Airport was the introduction of the MBTA Silver Line. The Silver Line SL1 route started service on June 1st, 2005, providing a direct link between South Station and all terminals at Logan Airport. While the existing Airport Station provided convenient access for travelers on the Blue Line, the Silver Line provided a more convenient connection for Red Line users, who previously had to transfer three times to reach any Logan terminal. The Silver Line also provides service to the South Boston Waterfront redevelopment area, including the expanded Boston Convention Center. Silver Line boardings at the airport have increased from 642,000 in 2006 (the first full year of service) to over 900,000 in 2011. A similar number of passengers are presumed to take the Silver Line to Logan Airport, although precise counts from South Station and South Boston are not available.

Usage of other HOV modes to the airport has not changed as significantly, according to Massport's 2010 Environmental Data Report (EDR). Usage of water transportation (including City Water Taxi, Rowes Wharf Water Transport, Boston Harbor Water Taxi, and MBTA Harbor Express) decreased from 112,000 in 2004 to 89,000 in 2010. Ridership on the Logan Express bus services has fluctuated over the past decade: there were 1.12 million trips in 2001 and 1.19 million trips in 2011, with a maximum of 1.31 million trips in 2006. Another trend with respect to the Logan Express buses is the increase of the employee mode share: the number of employees using the service has increased from 21% in 2001 to 45% in 2011. However, there were approximately 236,000 fewer air passenger trips on the service in 2011 than in 2001: the percentage of passengers using the service decreased from 79% to 55%.

The Massachusetts Department of Environmental Protection enforces a parking freeze at Logan Airport, which limits the number of commercial and employee parking spaces to 20,938. The original parking freeze was introduced in 1973, but it did not apply to parking spaces just beyond the boundary of Logan Airport and did not specify a limit for employee spaces. A revised regulation was introduced in the 1990s that included employee parking spaces in the global total. As the parking freeze stipulates the maximum number of parking spaces that can be provided at the airport, the role that parking can contribute to future travel demand is limited.

1.2 Project Impetus

1.2.1 Factors Influencing Ground Access to Logan Airport

Presently there are the following significant influences on ground access to Logan Airport:

- **Growth:** The number of trips to Logan Airport is increasing, which will put pressure on Logan Airport's ground transportation system in the future: the ground transportation system must be able to efficiently accommodate increasing volumes of passenger and employee trips if the airport is to continue to flourish.
- **Parking Freeze:** As discussed in **Section 1.1**, the Massachusetts Department of Environmental Protection enforces a parking freeze at Logan Airport which limits the total number of parking spaces (for both passengers and employees) to 20,938. Logan

[3] http://en.wikipedia.org/wiki/Airport_(MBTA_station)

Airport is subject to the parking freeze under the Federal Clean Air Act because the Boston airshed is exceeding its capacity limits in terms of emissions. The purpose of the parking freeze is to limit the number of vehicle trips to Logan Airport and encourage travel by more sustainable HOV modes that result in less congestion on regional roads and lower emissions. Massport reports that its parking facilities are operating close to capacity more than half the time and anticipates high demand day desired usage may exceed supply as soon as 2013-2014[4] at current prices. Given that the number of parking spaces is fixed by the parking freeze, this highlights the critical need to improve HOV modes to the airport to provide alternatives to the automobile. Parking freezes are also in place in other areas such as the South Boston Waterfront and Downtown Boston.

- **Physical Capacity Constraints:** There is a scarcity of available land at Logan Airport, as the airport is surrounded by water on three sides and established residential neighborhoods in East Boston on the fourth. As a result, allocation of land to specific functions at Logan Airport – such as airfield, passenger terminals, air cargo, taxi, car rental, ground access and parking – must be the outcome of a careful prioritization of airport needs. A reduction in the land required for parking will increase the space available for other important airport functions that will allow Logan Airport to continue accommodating increased levels of passengers in the coming decades. Even if increasing the amount of parking was not prohibited by the parking freeze, there is limited space at the airport to expand parking and such an expansion would consume space that could be allocated to uses which may be of higher priority. Given the space constraints at Logan Airport, construction projects also constrain and complicate airport operations.
- **Roadway Capacity:** One of the major elements of the Central Artery/Tunnel Project (the Big Dig) was the construction of the Ted Williams Tunnel, which is the third highway tunnel under Boston Harbor. It connects South Boston to Logan Airport and connects the final leg of the Massachusetts Turnpike (Interstate 90, or I-90) to Route 1A in East Boston. A major reason for constructing the tunnel was to increase capacity to Logan Airport and thereby increase the airport's accessibility. Capacity in the Ted Williams Tunnel is finite, however, and the tunnel also serves trips resulting from growth in downtown Boston and the South Boston Waterfront. As a result, it is necessary to increase the share of travel to the airport by HOV modes which make more efficient use of the finite roadway capacity.
- **Congestion at the Terminal Curb:** The curbside area must accommodate many different types of vehicles including private vehicle drop-offs and pick-ups, taxis, charter buses, rental car shuttles, Massport shuttles, the Logan Express and the Silver Line. Second curbs are used at Terminals A, C and E to increase curb space, but this forces pedestrians to cross lanes of traffic, decreasing travel speeds through the terminal area and raising safety concerns. Non-HOV modes, such as private vehicle pick-up and drop-off and taxis, contribute to congestion but generally transport fewer travelers per vehicle. However, the growth in popularity of PUDO and taxi is in large part driven by the improved travel time caused by the Ted Williams Tunnel and the high cost of parking at Logan, and not by the parking constraint (which has not yet been reached)
- **HOV Targets:** Massport has set a target of achieving 35.2% high-occupancy vehicle (HOV) trips at the 37.5 million air passenger annual level. However, in light of the

[4] Addressing Operational and Management Challenges at Boston-Logan International Airport http://www.aci-na.org/sites/default/files/leiner.pdf.

parking freeze which limits the number of parking spaces at Logan Airport, a more aggressive HOV goal of 44% will be required to transport increasing numbers of passengers and employees to the airport. At the state level, Richard Davey, the Massachusetts Secretary of Transportation, has set a target of tripling the share of travel by walking, cycling and transit

- **Quality of Life:** Quick, inexpensive connections between Logan Airport and the surrounding region enhance quality of life for local residents and employees and improve the experience of visiting Boston for tourists and business travelers alike

It is also important to recognize the distinct travel needs of residents, non-residents and employees:

- Non-residents, such as business travelers and tourists, arrive without automobiles and rely upon public transportation, taxis, rental cars and pick-up/drop-off (PUDO)
- Residents are much more likely to have access to automobiles, and have the option to park at the airport in addition to using other modes
- Employees commute to the airport multiple times per week; transportation options that reduce travel time and travel cost are particularly important to this group as they travel to the airport much more frequently than do air passengers

Improved transit service and an increased transit mode share can address these trends by accommodating trips to and from Logan Airport sustainably and cost-effectively, while reducing parking requirements and pick-up/drop-off traffic volumes at the terminal curbside. Furthermore, the scarcity of available land at Logan Airport, physical constraints, parking freeze and existing roadway network together result in a firm capacity constraint on the number of non-HOV trips that can be accommodated at Logan Airport. Using a horizon annual passenger level of 37.5 million trips, some simple calculations in **Section 1.2.2** and **1.2.3** demonstrate the need for improved HOV services.

1.2.2 Parking Capacity

Parking capacity at the airport is fixed, as discussed. According to Massport's 2010 Environmental Data Report (EDR), in 2010 27,428,962 total air passengers (arrivals and departures) passed through the airport, of whom approximately 55% are Boston-area residents, and the peak parking occupancy approached 17,000 spaces during 6 different weeks of the year[5]. As a result, 2010 design day demand has been conservatively set at 17,000 for this analysis. Proportional ratios have been used to forecast the annual passenger level that corresponds to the maximum commercial parking capacity with the existing number of spaces (18,265) and the design day demand with the horizon annual passenger level of 37.5 million trips. The results are shown in **Table 1-1**.

[5] Massport 2010 EDR, page 5-10

Table 1-1: Number of Annual Air Passengers and Commercial Parking Design Day Demand

	Annual Air Passengers	Design Day Demand
2010 Figures	27,428,962	17,000
Maximum Existing Commercial Parking Capacity	29,469,999	18,265
Horizon Air Passenger Activity Level	37,500,000	23,242

These forecasts show that without any changes to parking prices and significant improvements to public transportation to Logan, peak demand for parking will exceed existing parking capacity once the number of annual passengers exceeds 29.5 million. As Logan Airport served 29.3 million passengers in 2012, even modest increases in airport activity levels could result in insufficient parking capacity during peak weeks as early as 2013 or 2014. When parking demand meets or exceeds supply, it is both frustrating for travelers (who may incur long delays and feel anxiety about missing a flight while trying to find a parking space) and operationally demanding for Massport (which must use overflow lots that are more challenging to manage).

These forecasts also indicate that if existing travel trends continue, design day demand at the 37,500,000 annual passenger level will exceed the commercial parking supply of 18,265 by nearly 5,000 vehicles, or 27%. Some potential approaches Massport could take to address this problem are outlined below:

- Massport could convert additional employee parking spaces to commercial parking spaces; however, this would require alternative modes of access for the displaced employees
- Parking fees should increase as demand increases, to reduce demand for parking to a level that can be accommodated by the existing facilities.
- Massport could purchase off-airport parking lots (Pre-Flight, Park-Shuttle-and-Fly, Thrifty) to which the Parking Freeze does not apply. Massport could consolidate these parking lots onto the airport property without violating the existing parking freeze. Consolidation would be more convenient for people parking at the airport and would also provide Massport with additional revenue to direct toward improving HOV modes to the airport
- Massport could experiment with moving some rental car spaces to the Logan Express parking lots. Visitors who rent cars to travel within New England may appreciate the convenience of taking a Logan Express bus to one the suburban parking lots and renting a car there. This would allow them to bypass the congested and potentially confusing roadway network in the immediate vicinity of Logan Airport. Further, Massport could argue for a modification to the Parking Freeze that would permit them to convert rental car spaces to parking spaces, using the rationale that rental car spaces have more turnover than long-term parking spaces and thus result in greater VMT

In light of the fact that the parking supply is finite, these results highlight the critical need to improve alternatives to automobile access to Logan Airport. Parking constraints are expected to result in increased use of taxis, PUDO and public transportation; the price of parking and relative convenience of taxi, PUDO and public transportation will determine how the excess demand for parking is reallocated. Increases to taxi and PUDO use will further exacerbate congestion on terminal roadways, which is further explored in the following section.

1.2.3 Terminal Roadway Congestion

Roadway congestion also limits the magnitude of vehicle travel to Logan Airport. In addition, unconstrained growth in auto trips to Logan, in combination with growth of other regional attractions such as Boston's CBD, South Boston Innovation District, Kendall Square and the Longwood Medical Center could overload the regional road network. Existing data has been used to construct an approximate estimate of future vehicle volumes on airport roadways. An estimate of the 2010 average daily air-passenger related vehicle volumes on the roadway network is shown in **Table 1-2**. This estimate was developed using the following data:

- The modal split determined in the 2010 Logan Airport Air Passenger Ground Access Survey was applied to the average daily trips in 2010 (based upon dividing the annual number of trips by 365)
- Occupancies were applied based on the occupancies reported in Table 5-9 of Massport's 2010 EDR:
    - Private Vehicle: 2.3
    - Taxi: 1.9
    - Rental: 2.2
- A "return vehicle" factor of 2 was applied to PUDO modes and taxicabs to account for trips to and from the airport without an air passenger.
- Parking exits sorted by duration of stay (Table 5-5 of the Massport's EDR on page 5-11) were used to quantify types of trips to the airport:
    - Less than 4 hours: PUDO at airport parking lot
    - 4-24 hours: 65% of these trips assumed to be same-day parking trips; remainder assumed to be employees who must pay, deliveries, visits to the airport, etc.
    - Greater than 1 day: Parked at airport for trip
- Direct data on the number of PUDO trips at the curb is not available; however, the percentage of daily parking trips estimated from the parking data was subtracted from the total "private vehicle" mode share of 40.4% reported in Massport's EDR; the remaining private vehicle trips were assigned to PUDO on the curb
- If a passenger is dropped-off at the beginning of a trip and picked-up at the end of the trip, this results in 2 round-trips to the airport, whereas if a passenger parks at the airport and drives home at the end of the trip, this results in 1 round-trip to the airport. To capture this distinction, the trips were first estimated as outbound trips, and then multiplied by two to generate an estimate total of daily outbound **and** inbound trips

Table 1-2: 2010 Estimated Air Passenger Roadway Volumes

Non-HOV	2010 Percentage	Daily One-Way Person Trips	Estimated Vehicle Trips	Return Vehicle Trip Factor	Estimated Total Outbound Trips	Estimated Total Inbound and Outbound Trips
Park in Logan Parking Lot	20.4%	7,039	3,060	1	3,060	6,121
PUDO in Logan Parking Lot	11.5%	3,976	1,729	2	3,457	6,914
PUDO on curb	8.5%	2,951	1,283	2	2,566	5,132
Taxi	18.8%	6,499	3,420	2	6,841	13,682
Rental Car	10.9%	3,768	1,713	1	1,713	3,425
Total Non-HOV	70.1%	24,232	11,205		17,637	35,274
Total Daily One-Way Air Passenger Trips		**34,568**				

To estimate the traffic volumes at the project horizon year, Massport's target 35% HOV / 65% Non-HOV goal was applied to the daily volumes resulting from 37.5 million annual passenger trips, the horizon planning level. The results are shown in **Table 1-3**.

Table 1-3: Estimated Air Passenger Roadway Volumes at 37,500,000 Annual Air Passengers

Non-HOV	Percentage of Non-HOV	Daily One-Way Person Trips	Estimated Vehicle Trips	Return Vehicle Trip Factor	Estimated Total Outbound Trips	Estimated Total Inbound and Outbound Trips
Park in Logan Parking Lot	29.0%	8,923	3,880	1.00	3,880	7,760
PUDO in Logan Parking Lot	16.4%	5,040	2,191	2.00	4,382	8,765
PUDO on curb	12.2%	3,741	1,626	2.00	3,253	6,506
Taxi	26.8%	8,239	4,336	2.00	8,672	17,344
Rental Car	15.5%	4,777	2,171	1.00	2,171	4,342
Total Non-HOV	100.0%	30,719	14,205		22,358	44,717
Total Daily One-Way Air Passenger Trips		**47,260**				

The total number of air passenger ground transportation trips is projected to increase by 36.7% between 2010 and the horizon year. As a result of the decrease in the Non-HOV proportion from 70% to 65%, the number of vehicle trips increases by a smaller proportion of 27%. However, even if the 35% HOV target is achieved at the 37.5 million air passenger level, the number of vehicle trips for air passengers increases by approximately 9,500. Considering the existing level of congestion on the airport roadways and physical space constraints that limit capacity expansion, this increased number of vehicle trips may result in a deterioration of the operating environment. Further, the peak-based nature of travel to the airport will result in increased vehicle volumes during the peaks which are already congested. Finally, this increase is based solely on the increase in passenger volumes and does not consider increases in employee trips, maintenance trips, deliveries, etc.

1.2.4 Proposed New HOV Target

While these numbers are rough approximations, based upon estimates constructed from data in Massport's EDR, they serve to illustrate an important point that attaining a 35% HOV split at the 37.5 million annual passenger level will still result in a sizable increase in traffic volumes and congestion on airport roadways. In short, the 35% HOV split will be inadequate at the 37.5 million annual passenger level.

By the time Massport reaches the 30 million annual passenger level, demand for parking will exceed supply several weeks of the year (see **Section 1.2.2**). Further, if demand for parking shifts to PUDO or taxi, this will result in twice as much VMT because taxis and PUDO also have return trips. Therefore, it is not desirable for excess demand for parking to shift to these modes. Rather, all passengers beyond the 30,000,000 should use HOV modes. If all passengers beyond the 30 million threshold use HOV modes to access Logan Airport, this implies an HOV target of **44%** at the 37.5 million annual passenger level (assuming the existing HOV split for the 30 million base of passengers). Current HOV mode share for passengers and employees is 30%, or approximately 13,800 inbound and 13,800 outbound trips per day by public transportation modes. To achieve the 44% goal in the horizon year there will need to be approximately 24,700 inbound and 24,700 outbound daily trips by public transportation, representing a growth factor of nearly 1.8 over existing usage.

As a result of these factors, there is a clear need for improved transit access to Logan Airport that can attract an increased number of Boston-area residents, visitors and employees to HOV modes from private automobile and taxis. This report focuses on specific strategies to improve transit access to Logan Airport:

- Employee-specific policies
- Strategies to facilitate the transfer to transit modes at the airport terminals
- Transit fare policy
- Improved passenger experience
- Improving the quality of the Silver Line and shuttle connection to the Blue Line
- Attracting additional passengers to existing Logan Express services
- Opportunities to expand the network by creating new services, such as additional Logan Express routes, rapid transit (potentially using the urban ring configuration) into Everett and Chelsea and the extension of the Blue Line to Lynn

An alternate approach to increasing capacity to Logan would be to reduce ground access demand for travel to Logan Airport. Shorter distance air trips (i.e. trips less than 250 miles) could be served by coach buses, high-speed rail or other regional airports (such as Worcester Regional Airport).

1.3 Characteristics of Transit Connections to Airports

There are numerous characteristics of transit services to airports, which distinguish them from most other transit services in urban or suburban areas. These characteristics are summarized in **Table 1-4**.

There are several factors that influence a user's selection of a ground transportation mode at Logan Airport:

- **Cost:** the out-of-pocket cost, including parking fees, road tolls, taxi fare, rental car fee and transit fare
- **In-Vehicle Travel Time:** In-vehicle time required to travel to trip destination
- **Wait Time:** Time waiting for transit vehicle, queue time at rental car facility, etc; the comfort of the waiting area affects the user's perception of the wait
- **Access Time:** Time required to access the primary transportation mode (i.e. walk to parking garage, shuttle to rental car facility, walk to bus stop)
- **Reliability of Travel Time:** Given the significant cost and time penalty of missing a flight, inbound passengers are particularly sensitive to the reliability of the service
- **Ease of Use:** Level of complexity associated with accessing the ground transportation mode; for example, finding a taxi is generally easy, while finding a bus stop and determining the right bus to take is much more complex.
- **Connectivity:** Accessibility to destinations offered by the mode; for example, an out-of-state traveler will not be well served by local MBTA service, while walk and cycle trips are only feasible for trips originating in neighboring East Boston.
- **Comfort:** Level of comfort on the transportation mode, i.e. level of crowding, climate control, comfort of seats, Wifi access, etc.

Table 1-4: Characteristics of Transit Connections to Airports

Surrounding Land Uses	-Airport terminals are generally spatially separated from residential neighborhoods because they are large, emit noise and emissions and require large warehouses and maintenance facilities in the vicinity
Employees	-Airport employees make trips to and from the airport frequently, but they represent a minority of total airport trips
Air Passengers	-A majority of trips are made by air passengers who access the airport infrequently
User Familiarity	-Occasional users may be unfamiliar with transit service routes, headways, means of payment, waiting areas, boarding procedures, etc. -International visitors may be unfamiliar with English -Fatigued travelers may have reduced capability to understand signs or instructions and may be unwilling to learn how to use the transit service -Frequent travelers will become familiar with ground transportation options
Competition with Other Modes	-Residents may drive to the airport and park, or have friends or family pick them up / drop them off at the airport -Non-resident travelers will not have their own vehicle upon arrival at the airport, but may have several ground transportation options, including taxis, rental cars, courtesy shuttles, transit and pick-up
Comfort of Waiting Area	-The airport terminal curb is generally an uncomfortable area to wait for transportation: exposed to the elements, limited user information, little visual interest, no amenities (restrooms, concessions, etc.)
User Information	-Myriad ground access options (and decision points within the terminal) can result in complex signage which may challenge the users

Trip Origins and Destinations	-While there is generally a concentration of passenger trips that originate in the nearest large municipality, trip origins are generally distributed throughout the airport's catchment area
Peak Periods	-Travel occurs to and from the airport throughout the day -Large proportion of employee trips to the airport occur before 8:00 AM
Value of Reliability	-Travelers heading to catch a flight at the airport are expected to place significant value on a reliable service with consistent and predictable headways and travel times

Massidda et al report in "A Sketch Planning Model for Estimating Airport Ground Access Using Rail Service"[6] that the three most important factors that influence rail modal share at an airport are:

- Total rail network length
- Rail headway
- Transfer time from the rail station to the airport terminals

This implies that service characteristics (time and convenience) are more important to travelers than cost-based parameters. Other studies of airport ground access have found that out-of-vehicle travel time (i.e. wait time and walk time) have greater disutility than in-vehicle travel time[7] which highlights the importance of short headways and efficient transfers to the transit mode. Further, Wong[8] notes that the presence of a rail connection to an airport does not guarantee appreciable usage of this mode, citing the following airports as examples:

- Lambert St. Louis: 3.3% rail modal split
- Cleveland Hopkins International Airport: 2.8% rail modal split
- Baltimore-Washington International Airport: 1-2% rail modal split

In an age of fiscal constraint and limited government resources, investments in transit infrastructure to airports should be planned with consideration of operating costs and expected ridership. Opportunities to improve transit service using less expensive bus technologies should also be investigated. The major ground transportation modes from Logan Airport are plotted on axes of cost and convenience in **Figure 1-2**. "Convenience" encapsulates several factors including travel time, wait time, network connectivity, ease of use, etc.

[6] Massidda, A., "A Sketch Planning Model for Estimating Airport Ground Access Using Rail Service", 2013
[7] Ameen, N. and Kamga, C., "Forecast Of Airport Ground Access Mode Choice Using The Incremental Logit Model: A Case Study Of The Airtrain At JFK International Airport", 2013
[8] Wong, D. "Airport Ground Transportation Policies and the Future of Rail Connections at US Airports", 2012

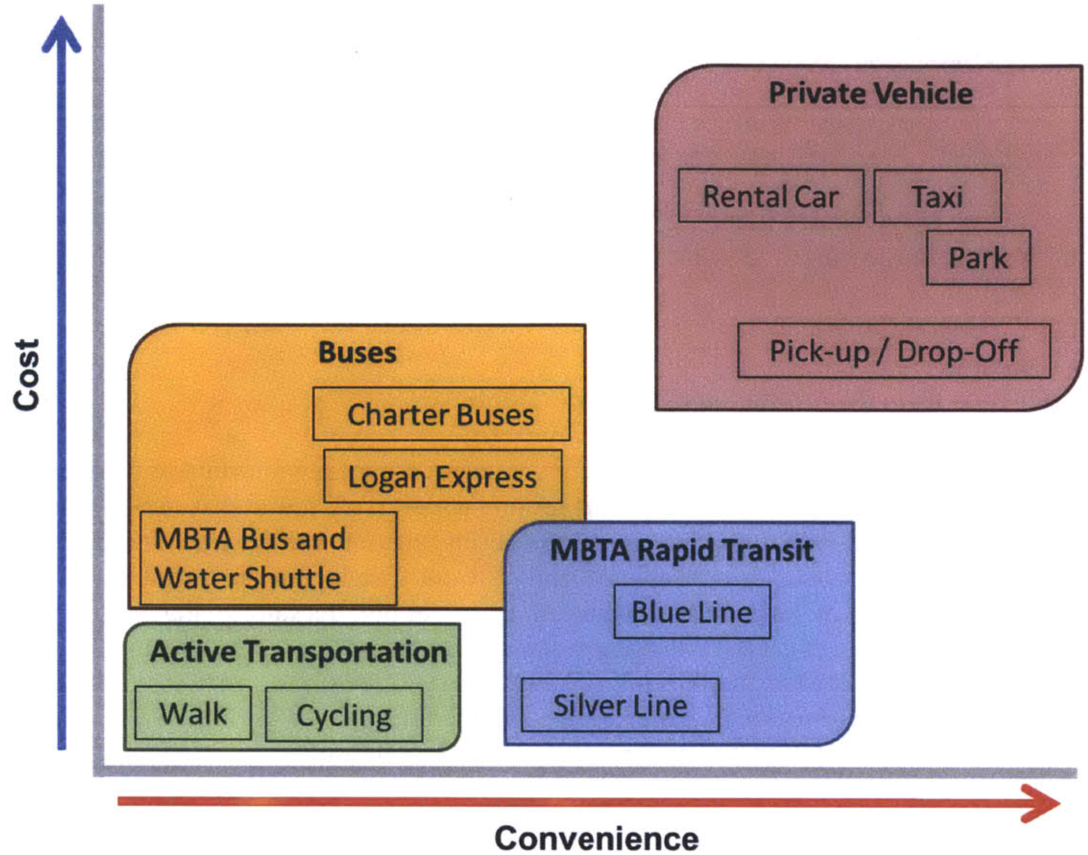

Figure 1-2: Relative Cost and Convenience of Ground Access Modes at Logan Airport[9]

Private vehicle travel generally offers the greatest convenience, but at the greatest cost. Transit services are less expensive than private vehicle travel, but usually require longer travel times and wait times. Walk and cycle trips have the least cost, but are only feasible for the small proportion of trips originating within the immediate vicinity of the airport.

[9] Inspired by presentation by L. Dantas at TRB 2013, "Operational and Passenger Responses to Free-Fare Transit Boardings at Logan Airport: Summer 2012 Silver Line Pilot Program"

1.4 Report Outline

Chapter 1 – Ground Access to Logan Airport: Context and Trends has provided an overview of the development of public transportation to Logan Airport and reviewed future trends to explain the impetus for the study
Chapter 2 – Ground Access Demand to Logan Airport reviews existing travel demand to Logan Airport, considering travel trends of both employees and air passengers
Chapter 3 – Transit Services to Logan Airport focuses specifically on the existing transit services to Logan Airport, with a review of operating characteristics and ridership
Chapter 4 – MBTA Network Connectivity studies the complementary nature of the Silver Line and the Blue Line and assesses their function as part of the larger rapid transit network
Chapter 5 – Future Vehicle Technology Alternatives explores alternative vehicle technology options to replace the existing Silver Line fleet
Chapter 6 – Operational Improvements to the Silver Line analyzes approaches to improve the Silver Line Bus Rapid Transit service to Logan Airport
Chapter 7 – Infrastructure Improvements at D Street and the South Boston Transitway evaluates potential infrastructure upgrades to improve Silver Line operations at the intersection of D Street and the South Boston Transitway.
Chapter 8 – Massport Transit Services recommends potential improvements for the airport shuttles and Logan Express
Chapter 9 – Ease of Transferring to Transit outlines strategies to facilitate the transfer from the Logan Airport terminals to public transportation modes, with an emphasis on wayfinding, fare collection and the layout of the curbside area
Chapter 10 – Potential Future Transit Services explores the potential for new transit services to Chelsea and Worcester
Chapter 11 – Conclusions and Recommendations summarizes the major findings of the study

Appendices
Appendix A – Resource Provision and Fees for Ground Transportation to Logan reviews Massport's provision of resources to ground transportation at Logan Airport. The information presented in this section is largely based on the team's estimates of Massport's costs and revenues for the various services, since Massport's budget was not available during the study period.
Appendix B – Airport Shuttle Weekly Vehicle Hours summarizes the weekly vehicle hours for the airport shuttles.

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2 Ground Access Demand to Logan Airport

This chapter reviews existing travel trends to Boston Logan International Airport. It is organized as follows:

- Section 2.1: Accessibility to Logan Airport
- Section 2.2: Airport Ground Access Origins and Destinations
- Section 2.3: Passenger Travel Patterns and Modal Split to Logan Airport
- Section 2.4: Employee Travel Patterns and Modal Split to Logan Airport
- Section 2.5: Estimated Transit Demand by Mode to Logan Airport
- Section 2.6: Conclusions

2.1 Accessibility to Logan Airport

Logan Airport is located 2 miles from Boston's financial center and has direct highway and transit connections (see **Figure 2-1**).

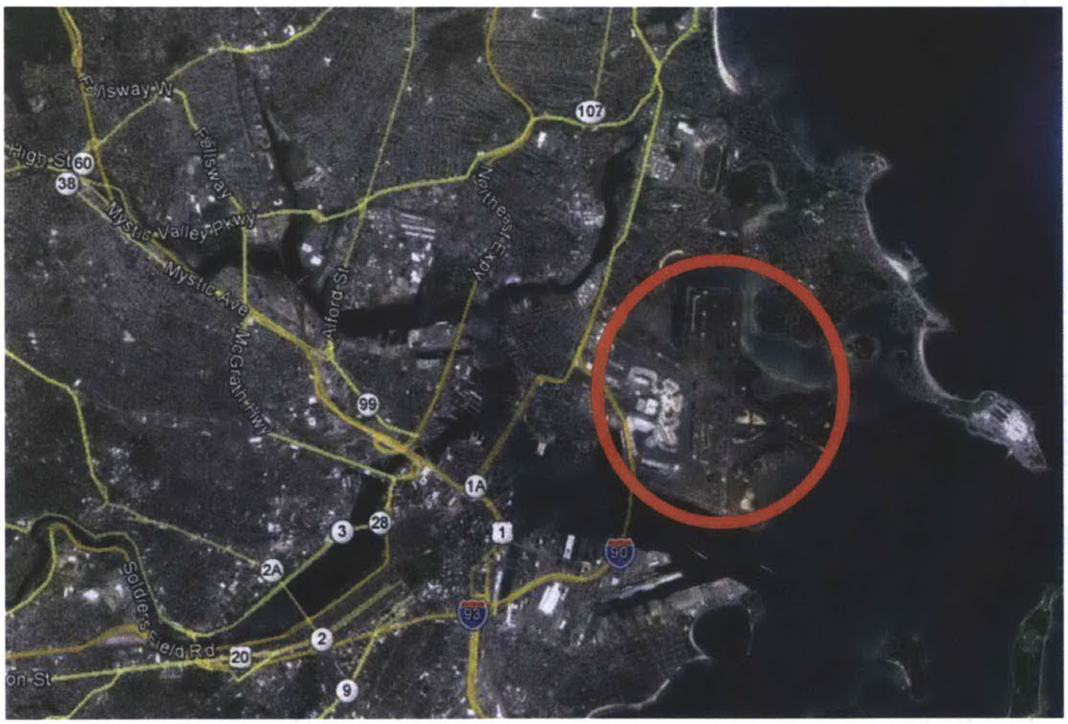

Figure 2-1: Location of Logan Airport

By <u>automobile or taxi</u>, Logan Airport is accessible via:

- Massachusetts Turnpike / Ted Williams Tunnel / I-90; connectivity to I-93
- William F. McClellan Highway / Callahan Tunnel / Sumner Tunnel
- Local streets in East Boston and Chelsea

By <u>MBTA transit</u>, Logan Airport is accessible via:

- Silver Line Route 1 (SL1), bus rapid transit which connects Logan Airport to South Station in downtown Boston where there are subway and commuter rail connections

- Airport Station on the Blue Line, which is connected to Logan Airport by Airport Shuttles run by Massport. The Blue Line connects downtown Boston with East Boston and the North Shore, with transfers to the Green Line at Government Center and to the Orange Line at State.
- Water taxis between Boston's financial district and the airport, with airport-side connection by Massport shuttles
- MBTA buses to Terminal C at Logan Airport:
    - Bus Route 448/449: Provide service between Marblehead and Downtown Crossing, with a stop at Terminal C.
    - Bus Route 459: Provides service between Salem and Downtown Crossing, with a stop at Terminal C.

Logan Airport's connections to the MBTA system are shown in **Figure 2-2**.

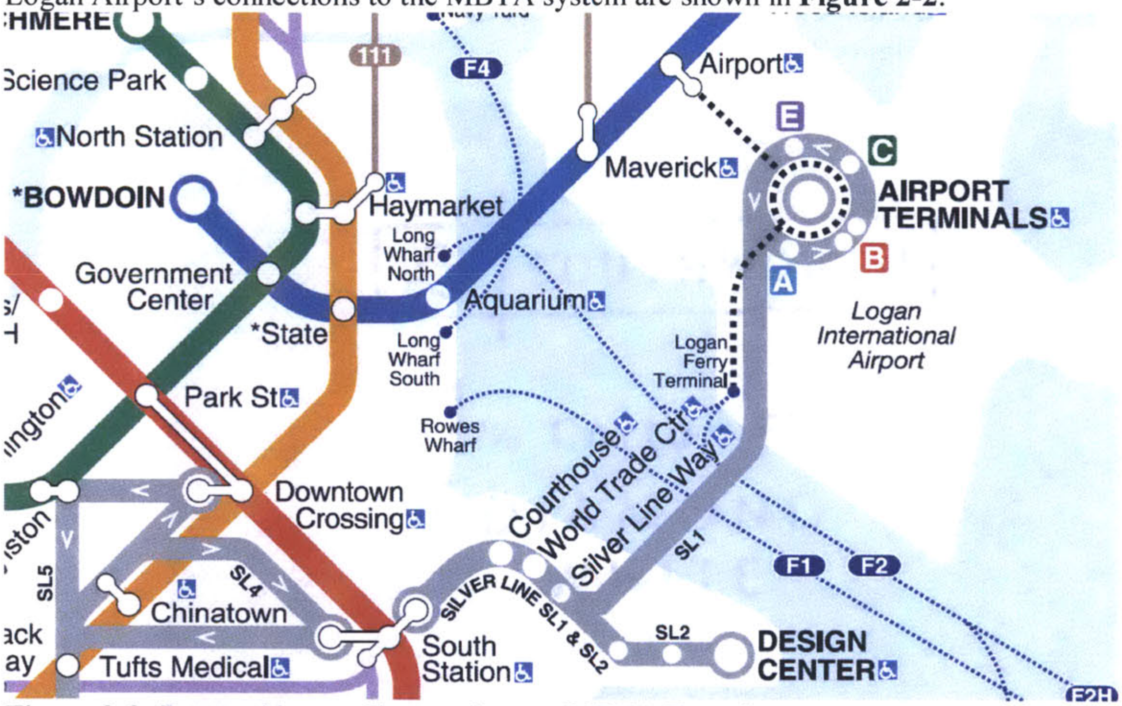

Figure 2-2: Logan Airport Connections to MBTA Transit

By scheduled buses Logan Airport is accessible via:

- Logan Express buses (run by Massport) to and from the following locations:
    - Braintree
    - Framingham
    - Peabody
    - Woburn
- Private bus lines including:
    - Peter Pan, serving destinations in Massachusetts, Connecticut and Rhode Island
    - Boston Express, serving I-93 corridor and Route 3 corridor
    - Concord Coach Lines, serving Maine and New Hampshire

By courtesy shuttles, Logan Airport is accessible via:

- Shuttles from nearby rental car facilities, such as:
  - Avis
  - Budget
  - Hertz
  - National / Enterprise / Alamo
- Shuttles from nearby hotels such as:
  - Wyndham
  - Hilton
  - Embassy Suites
  - Hyatt
  - Courtyard Marriot

These complementary transit services provide access to Logan Airport over a range of distances:

- Local East Boston passengers or employees can walk to Airport Station on the Blue Line and take a shuttle to the terminals
- The Boston area is well-served by the MBTA which has good connectivity to Logan Airport
- The Regional area is served by Logan Express buses, commuter rail that connects to the MBTA, and coach buses
- Nearby states, including Rhode Island, New Hampshire and Maine, are served by coach buses (i.e. Peter Pan, Concord Coach Lines)

2.2 Airport Ground Access Origins and Destinations

2.2.1 Air Passenger and Employee Trip Origins

In 2012, 29.3 million passengers passed through the airport (arrivals and departures). Accounting for an estimated 8% of passengers connecting between flights[10], this corresponds to approximately 36,900 inbound and 36,900 outbound daily passenger trips. There are approximately 14,685 employees[11] at the airport which translates to approximately 9,000 inbound and 9,000 outbound employee trips per day.

Massport has produced a figure illustrating the origin zones of air passenger ground access trips to Logan Airport (see **Figure 2-3**), based upon the data collected in its 2010 Air Passenger Ground Access Survey. The greatest concentrations of passenger trips are in Boston and the area inside Route 128, but a significant proportion of trips also originate around Worcester, Framingham and Lowell. Most tourists are likely spending time in Boston and contribute to the proportion of trips originating in the Boston area.

The 2010 Air Passenger Ground Access Survey and 2007 Logan Airport Employee Commute Survey present a breakdown of airport trip origins, which are summarized in **Table 2-1**.

[10] L. Dantas, Massport, personal communication, February 20, 2013

[11] ACRP Synthesis Report 36, page 12

Table 2-1: Passenger and Employee Trip Origins

	Percentage of Employees[1]	Percentage of Air Passengers[2]
Immediate Vicinity: East Boston, Chelsea, Everett, Revere, Winthrop	26%	52%
Within Route 128	33%	
10-30 miles / Route 128 to Route 495	23%	24%
Greater than 30 miles / Outside Route 495	17%	24%

[1]From 2007 Logan Airport Employee Commute Survey; all Logan employees, regardless of employer, were eligible participants in the survey
[2]From 2010 Passenger Ground Access Survey

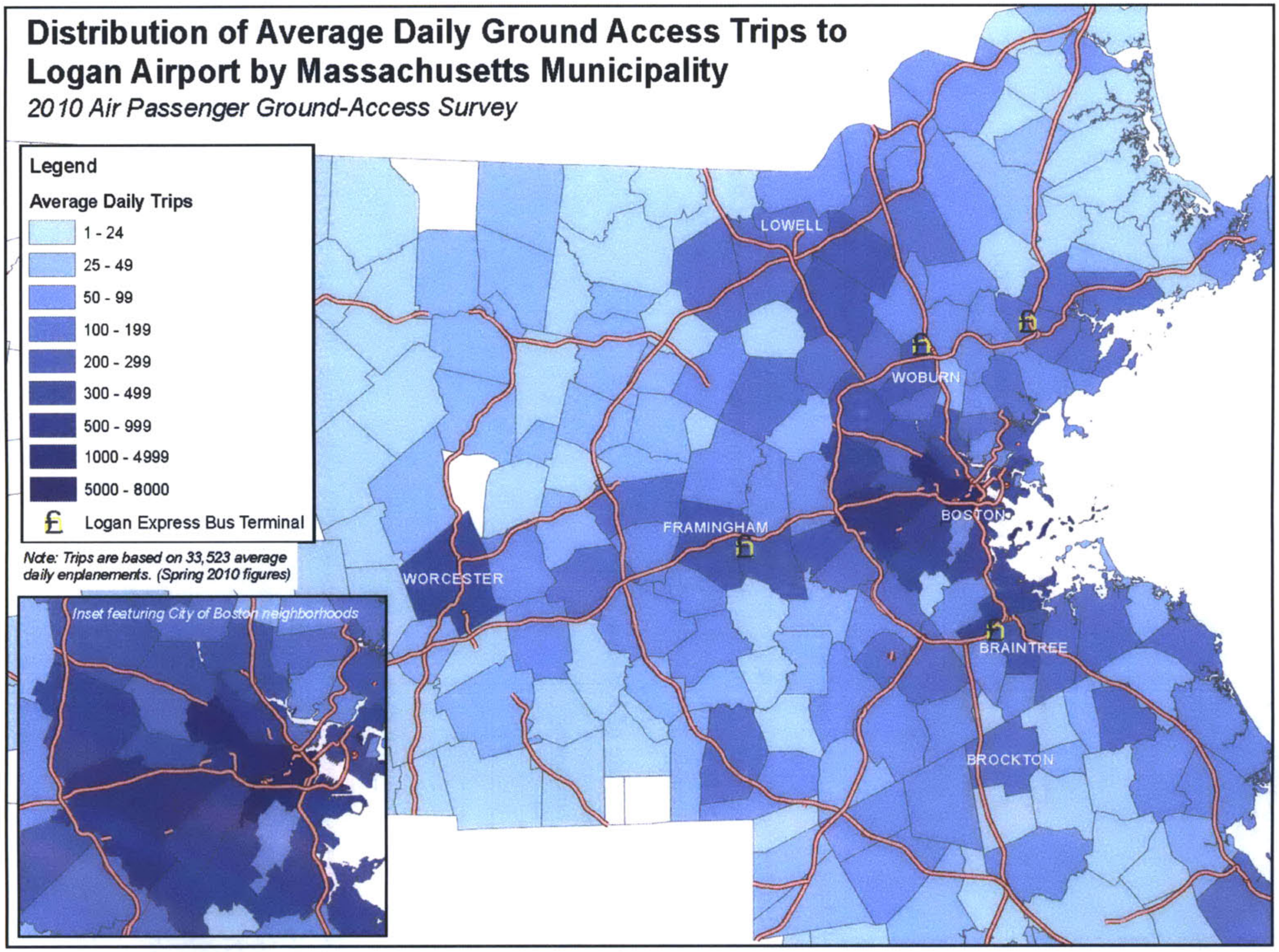

Figure 2-3: Daily Passenger Ground Access to Logan Airport

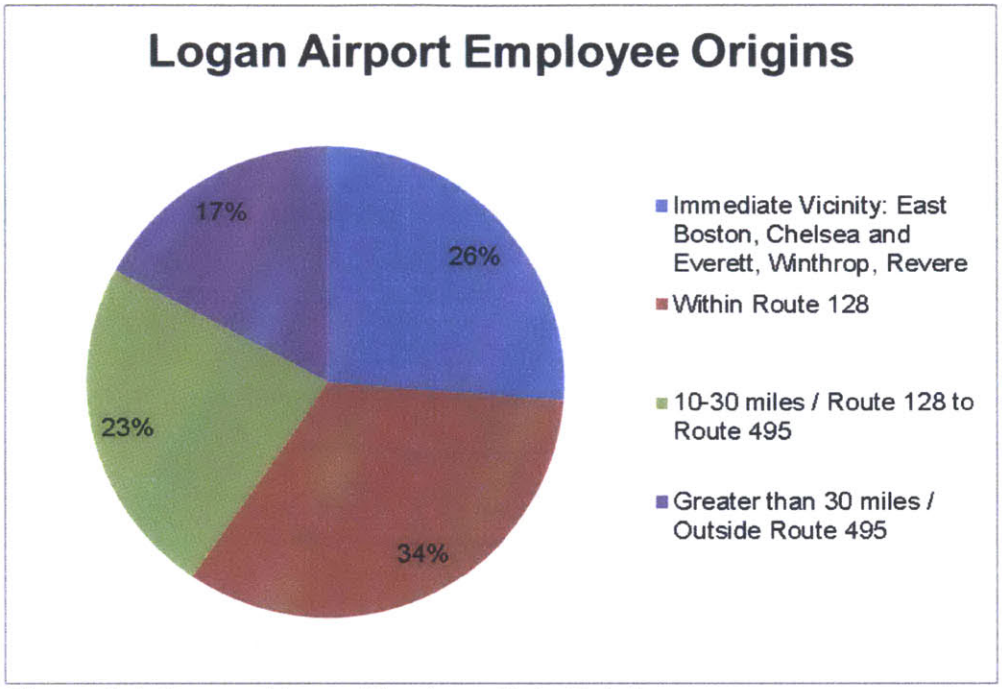

Figure 2-4: Logan Airport Employee Trip Origins

As expected, employee origins (**Figure 2-4**) tend to be closer to the airport than air passenger origins. A small proportion of employees, however, commute to Logan Airport from out of state, as shown in **Table 2-2**. This data, from 2010, is for all badged employees at the airport (representing approximately 95% of total employees).

Table 2-2: Employee State of Residence

State	Percentage of Employees
Connecticut	0.4%
Massachusetts	92.7%
Maine	0.7%
New Hampshire	4.7%
Rhode Island	1.5%
Vermont	0.1%

In conclusion, air passengers and employees travel a wide range of distances to access Logan Airport, varying from communities in the immediate vicinity to communities in nearby states. This highlights the need for a range of transit services that provide accessibility both locally and regionally.

2.2.2 Ground Access Market Segments

The 2010 Ground Access Survey also identified the distribution of four key market segments of weekday air travelers:

- Resident Business: 21%
- Resident Non-Business: 34%
- Non-Resident Business: 20%
- Non-Resident Non-Business: 26%

Approximately 55% of travelers are local residents, using Logan Airport to travel to another destination. Thus, slightly fewer than half of travelers accessing Logan Airport are non-residents of the region. In terms of trip type, approximately 60% of trips are non-business and approximately 40% are business. Each of these market segments has distinct travel characteristics, as summarized in **Table 2-3**.

Table 2-3: Ground Access Market Segments

	Business	**Non-Business**
Resident	Example: Boston resident travelling to London for business -Higher value of time and less sensitivity to cost -May have access to private vehicle -Trips originate in both residential and employment areas -Familiar with how to access airport -Less travel during weekends and holiday periods	Example: Boston resident travelling to California for vacation -Lower value of time and more sensitivity to cost -May have access to private vehicle -Trip origins and destinations dispersed throughout Logan's catchment area -Familiar with how to access airport -More travel on weekends and during holidays periods
Non-Resident	Example: London resident travelling to Boston for business -Higher value of time and less sensitivity to cost -No access to private vehicle; may rent vehicle -Trip origins and destinations in commercial areas with hotels and employment -Less familiar with how to access airport -Less travel on weekends and during holiday periods	Example: California student travelling to Boston to visit graduate schools -Lower value of time and more sensitivity to cost -No access to private vehicle; may rent vehicle -Trip origins and destinations dispersed throughout Logan's catchment area -Less familiar with how to access airport -More travel on weekends and during holiday periods

In conclusion, different strategies for each market segment will increase the utility of using transit:

- Travelers unfamiliar with the airport will benefit from clear signage and guidance upon arrival at the airport
- Travelers with a higher value of time will benefit from rapid, high-quality service with few transfers
- Cost-sensitive travelers will benefit from subsidized transit fares
- Residents with access to a vehicle will be more likely to use transit if parking fees are high and transit is convenient and inexpensive

2.3 Passenger Travel Patterns and Modal Split to the Airport

Approximately every three years, Massport conducts the "Logan Airport Air Passenger Ground Access Survey", which provides insight into how passengers access the airport. The most recent survey was conducted in May 2010. The survey is administered in passenger lounges while passengers are waiting to board their flight. For the 2010 survey, over 281 flights were surveyed, yielding more than 9,350 usable responses (Massport 2010 EDR, page 5-26). While this survey only captures travel **to** the airport, Massport assumes for planning purposes that passengers use the same mode when they travel **from** the airport to their destination in the Greater Boston Area.

The findings of this survey and previous surveys from 2007 and 2004 are shown in **Table 2-4**[12].

Table 2-4: Ground Access Mode Share (all Passengers) by Survey Year

Ground Access Mode	2004	2007	2010
Non-HOV			
Private Automobile	36.0%	40.2%	40.4%
Taxi	22.8%	19.7%	18.8%
Rental Car	10.9%	12.4%	10.9%
Total Non-HOV Share	**69.7%**	**72.3%**	**70.1%**
HOV/Shared-Ride			
Unscheduled HOV	8.1%	7.3%	7.6%
Scheduled HOV	10.6%	6.9%	8.2%
Transit	6.5%	6.7%	7.6%
Courtesy Shuttle	3.1%	3.5%	4.6%
Other	2.0%	3.4%	1.8%
Total HOV Share	**30.3%**	**27.8%**	**29.9%**

Note the following definitions of the categories above:

- Private Automobile refers to passengers who are dropped off at the airport or who drive and park at the airport
- Taxi refers to passengers who are driven to the airport in a taxi
- Rental Car refers to passengers who use a rental car to arrive at the airport
- Unscheduled HOV refers to unscheduled limousines or vans
- Scheduled HOV refers to scheduled limousines, buses and vans, including the Logan Express and private bus operators
- Transit refers to the MBTA Silver Line and Blue Line services and water transportation services; trips from Airport Station on the Blue Line and the water transportation services includes a trip on the Massport shuttle that links these services to the airport terminals
- Courtesy Shuttle refers to shuttles that provide service from hotels or convention centers to the airport
- Other refers to walk trips, cycle trips and charter bus trips

[12] Reproduced from Table 5-8, page 5-27 in Massport's 2010 EDR

2.4 Employee Travel Patterns and Modal Split to the Airport

Employees represent a distinct and substantial set of people who travel to the airport to work for airlines, Massport, the federal government (TSA), retailers, hotels, cargo and others. Employees arrive at and depart from the airport at all times of day, including some arriving for early morning shifts that begin before MBTA service has started. As of December 2010, there were approximately 14,685 employees at Logan Airport[13].

It is important to provide employees with transportation options that are convenient and reliable. Given that the supply of parking is limited at Logan Airport – and given that employee spaces can be converted to commercial spaces to increase revenue for Massport – public transportation can play a critical role in facilitating employee access to Logan Airport.

2.4.1 Results of 2007 Logan Airport Employee Commute Survey

Approximately every 5 years, Massport conducts a comprehensive employee commute survey, the most recent having been completed in 2007. This survey generated a sample of 1,684 usable responses by employees who worked at the airport at the time. Three methods were used to distribute the questionnaires to the employees:

1. Airport Employers: Massport provided the surveys to major employers, and the employers distributed and collected the surveys from their staff. 1,287 surveys were returned.
2. Logan Express: On the same day, surveys were distributed to all employees boarding the morning and mid-day departures to Logan. Drivers had collection envelopes and returned the surveys to Massport. 127 surveys were returned.
3. Chelsea Parking Garage: The bus operator of the 77 shuttle (which links the parking garage to the airport) distributed the surveys to passengers boarding during a 12 hour period. 279 surveys were returned.

The surveys distributed on the Logan Express had the best response rate (greater than 50%), likely because employees had time to complete the survey while taking the bus to work. Because surveys were distributed by three different processes, the resulting sample cannot be classified as a *random* sample (2007 Logan Airport Employee Commute Survey, page 1). Nevertheless, the results do provide insight into employee commute travel patterns.

The survey results provide insight into the arrival and departure times of most employees. The data from the survey have been used to produce **Figure 2-5**, which shows the arrival and departure times of airport employees.

[13] ACRP Synthesis Report 36, page 12

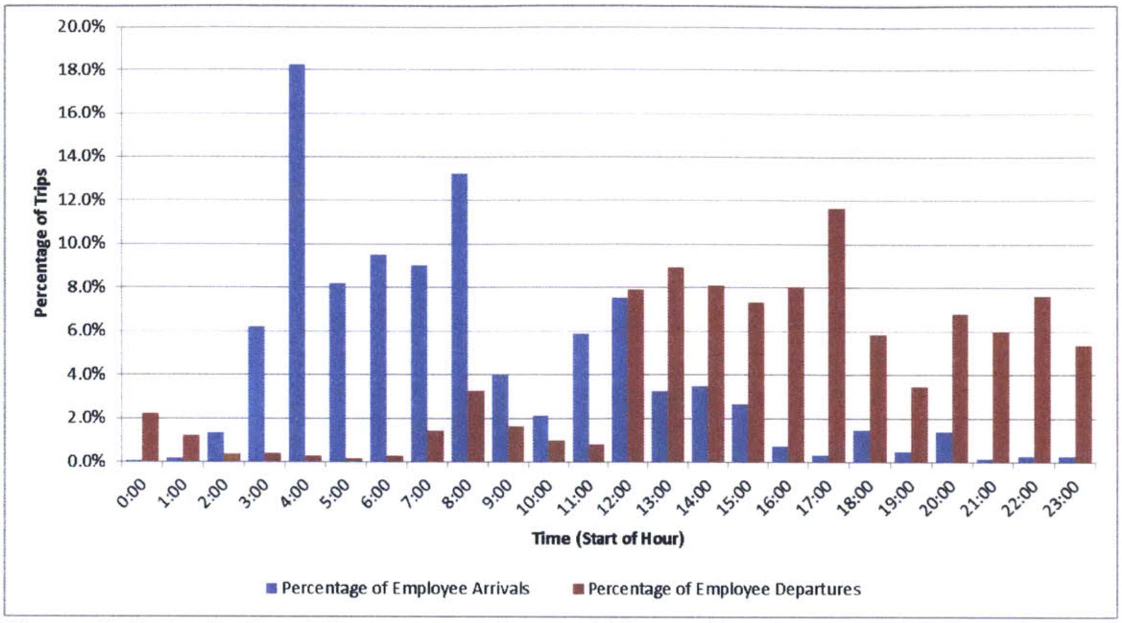

Figure 2-5: Arrival and Departures Times of Airport Employees

The following observations can be made regarding these data:

- The greatest proportion of employees arrive between 4:00 and 5:00 AM for the start of early morning shifts
- More than 50% of employee arrivals occur before 8:00 AM
- Approximately 13% of employee arrivals occur between 11:00 AM and 1:00 PM, as employees arrive for the start of second shifts
- There is a steady flow of departures between noon and midnight
- The employee travel patterns are more dispersed throughout the day than the standard "9 to 5" work pattern

These findings indicate that transportation options for employees must be provided throughout the day, especially during the period between 3:00 and 6:00 AM when MBTA service is less frequent or does not operate at all.

Other key findings of the survey pertain to the mode used by employees to get to the airport. The primary mode of travel results of the survey are shown in **Table 2-5**. To account for potential bias arising from the sampling method, only the results from the surveys submitted by Airport Employers were used in the tabulation (the results from the surveys submitted by Logan Express passengers and passengers on the Chelsea employee parking shuttles were not included).

Table 2-5: Logan Airport Employee Commute Primary Mode of Travel

Primary Commute Mode	Adjusted Count	% of Known Responses
Bicycle or Walk	20	1.6%
Blue Line	93	7.4%
Carpool/Vanpool	40	3.2%
Commuter Rail and Blue Line	8	0.6%
Commuter Rail and Silver Line	21	1.7%
Dropped Off	42	3.3%
Logan Express	130	10.3%
MBTA Bus	48	3.8%
MBTA to Silver Line	16	1.3%
Private Vehicle	790	62.6%
Private Vehicle-Occasional Other	37	2.9%
Silver Line	9	0.7%
Taxi	3	0.2%
Water Taxi/Ferry	5	0.4%
Total	**1262**	**100%**

The results are aggregated into broader categories in **Table 2-6**.

Table 2-6: Employee Commute Primary Mode of Travel

Commute Mode	Adjusted Count	% of Known Responses
Private Vehicle / Dropped Off / Taxi	871	69.0%
Logan Express or Scheduled Bus	130	10.3%
Carpool / Vanpool	40	3.2%
MBTA (Blue Line, Silver Line, Buses)	201	15.9%
Active Transportation (Walk and Cycle)	20	1.6%
Total	**1262**	**100%**

The following observations can be made based upon these survey results:

- There is a similar modal split between passengers and employees, with approximately 70% accessing the airport by private vehicle and approximately 30% accessing the airport using HOV modes
- Logan Express Bus and Scheduled Bus Services serve more than 10% of employee trips; thus, they are important transit connections for both passengers and employees
- MBTA services (Blue Line, Silver Line, buses) and Logan Express / scheduled services serve a comparable proportion of employee trips (i.e. in the range of 10-16%)

Massport's "2007 Logan Airport Employee Commute Survey" provides the following observations which provide insight into employee transit access to the airport:

- The introduction of the Silver Line may have resulted in a small shift of employee trips from the Blue Line to the Silver Line (page 5)
- The most popular modes for employees who live in the **immediate vicinity and within 10 miles of the airport** are drive alone, MBTA services, drop-off and carpool/vanpool (page 7)
- The most popular modes for employees who live **outside Route 128** are drive alone, Logan Express and other scheduled bus services, and joint commuter rail/MBTA trips (page 7)

- Employees arriving between 5:00 AM and 9:00 AM are more likely to drive alone, despite the availability of public transit service (page 15)
- Employees arriving between 11:00 AM and 1:00 PM are more likely to use modes other than drive alone, likely because parking is more limited at this time and because transit services are available both at the beginning and the end of the shift (page 15)
- There are relationships between transportation choices and employer types:
    - Employees at stores, restaurants and hotels are more likely to use the Blue Line, walk, bike or be dropped-off at the airport. This implies that they live closer to the airport
    - Over 20% of government airline employees report using the Logan Express, compared with less than 3% of general service and store/restaurant employees (page 19). This implies that government and airline employees live further from the airport, potentially as a result of the differences in income for these employee types.
    - Cargo, Rent-a-Car, airline and general service employees are most likely to drive alone to work. Cargo and rent-a-car employees may be more likely to drive because of parking availability and convenience

As the employee survey is an important source of data for Massport, it should be conducted regularly every 2 years. The survey should also be extended to airport employers who can provide information about their particular policies and subsidies for employees.

2.4.2 Employee Parking

Parking supply influences employee modal split. While complying with the Logan Airport Parking Freeze, Massport has been reducing employee parking spaces and increasing passenger parking spaces, as shown in **Table 2-7** and **Figure 2-6**.

Table 2-7: Parking Allocation at Logan Airport

Year	On-Airport Commercial Spaces	On-Airport Employee Spaces	Total Logan Airport Spaces Permitted
1992 – 1994	12,215	7,100	19,315
1995 – 1997	12,890	6,425	19,315
1998 – 2000	14,090	5,225	19,315
2001 – 2006	15,467	5,225	20,692
2007 – 2010	17,319	3,373	20,692
2011 – 2012*	18,265	2,673	20,938

1992 to 2010 from Chapter 5 of Massport 2010 Environmental Data Report, Page 5-7
*2011 to 2012 from September 2012 "Logan Airport Parking Space Inventory" sent to the Department of Environmental Protection

Between 1992 and 2012, the number of on-airport employee parking spaces at the airport decreased by 63%. Parking is an important revenue source for Massport: according to the Massport Comprehensive Annual Financial Report for Fiscal Year 2010, revenue from parking fees generated more than $100 million of the total $527.9 million operating revenue derived from fees, tolls, rentals, concessions and operating grants. As a result, pressure on the employee parking supply is expected to continue as airport traffic continues to grow. This highlights the need for effective transportation alternatives to private vehicle travel (such as carpools, vanpools, transit, active transportation, etc.) to serve an increasing proportion of the sizable number of daily employee trips.

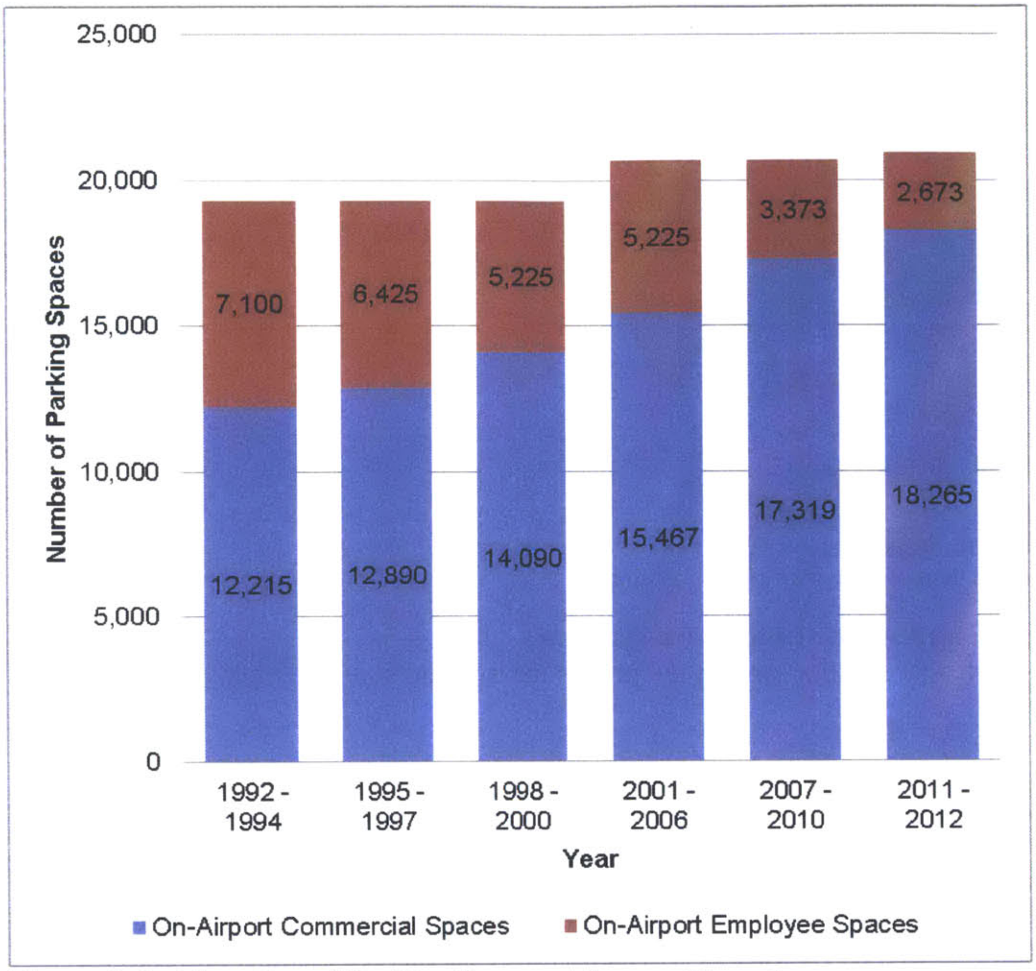

Figure 2-6: Allocation of Parking Spaces at Logan Airport

Additionally, Massport operates the off-site employee-only Chelsea Garage which contains approximately 1,550 employee parking spaces. The Chelsea Garage is connected to the airport by the Massport Shuttle route #77. The location of the Chelsea Garage in relation to Logan Airport is shown in **Figure 2-7**. Although there are only 1,550 spaces in this garage, Massport reports that 3,600 to 3,800 employees sign-up to use this garage on a monthly basis[14]. As many employees work early morning or late-night shifts, each parking space can be used multiple times per day. Massport reports that during the peak mid-day period there are only 150-200 vacant spaces in this garage, indicating a high level of occupancy for the garage.

[14] Personal communication, M. Deangelis, January 18th, 2013

Figure 2-7: Chelsea Employee Parking Garage

2.4.3 Massport Support for Employee Access

Massport has also introduced some employee-specific measures to support employee access to the airport:

Logan Transportation Management Association (TMA)

Massport founded the Transportation Management Association (TMA) in 1997. The function of the TMA is to provide information to airport employers and employees, assist employees with trip planning and rideshare matching and administer the Sunrise Shuttle (ACRP 36, page 12). The TMA also runs a program called NuRide where commuters can register on a website and earn points for non-private vehicle trips. At one point the TMA charged membership fees for airport employers, but many employers did not join as it was felt that the TMA's services could be achieved elsewhere (ACRP 36, page 17). Membership fees have now been eliminated and the next step for Massport is to refine the TMA's mission.

Transit Subsidies

MBTA: Massport funds shuttles between Airport station on the Blue Line and the airport terminals, which serve both employees and air passengers. Massport also purchased eight buses for the Silver Line route, provides an annual operating subsidy (ACRP 36, page 16) and is presently subsidizing free Silver Line boardings at the airport. Massport subsidizes transit passes by 50% for its own employees (up to $100), which may be paid with pre-tax income (ACRP 36, page 17).

Logan Express: Massport offers fare and parking discounts for all Logan Airport employees on the Logan Express:

- Although the one-way full fare for the Logan Express is $12, employees may purchase a book of 44 bus tickets for $75 ($1.70 per ticket).
- Monthly parking pass for $40
- Employees can also purchase a combined monthly pass for both parking and bus use for $100 (ACRP 36, page 16).

Massport employees can park free at the Logan Express lots, and are also eligible for the discounted Logan Express tickets.
Private Bus Operators: Massport also encourages private bus operators to offer employee discounts (ACRP 36, page 17).

Transit Services – Sunrise Shuttle
The Sunrise Shuttle was introduced in August 2007 as a partnership between Massport and the Logan Airport Transportation Management Association. The original service – the Southern Route – provides early-morning access for employees in East Boston who need to arrive at work before MBTA services have begun. A second shuttle to provide early morning service to the Orient Heights neighborhood – the Northern Route – was introduced in October 2011. The fare for the shuttle is $1, and monthly ridership is approximately 1,300.

Addressing Imbalance between Parking and Transit Subsidies
There is an imbalance in the way Massport employee subsidies are currently structured; employee parking is 100% subsidized while 50% subsidies are offered for transit passes. This strategy goes against Massport's goal of increasing public transportation access to Logan Airport. It is recommended that Massport provide 100% subsidized transit passes for employees to match the parking subsidies and possibly encourage a mode shift to public transportation. Once employee transit passes are fully subsidized, Massport can convert some of the employee parking spaces to commercial spaces so as to earn more parking revenue, which can be used in financing the transit subsidies. Other airport employers should also be encouraged to incentivize employee transit use.

A more detailed summary of Massport's allocation of funds for airport ground transportation services to Logan Airport is provided in **Appendix A: Resource Provision and Fees for Ground Transportation to Logan**.

2.4.4 Estimated Employee Trip Generation and Modal Split

Average daily employee trip generation and modal split, shown in **Table 2-8**, has been estimated using the following sources:

- 2007 Employee Commute Survey
- 2011 and 2012 transit ridership data
- Team field observations
- Consultation with Massport

Employee trips are dynamic, as some employees work different shifts on different days; further, the total number of employees at the airport also varies day-to-day. Thus, the employee trip generation rate and modal split is only intended to provide an order-of-magnitude assessment of employee trips to Logan Airport.

Table 2-8: Estimated Employee Trip Generation and Modal Split

Mode Family	Mode	Percentage of Trips	Number of Trips	Notes / Assumptions
Vehicular Access	Private Vehicle / Carpool	68%	6150	-Assume the 1551 spaces in the Chelsea Garage are used 1.85 times per day, with average vehicle occupancy of 1.1 -Assume the 2598 on-airport employee spaces are used 1.1 times per day with vehicle occupancy of 1.05
	Dropped Off	3%	300	-Use the percentage of overall employee trips from 2007 survey
	Taxi	0.2%	20	
Non-MBTA Buses	Logan Express and Scheduled Buses	8%	730	-2011 annual number of Logan Express employee trips converted to a daily value
MBTA Transit	Silver Line	5%	450	-Assume 15% to 20% of Silver Line (SL1) trips are employee trips (based on field observation)
	Blue Line	10%	900	-Assume 30% to 40% of Blue Line (Airport Station) trips are employee trips (based on field observation)
	MBTA Bus	4%	350	-Use the percentage of overall employee trips from 2007 survey
	Water Taxi	0.40%	40	
Active Transportation	Bike or Walk	2%	150	
	Total*	**100%**	**8,800** to **9,300**	
	Average		**9,050**	

*Totals does not sum exactly to 100% due to rounding

According to this estimate, there are approximately 8,851 to 9,269 employee trips to Logan Airport per day, with an average of about 9,060 which corresponds to a total of about 3.3 million trips per year. If this total is divided by the 14,685 employees at Logan Airport, it results in a total of 225 trips to Logan Airport per employee per year. An employee who works 5 days a week for 50 weeks a year would make 250 trips to Logan Airport. Given the number of shift workers, part-time workers and airline flight crews who make fewer than 250 trips per year, 225 trips per employee per year is a reasonable employee trip generation value. ACRP Report 40 notes that 40% of employees at Logan Airport are absent on a given workday[15]; multiplying the number of employees by 0.6 results in 8,811 which is within the range of estimated daily employee trips.

[15] ACRP 40, Airport Curbside and Terminal Area Operations, page 24, 2010

2.5 Estimated Transit Demand by Mode to Logan Airport

Based upon the trends discussed in this chapter and data made available by Massport and the MBTA, transit demand by mode to Logan Airport has been estimated and is presented in **Table 2-9**. The data was determined from the following sources:

- **Logan Express:** Annual ridership records for the Logan Express from 2011 were obtained and converted to average weekly values. Then, the percentage of trips for Tuesdays, Fridays and Sundays were applied to the weekly value. Day-of-week percentages varied slightly across routes and trip types (i.e. employee trip or air passenger trip).
- **Silver Line:** The CTPS (Central Transportation Planning Staff) completed point-check loads on the Silver Line from November 2012, which are presented here. The employee share of Silver Line trips was estimated at **15% to 20%**, based on field observations and the results of the 2007 Logan Airport Employee Commute Survey. These proportions were applied to Sunday trips; the number of Tuesday and Friday trips were assumed to be consistent
- **Blue Line / Airport Station:** Massport completed ridership counts on the shuttles that connect Logan Airport to Airport Station in the spring of 2011 and 2012. The 2011 and 2012 values have been averaged and included in the table. The employee share of trips was estimated at **30% to 40%**, based on field observations and the results of the 2007 Logan Airport Employee Commute Survey. These proportions were applied to Sunday trips and the number of trips on Tuesdays and Fridays were assumed to be equivalent.
- **Sunrise Shuttle:** Average ridership for the Sunrise Shuttle was provided by Massport. All riders on the Sunrise Shuttle are employees.
- **Water Transportation:** 2010 ridership numbers from Massport's Environmental Data Report were factored to weekday and Sunday values. The employee share was estimated based on the results of the 2007 Logan Airport Employee Commute Survey.

Table 2-9: Estimated Daily Transit Access by Mode to Logan Airport

	Tuesday						Friday						Sunday					
	Inbound			Outbound			Inbound			Outbound			Inbound			Outbound		
Transit Service	Empl	Pass	Total	Empl	Pass	Total	Empl	Pass	Total	Empl	Pass	Total	Empl	Pass	Total	Empl	Pass	Total
Logan Express[1]																		
Braintree	411	332	**743**	406	317	**724**	395	347	**741**	424	364	**788**	375	251	**626**	315	269	**584**
Framingham	100	384	**483**	95	381	**477**	96	409	**506**	101	435	**536**	77	268	**346**	70	312	**382**
Peabody	52	43	**95**	50	36	**87**	45	40	**85**	43	37	**80**	26	22	**48**	22	22	**44**
Woburn	235	174	**409**	235	162	**396**	204	174	**378**	206	177	**383**	173	160	**332**	182	163	**345**
Total	797	933	**1730**	786	897	**1683**	740	969	**1710**	774	1013	**1787**	651	701	**1352**	589	766	**1355**
Silver Line[2]																		
Empl- Low	371	1403	**1774**	371	1993	**2364**	371	2448	**2819**	371	3030	**3401**	371	2102	**2473**	371	2083	**2454**
Empl- High	495	1279		495	1869		495	2324		495	2906		495	1978		495	1959	
Blue Line[3]																		
Empl- Low	767	2555	**3322**	767	2016	**2783**	767	3216	**3983**	767	2559	**3326**	767	1790	**2558**	767	1758	**2525**
Empl- High	1023	2299		1023	1760		1023	2960		1023	2303		1023	1535		1023	1502	
Sunrise Shuttle[4]																		
	43	N/A	**43**	N/A	N/A	**0**	43	N/A	**43**	N/A	N/A	**0**	43	N/A	**43**	N/A	N/A	**0**
Water Transportation[5]																		
	36	96	**133**	39	93	**133**	36	96	**133**	39	93	**133**	36	70	**106**	31	74	**106**
Total – Empl Low	2015	4987	**7002**	1964	4999	**6963**	1958	6730	**8687**	1951	6696	**8647**	1868	4663	**6531**	1759	4681	**6440**
Total – Empl High	2394	4608		2343	4620		2337	6350		2331	6316		2248	4283		2138	4302	

[1]Logan Express numbers from 2011 data sent by L. Dantas, Massport, November 2012; data used to determine Tuesday/Friday/Sunday split provided by Massport, 2013
[2]Silver Line boardings and alightings based on CTPS data collection in November 2012; employees estimated as 15% to 20% of total Sunday trips
[3]Blue Line / Airport Station entrances and exits based upon Massport shuttle load counts to and from the Airport, average of spring 2011 and spring 2012 counts; employees estimated as 30% to 40% of total Sunday trips; adjustment factors applied to convert counts until 8 PM to full day counts (more detailed discussion in **Section 3.2.4**).
[4]Sunrise Shuttle figures based on personal communication with L. Dantas, Massport, November 2012
[5]Water Taxi figures based upon data in Massport 2010 Environmental Data Report

"Inbound" refers to trips **to** Logan Airport
"Outbound" refers to trips **from** Logan Airport

2.6 Conclusions

The following conclusions can be drawn from this review of the ground access demand to Logan Airport:

- Employees represent a significant proportion the ground access demand to Logan Airport, and transit services should be planned with consideration for their needs (i.e. early morning services, need for low-cost options). Given the continued anticipated pressure on the supply of employee parking, transit will become increasingly necessary for employee travel
- Employees are generally based in the Boston-area and make the trip to the airport several times a week: they are thus a natural group to target for a mode shift to transit via Silver Line, Blue Line, Logan Express or special vans such as the Sunrise Shuttle. Further, on-airport employee parking spaces can be converted to commercial spaces which generate more revenue (which can be used to support HOV goals). The conversion of one employee parking space to a commercial space would generate $6,750 annually to Massport if it is used for 250 days a year at the daily rate of $27. A portion of this additional revenue could be used to improve or incentivize transit options for employees
- It is recommended that Massport provide 100% subsidized transit passes for employees to match the parking subsidies and possibly encourage a mode shift to public transportation.
- As the employee survey is an important source of data for Massport, it should be conducted regularly every 2 years. The survey should also be extended to airport employers who can provide information about their particular policies and subsidies for employees. Web-based surveys accessed through individual email links for employees and employers should also be considered
- Employees can provide a reliable base of customers who will use new transit services
- The trip origins of air passengers and employees are spread throughout the Greater Boston Area and even extend to neighboring states. This indicates the need for an integrated system of complementary transit services that can serve both local and regional trips
- Non-residents – who rely on taxis, rental cars, public transportation or PUDO – represent approximately 45% of all air passengers. Special efforts should be made to introduce this market to transit services, as they do not have immediate access to automobiles

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3 Transit and HOV Services to Logan Airport

This chapter describes the existing transit and HOV services at Logan Airport. It is organized as follows:

- Section 3.1: Silver Line
- Section 3.2: Blue Line and Massport Shuttles
- Section 3.3: Other MBTA Buses to the Airport
- Section 3.4: Logan Express
- Section 3.5: Sunrise Shuttle
- Section 3.6: Conclusions

Throughout this report, **inbound** refers to trips **to** Logan Airport and **outbound** refers to trips **from** Logan Airport. Thus, while the MBTA refers to an "inbound" Silver Line trip as a return trip from the airport to South Station, for the sake of consistency an "inbound" Silver Line trip in this report refers to a trip from South Station to Logan Airport.

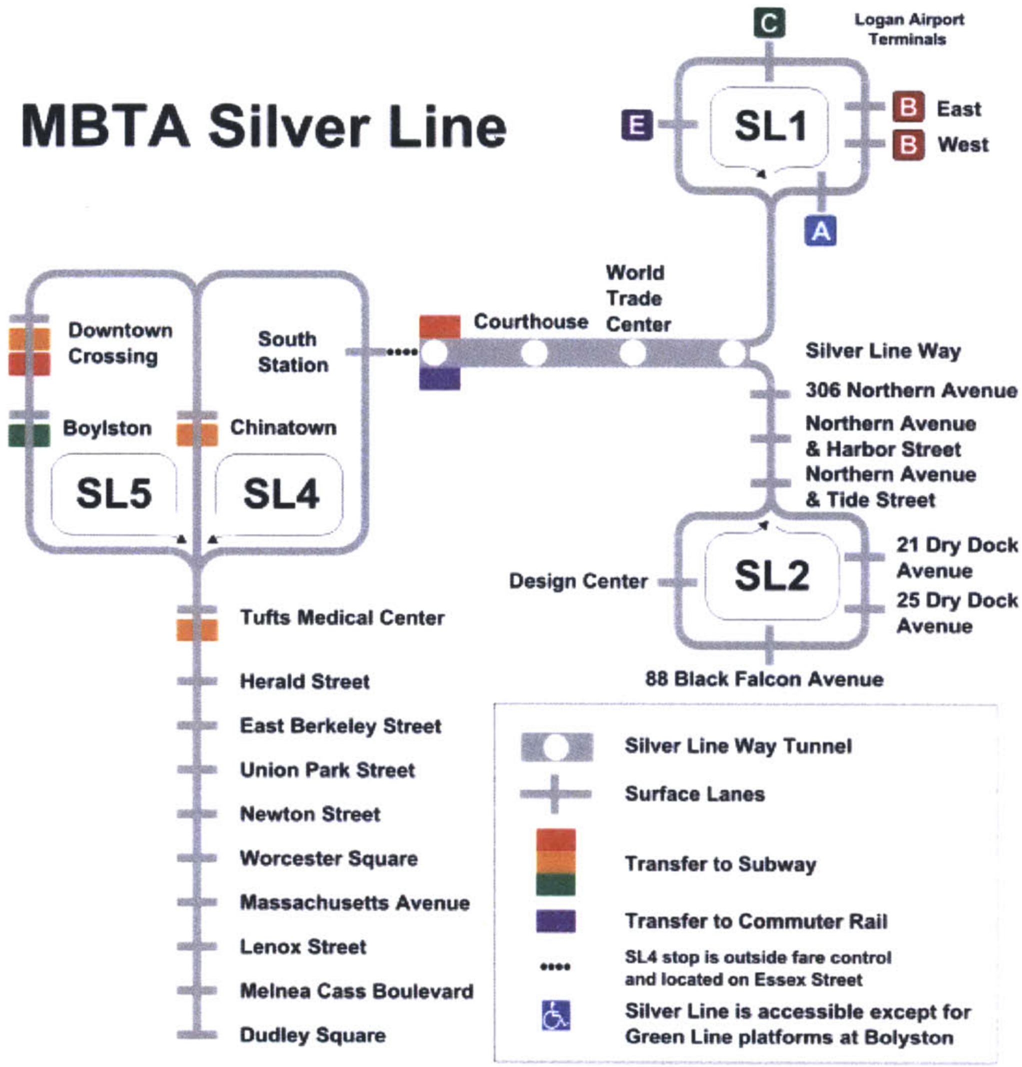
3.1 Silver Line

3.1.1 Route and Existing Vehicle Technology

There are 32 buses which are operated on the Silver Line routes that service the Airport (SL1) and the waterfront in South Boston (SL2). There are two additional Silver Line routes (SL4 and SL5) which are independent of the SL1 or SL2 routes at this point in time. While there is a potential Phase III of the Silver Line that would connect the two halves of the service, there are no plans or timetable to implement this service. SL3 formerly ran to City Point via the Boston Marine Industrial Park, but was discontinued in 2008 due to insufficient ridership[16]. The MBTA also runs a short-turn route between South Station and Silver Line Way during the AM and PM peak periods to serve heightened demand between these stops. A schematic of the existing Silver Line services is shown in **Figure 3-1**.

The SL1 and SL2 run in an exclusive tunnel between South Station, Courthouse Station and World Trade Centre Station. The buses emerge from a portal after World Trade Centre station and come to the surface at D Street in the South Boston Waterfront. After crossing D Street at-grade, the buses detach from the overhead electrical wires and switch to diesel. Some drivers stop beneath the Manulife building to transition to diesel power, while others continue to the Silver Line Way surface stop and switch from the electrical overhead wires to diesel power there. After the Silver Line Way stop the buses use surface streets to reach the waterfront (SL2) and the Ted Williams tunnel to reach Logan Airport (SL1). The SL1 is of particular relevance to this project, as it is the route that serves Logan Airport.

[16] http://en.wikipedia.org/wiki/City_Point_(MBTA_station)



Source: http://en.wikipedia.org/w/index.php?title=File:MBTA_Silver_Line_map.svg&page=1

Figure 3-1: Silver Line Schematic

SL1 buses make the following stops at Logan Airport:

- Terminal A
- Terminal B – Stop 1
- Terminal B – Stop 2
- Terminal C
- Terminal E

Passengers are dropped off and picked up at the same location in each terminal. The buses stop at the (lower) arrivals level.

The buses used for the SL1 service between South Station and Logan Airport are Neoplan USA AN460LF dual-mode 60 foot articulated buses, allowing for additional passenger capacity and also space for luggage. The seating capacity for these buses is shown below:

	Number of People
Seated Capacity*	38
Planned Capacity*	65
Crush Capacity*	96
Team Estimated Realistic Capacity with Luggage	80

*From MBTA Blue Book 2010, page 64

The crush capacity is listed as 96 people, based on a calculation of 2 square feet per person under crush conditions. The team estimates the realistic capacity to be approximately 80 people, as many people on the Silver Line have luggage which takes up space on the seats or in the aisle, thus reducing the capacity. Neoplan USA filed for Chapter 11 bankruptcy in August 2006[17]. Opportunities to deploy new buses on the Silver Line once the existing buses reach the end of their service life are discussed in **Chapter 0**.

3.1.2 Timetable Analysis and Operating Characteristics

The MBTA varies the headways on the SL1 by time of day and day of week. As of September 2012, the MBTA operated the SL1 with the following headways:

Table 3-1: SL1 Headways, September 2012

Weekday	5:50 AM to 6:50 AM	15 minutes
	6:50 AM to 8:00 PM	10 minutes
	8:00 PM to 12:30 AM	12 minutes
Saturday	6:00 AM to 12:30 AM	12 minutes
Sunday	6:12 AM to Noon	12 minutes
	Noon to Midnight	8 minutes
	Midnight to 12:30 AM	10 minutes

Source: http://www.mbta.com/schedules_and_maps/bus/routes/?route=SL1

The MBTA Blue Book 2010 summarizes the number of vehicles and headways for the SL1, as shown in **Table 3-2**.

Table 3-2: SL1 Vehicles and Headways

Time Period		Number of Vehicles	Headway (minutes)
Weekday	AM Peak	5	10
	AM Base	5	10
	PM Peak	6	10
	PM Base	5	10
	Late	4	12
Weekend	Saturday Peak	4	12
	Sunday Peak	6	8

[17]http://en.wikipedia.org/wiki/Neoplan_USA

A detailed assessment of the MBTA's Headway Report for the SL1 on a weekday has been undertaken, and the results are shown in **Table 3-3**.

Table 3-3: Silver Line Timetable Analysis

Time Period	Number of Vehicles	Headway	Running Time	Recovery Time at South Station	Cycle Time
Open: 5:38 AM to 7:00 AM	4	15	38	Varies	Varies
AM: 7:00 AM - Noon	5	10	38	12	50
Midday: Noon - 2:30 PM	5	10	38	12	50
PM Base: 2:30 PM - 4:50 pm	5	10	40	10	50
PM Peak: 4:50 - 6:30 PM	6	10	40	20	60
PM Base: 6:30 - 8:40 PM	5	10	40	10	50
Evening: 8:40 - Midnight	4	12	40	8	48
Close: Midnight - 1:10 AM	4	15	40	Varies	Varies

The following observations can be made regarding the timetable:

- An additional (sixth) bus is provided in the PM Peak, although the recovery time at South Station is doubled from 10 minutes to 20 minutes during this period with headways and the running time held constant. Although the timetable implies that the running time does not change during this period, the 20 minutes of recovery time are likely intended as a buffer to account for longer running times caused by roadway and airport terminal congestion during the PM Peak
- The running time in the schedule is increased from 38 minutes during the AM peak to 40 minutes during the PM peak to account for increasing roadway and airport congestion after 2:30 PM
- There may be opportunities to reduce the recovery time at South Station in order to decrease headways or operator costs. Potential operational improvements are discussed in **Chapter 6.6.3**.
- The recovery time and cycle time vary during the early morning and late evening periods as schedules are adjusted to account for buses coming in and out of service

The average and standard deviation of manually observed Silver Line headways are shown in **Table 3-4**.

Table 3-4: Comparison of Scheduled Headways with Measured Headways

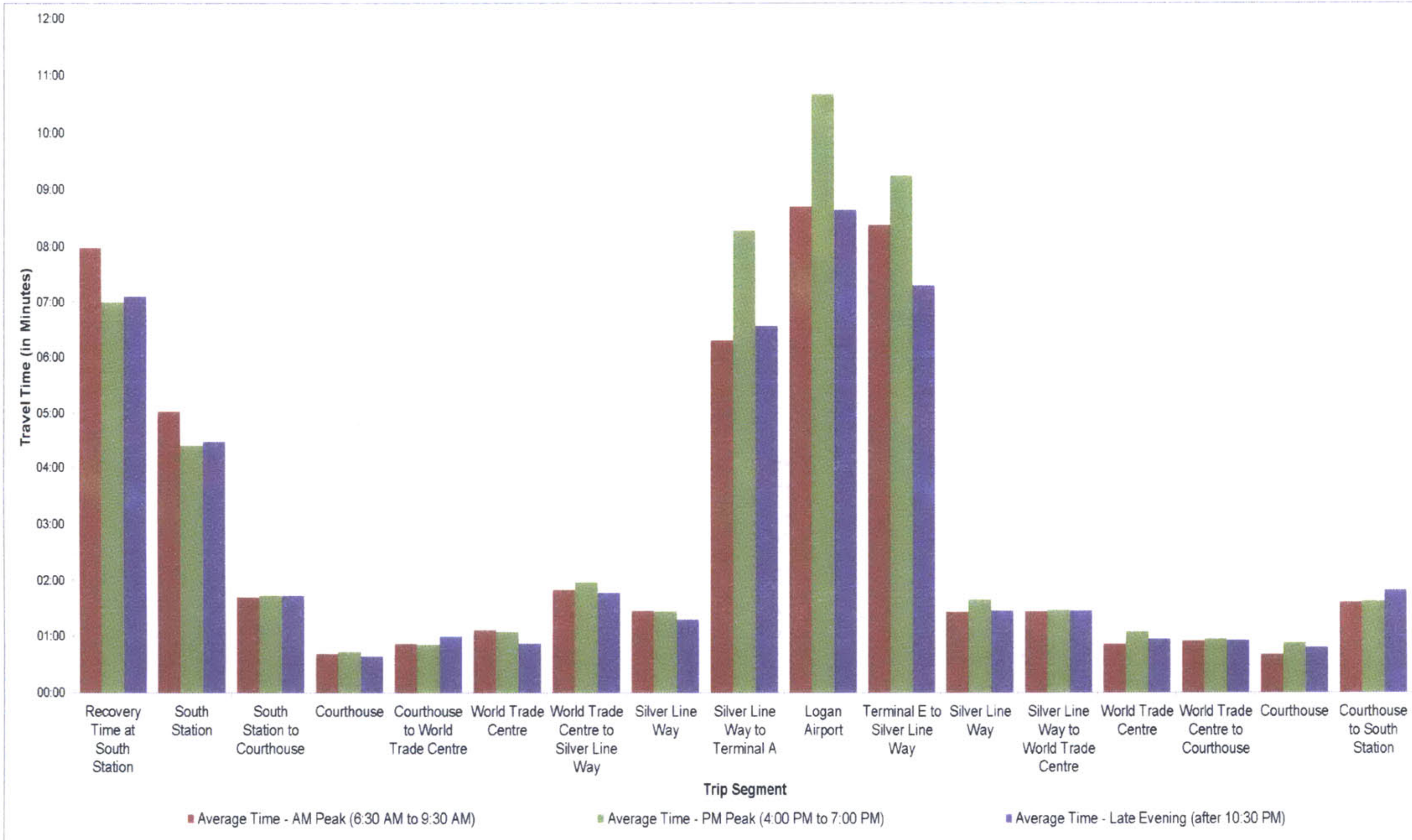
Date	Location	Period of Day	Scheduled Headway	Average Measured Headway	Standard Deviation of Headways
Friday, November 16th, 2012	Terminal A	**AM** 8:45-10:15 AM	10:00	9:55	1:55
Friday, January 11th, 2013	D Street – Outbound from Logan Airport	**Midday** 12:30-2:00 PM	10:00	9:37	4:00
Friday, January 11th, 2013	D Street – Outbound from Logan Airport	**PM** 3:30-5:00 PM	10:00	10:43	2:34

While these measurements are based on a relatively small number of data points, they show that headways are clustered around the scheduled headway of 10 minutes. The headways are actually slightly less than 10 minutes during the AM and Midday periods when there is less congestion, although the standard deviation indicates that the headways are variable. Average headways increase during the PM Peak period and exceed 10 minutes. These data are collected prior to the introduction of the sixth bus (at South Station at 4:50 PM) and suggest that an earlier introduction of the sixth bus could result in more timely and consistent headways in the afternoon. Strategies to improve Silver Line operation are further discussed in **Chapter 6**.

3.1.3 SL1 Existing Travel Times and Dwell Times

Automated Vehicle Location (AVL) data available from the MBTA for the Silver Line were used to develop travel time and speed profiles for the SL1 route. **Figure 3-2** shows the average travel time for each segment of the trip and average dwell times. Some key observations about this data are:

- The longest elements of the trip are the time spent at South Station (dwell and recovery time) and time spent at Logan Airport
- The travel time from Silver Line Way to Terminal A, and from Terminal E to Silver Line Way are the two longest travel times. Travel times during the PM Peak period are noticeably longer than times during the AM Peak and Late Evening.
- The outbound trip from Terminal E to Silver Line Way is longer than the inbound trip from Silver Line Way to Terminal A
- In many cases the travel time between stops is comparable to the dwell time at the stop. This implies that a significant proportion of the total travel time of the trip is spent in dwell. Thus, efforts should be made to not only reduce travel time but also to reduce dwell time



Average Dwell Times are based on the period from June 6, 2012 to October 15, 2012, once fare payment to board was eliminated at the terminals at Logan Airport

Figure 3-2: Average Time for SL1 Round-Trip from South Station to Logan Airport

Table 3-5: Average Travel Times for SL1 to Logan Airport

Location	Average Time - AM Peak (6:30 AM to 9:30 AM)	Average Time - PM Peak (4:00 PM to 7:00 PM)	Average Time – Late Evening (after 10:30 PM)
Recovery Time at South Station	07:59	07:00	07:06
South Station Dwell and Turnaround*	05:01	04:24	04:28
South Station to Courthouse	01:41	01:43	01:43
Courthouse	00:41	00:43	00:38
Courthouse to World Trade Centre	00:52	00:51	00:59
World Trade Centre	01:06	01:04	00:52
World Trade Centre to Silver Line Way	01:49	01:58	01:46
Silver Line Way	01:27	01:26	01:17
Silver Line Way to Terminal A	06:18	08:17	06:34
Logan Airport	08:42	10:40	08:38
Terminal E to Silver Line Way	08:23	09:15	07:18
Silver Line Way	01:25	01:39	01:27
Silver Line Way to World Trade Centre	01:26	01:27	01:27
World Trade Centre	00:51	01:04	00:57
World Trade Centre to Courthouse	00:55	00:57	00:55
Courthouse	00:40	00:53	00:48
Courthouse to South Station	01:36	01:37	01:49
Total Trip Running Time	**39:00**	**44:40**	**38:17**
Total Trip Cycle Time (includes Recovery)	**50:53**	**54:57**	**48:43**

*Split of time between recovery and dwell/turnaround not available from AVL; proportional split determined by field observations at South Station from 2:00 to 5:00 PM on Friday, March 1, 2013

The AM Peak cycle time has been corroborated by field data recorded the morning of Friday, November 16th, which reports an average cycle time of 49:21. During the Thanksgiving Rush PM Peak (see **Section 3.1.5** for further discussion) the average cycle time was 48:31, suggesting that recovery times at South Station were shortened to serve the heightened demand.

Average travel speeds during the AM Peak (6:30 AM to 9:30 AM), PM Peak (4:00 PM to 7:00 PM) and Late Evening (after 10:30 PM) have been calculated for each segment of the trip, using the average travel times and link distances. Data from June 6, 2012 to October 15, 2012 was analyzed to determine these averages. The speed profile for the route is presented in **Table 3-6** and **Figure 3-3**.

Table 3-6: Average Speed (mph) for SL1 to Logan Airport

Route Segment	All Day	AM Peak (6:30 to 9:30 AM)	PM Peak (4:00 to 7:00 PM)	Late Evening (after 10:30 PM)
South Station to Courthouse	19	19	19	19
Courthouse to World Trade Centre	25	25	25	22
World Trade Centre to Silver Line Way	8	8	7	8
Silver Line Way to Terminal A	31	33	25	31
Terminal A to Terminal B1	19	20	17	19
Terminal B1 to Terminal B2	23	25	21	23
Terminal B2 to Terminal C	13	13	12	14
Terminal C to Terminal E	16	19	13	15
Terminal E to Silver Line Way	23	22	20	25
Silver Line Way to World Trade Centre	9	9	8	8
World Trade Centre to Courthouse	24	23	22	23
Courthouse to South Station	18	19	19	17

Key observations are:

- Speeds are more consistent between different times of day in the tunnel, where buses do not travel in traffic.
- The slowest average speed for both inbound and outbound directions is the link between World Trade Centre station and Silver Line Way: this reflects the stops the bus must make before the gate at the portal, at D Street, and for the technology transition.
- The outbound trip from Terminal E to Silver Line Way is slower than the inbound trip from Silver Line Way to Terminal A.
- Travel speeds are slower during the PM Peak, as a result of congestion
- Travel speeds between airport terminals are slower during the PM Peak, when there are more buses, taxis and pedestrians in the terminal area

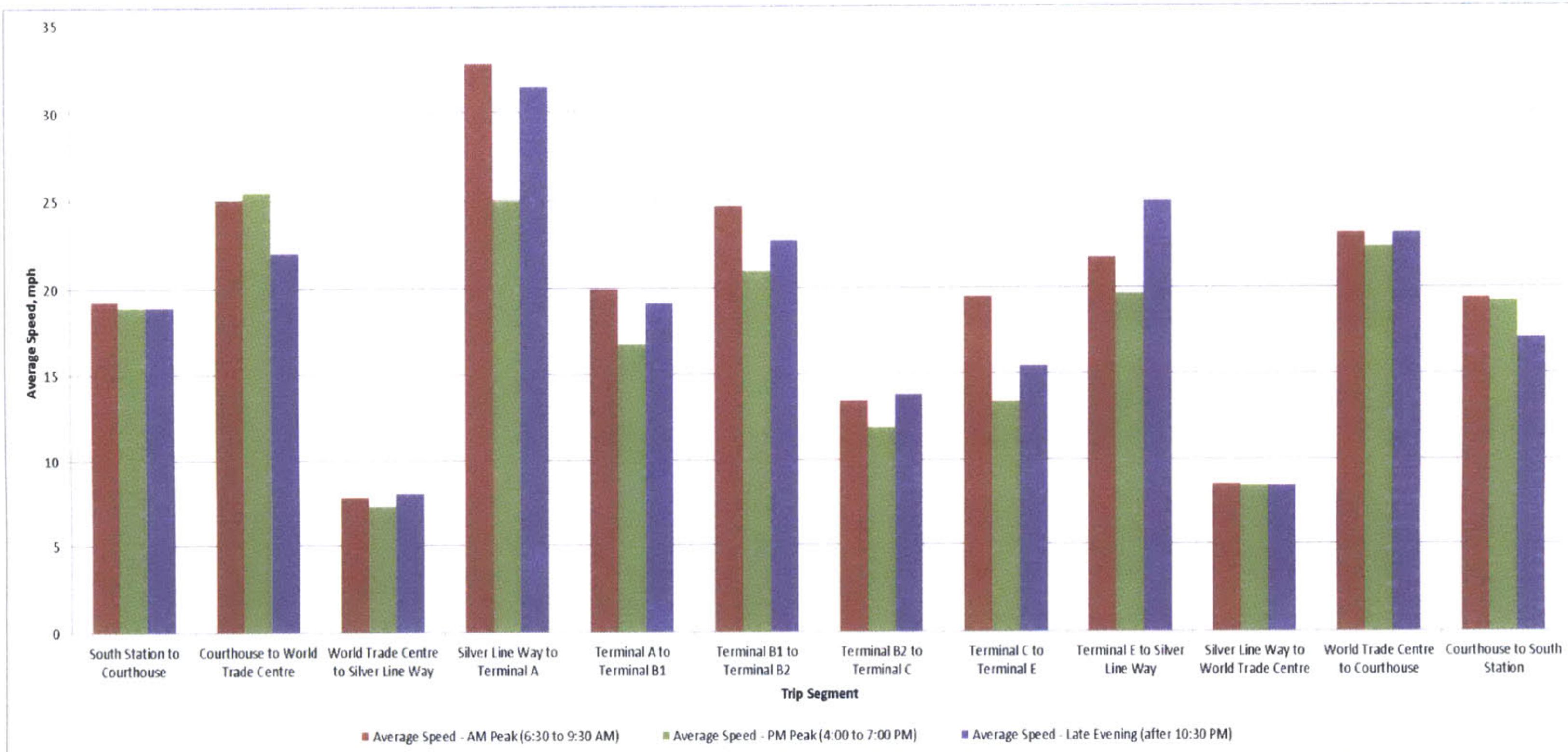


Figure 3-3: Average SL1 Travel Speed by Route Segment

3.1.4 SL1 Ridership

Annual boardings on the Silver Line at Logan Airport are summarized in **Figure 3-4**.

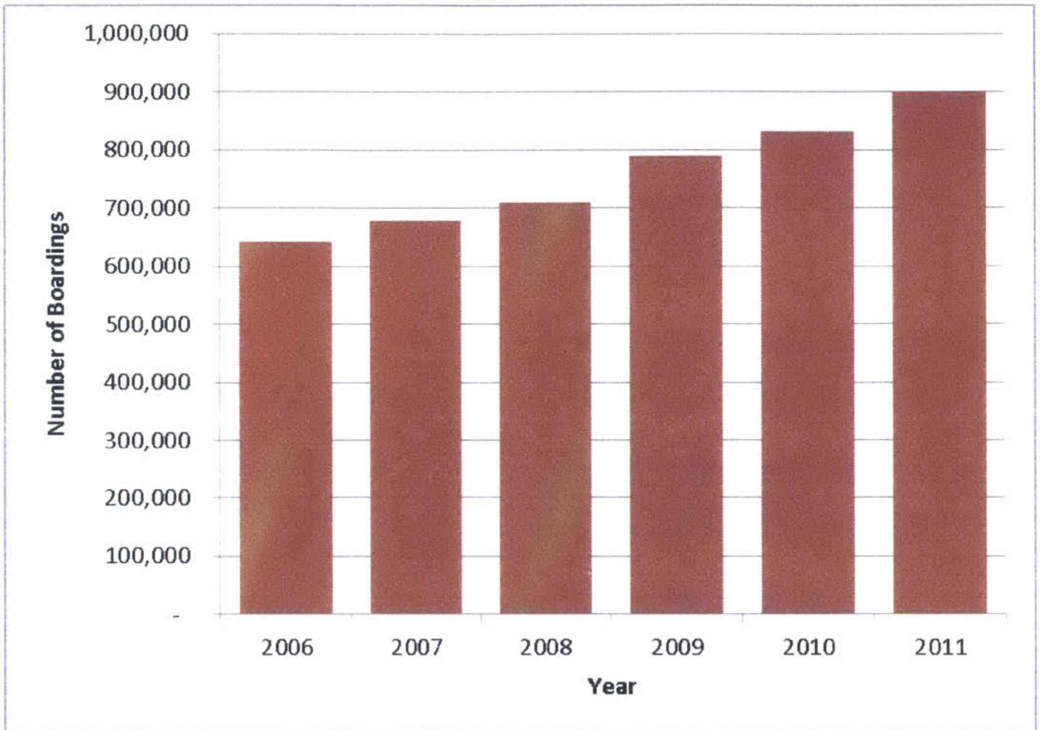


Figure 3-4: Annual Silver Line Boardings at Logan Airport

As shown above, boardings at Logan Airport have been steadily increasing. Boardings increased by 8.3% between 2010 and 2011. AFC data for boardings at Logan Airport are not available after May 2012, as fare payment at Logan Airport was removed. However, data for the first 5 months of 2012 is compared in **Table 3-7** to the same time period in previous years to assess changes to ridership in 2012.

Table 3-7: January to May Boardings by Year

January - May Boardings by Year	
2006	220,697
2007	256,835
2008	277,893
2009	306,719
2010	334,657
2011	355,028
2012	357,322

Ridership for the first five months of 2012 increased modestly compared to the same period in 2011.

Average daily boardings (by month) from the initiation of the service in June 2005 to May 2012 are shown in **Figure 3-5**. There are some pronounced monthly trends:

- Lowest boardings in December, January and February are likely because there are fewer holidays and passengers are less likely to use transit during inclement winter months
- Highest boardings in November, likely due to personal travel associated with Thanksgiving and business travel before Thanksgiving

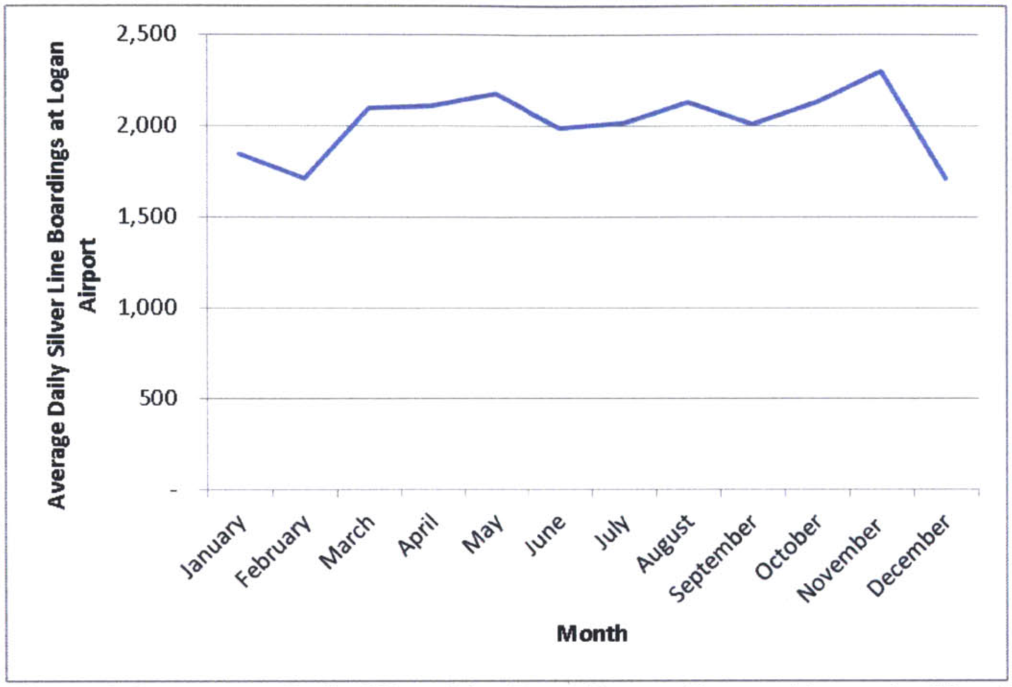


Figure 3-5: Average Daily Silver Line Boardings at Logan Airport by Month (June 2005 to May 2012)

To further assess the existing level of transit ridership to Logan Airport, data available from the MBTA were reviewed. The MBTA and CTPS collected inbound and outbound Silver Line loads at Logan Airport for a sample Tuesday, Friday and Sunday in November 2012; the results are shown in **Table 3-8**. Based on the team's observations and the results of the 2007 Logan Airport Employee Commute Survey, employee trips have been estimated to represent 15% to 20% of Sunday SL1 trips to the airport.

Table 3-8: SL1 Ridership based on November 2012 Ridership Count

Survey Date		Inbound: Alighting at Logan Airport			Outbound: Boarding at Logan Airport		
		Employees	Air Passengers	Total	Employees	Air Passengers	Total
Tuesday, November 13, 2012	Empl Low	371	1403	**1774**	371	1993	**2364**
	Empl High	495	1279		495	1869	
Friday, November 16, 2012	Empl Low	371	2448	**2819**	371	3030	**3401**
	Empl High	495	2324		495	2906	
Sunday, November 18, 2012	Empl Low	371	2102	**2473**	371	2083	**2454**
	Empl High	495	1978		495	1959	

These data show that Friday is the busiest day (in terms of both boardings and alightings), followed by Sunday and then Tuesday. On Tuesday and Friday the boardings at Logan Airport exceed alightings, while the pattern was more balanced on the Sunday.

Based on MBTA ridership data, boardings and alightings at Logan Airport have been tabulated in **Table 3-9**. The boardings and alightings are taken from the MBTA's 2010 Blue Book ridership profile for the SL1, which is replicated as **Table 3-10**. Growth factors based on the change in annual SL1 boardings at the airport (see **Figure 3-4**) have been used to convert the weekday values from 2009 to 2011, and the Saturday and Sunday values from 2006 to 2009.

Table 3-9: SL1 Ridership based on MBTA Blue Book Data

	Raw Data: Weekday 2009, Saturday and Sunday 2006		Factored to 2011	
	Inbound: Alightings at Logan Airport	Outbound: Boardings at Logan Airport	Inbound: Alightings at Logan Airport	Outbound: Boardings at Logan Airport
Weekday*	1935	2626	2,207	2,995
Saturday**	1384	1390	1,940	1,949
Sunday**	1229	1706	1,723	2,392

*Growth factor of 14% applied based on growth in boardings of SL1 at Logan Airport
**Growth factor of 40% applied based on growth in boardings of SL1 at Logan Airport

The Blue Book data also shows a trend of boardings at Logan Airport exceeding alightings. The average weekday alightings and boardings from the November 2012 counts in **Table 3-8** are 2,296 and 2,882, respectively; these ridership volumes are consistent with the factored weekday boardings shown in **Table 3-9**. Sunday boardings are consistent between the two datasets (2,454 vs 2,392), while alightings based on the November 2012 count (2,473) exceed the factored Blue Book count (1,723).

Table 3-10: SL1 Ridership Profile, from MBTA 2010 Blue Book[18]

SL1 (741)	Weekday - Spring 2009				Saturday - Spring 2006				Sunday - Spring 2006			
	Outbound*		Inbound*		Outbound		Inbound		Outbound		Inbound	
Stop Description	Total Ons	Total Offs	Total Ons	Total Offs	Total Ons	Total Offs	Total Ons	Total Offs	Total Ons	Total Offs	Total Ons	Total Offs
BOL Dummy	1427	0	0	1416	1166	0	0	1161	1057	0	0	1057
Terminal A	588	27	0	490	166	9	82	273	242	13	40	228
Terminal B1	454	317			157	206			290	209		
Terminal B2	442	280			141	185			239	112		
Terminals C&D	789	588			680	569			749	523		
Terminal E	353	233			246	142			186	144		
Congress@ World Trade Centre	5	137			4	0			0	0		
Silver Line Way at Manulife	153	70	100	168	40	22	29	48	33	28	12	59
World Trade Centre	529	15	81	574	426	108	75	596	207	45	32	194
Court House Station	186	36	54	252	56	16	10	80	36	13	14	58
South Station Silver Line	0	3220	2664	2		1816	1962		0	1946	1498	
EOL Dummy	0	3	3	0		0			0	0	0	
Totals	**4926**	**4926**	**2902**	**2902**	**3082**	**3073**	**2158**	**2158**	**3039**	**3033**	**1596**	**1596**
Net Ridership	**4923**		**1486**		**3082**		**997**		**3039**		**539**	

* The "inbound" and "outbound" labels from the Blue Book have been switched above for consistency for the directional convention established for this report

18 Page 39, MBTA 2010 Blue Book

3.1.5 Thanksgiving Peak Loading Conditions

The project team collected data on Friday, November 16th and Wednesday, November 21st, 2012, the day before Thanksgiving in 2012. As there is a significant amount of travel before Thanksgiving, this is one of the highest ridership days for the Silver Line. At South Station, platform crowding was observed and several riders were unable to board the first bus that arrived. Many SL1 buses were loaded to crush capacity. The data from Friday, November 16th serves as a baseline comparison.

Table 3-11: Silver Line Operation: Thanksgiving and Baseline Condition

	Thanksgiving (PM Peak, 4:00 to 8:00 PM)	Baseline (AM Peak, 9:00 AM to 10:00 AM)
Average Estimated Hourly Trips to Logan Airport	481	207
Average Hourly Trips from Logan Airport	224	212
Average Headway	6:04	9:55
Headway Standard Deviation	3:42	1:55
Average Cycle Time	48:31	49:21
Average Dwell Time (Terminal A)	51 seconds	55 seconds
Average Travel Time through Airport	10:07	7:48

Silver Line Platform at South Station, November 21, 2012, PM

Silver Line Platform at South Station, November 21, 2012, PM

The results show that there was twice as much hourly travel to Logan Airport on the Silver Line the day before Thanksgiving. During the baseline case, the average headway was 9:55, close to the scheduled 10 minute headway during that time period. The MBTA ran additional buses during the Thanksgiving rush, and the average headways decreased to approximately 6 minutes. However, the standard deviation of the headways increased from 1:55 to 3:42. At some points two buses arrived at the same time, while at other points there would be long periods between buses. The maximum headway observed during the peak was 13:25. The data also show that more than twice as many travelers alighted at the airport as boarded during the PM Peak on the day before Thanksgiving. This may be the result of the large cost-sensitive student population in Boston, many of whom who were travelling to the airport by transit to go home for Thanksgiving. As most trips were non-business travel on this day, it is possible that many arriving passengers were picked up at the airport by family members.

The average travel time through the airport (between arriving at Terminal A and departing at Terminal E) increased by 30%, from 7:48 to 10:07. This is due to both increased boardings and alightings and increased congestion through the airport in terms of buses, taxis, pedestrians in crosswalks, etc. Notably, the average cycle time and average dwell time (measured at Terminal A) actually decreased slightly during the Thanksgiving rush. This suggests that drivers were responding to the peak conditions by leaving stops efficiently and not dwelling excessively at South Station. Although 6 buses are regularly scheduled during the PM Peak, 13 distinct Silver Line buses (identified by bus IDs) served Logan Airport during the Thanksgiving PM Peak, indicating that the MBTA ran additional buses to serve the increased demand.

3.2 Blue Line Service and Massport Shuttles

3.2.1 Shuttle Routes and Airport Station

Massport provides free shuttles between the airport terminals and Airport Station on the Blue Line. The Blue Line connects downtown Boston with East Boston and the North Shore, with transfers to the Green Line at Government Centre and transfers to the Orange Line at State. Potential future expansions of the Blue Line include an extension to Lynn and a connection to the Red Line; these extensions would improve transit accessibility to Logan Airport, which should be considered when evaluating the benefits of those projects. The entrance facing Bremen Street, which provides convenient access for members of the surrounding community, opened in June 2007. An aerial image of Airport Station is shown in **Figure 3-6** and the shuttle route between the Logan Airport terminals and Airport Station is shown in **Figure 3-7**.

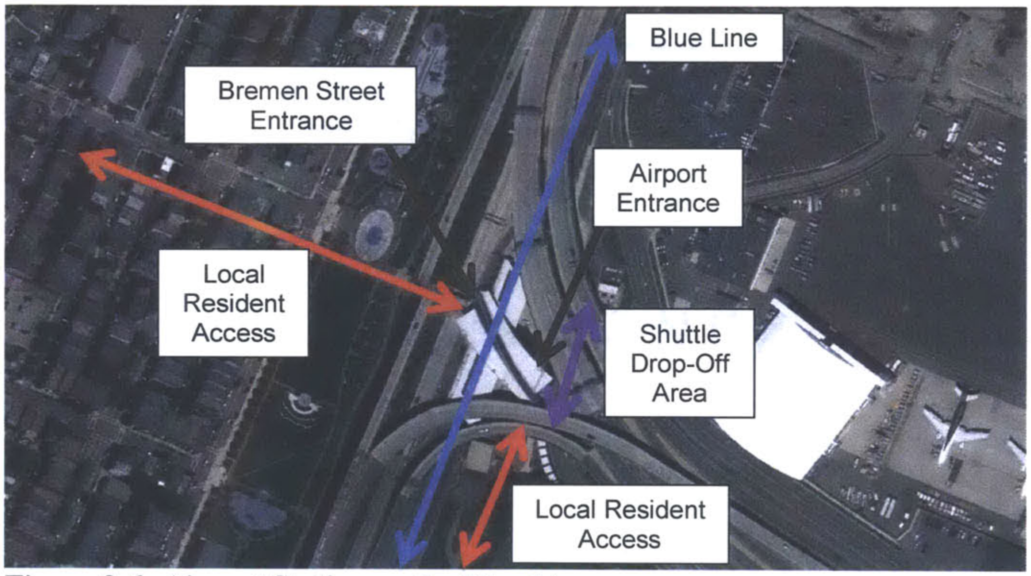


Figure 3-6: Airport Station on the Blue Line

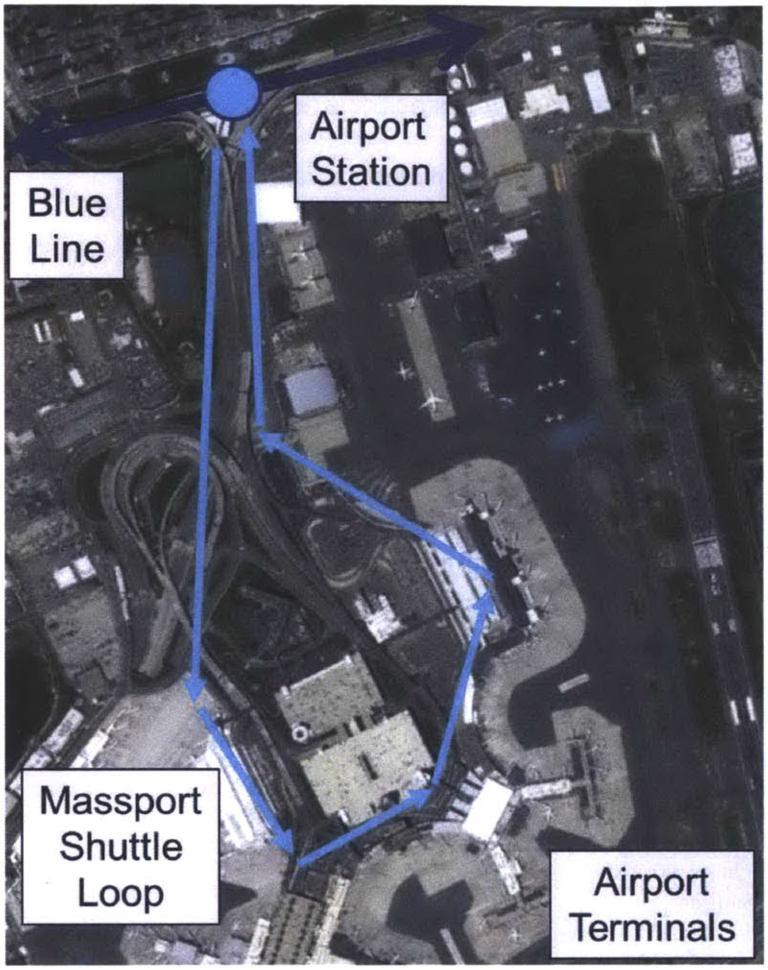


Figure 3-7: Airport Station and Logan Airport Terminals

Airport Station serves three distinct markets of transit users:

- Local residents of East Boston, who access Airport Station through both the western Bremen Street entrance and the eastern airport-side entrance
- Airport users, who use Massport Shuttles that connect the terminals at Logan Airport to the eastern Airport entrance. Massport Shuttle riders include:
    - Air Passengers
    - Airport Employees
- Courtesy Shuttle riders, who are dropped-off and picked-up at Airport Station in vans run by local hotels and rental car facilities, including the following:
    - Avis
    - Budget
    - Courtyard Marriot
    - Embassy Suites
    - Hilton
    - Hyatt
    - Wyndham

A small number of users were observed to walk directly from the neighboring community to the Massport shuttles, effectively making a through-trip at Airport Station.

3.2.2 Blue Line and Massport Shuttle Operating Characteristics

Massport operates free shuttles that connect the terminals with parking areas, water transportation and Airport Station on the Blue Line. These shuttles are a critical element of Logan's ground transportation system, as some routes connect travelers directly to MBTA subway service. These shuttle services are summarized in **Table 3-12**. Cycle times, which are not included in Massport's contract with the bus operator, have been estimated as the product of the headway and the number of buses.

Table 3-12: Massport Shuttle Services

Route	Serving	Service Time	# of Buses	Headway	Estimated Cycle Time
11	All Terminals Only	11:00 AM – 10:00 PM	2	6 min	12 min
22	A-B-Blue Line	Sat-Wed: 11:00 AM – 10:00 PM Thur – Fri: Noon – 6:00 PM	2 3	6 min	12 min 18 min
33	C-E-Blue Line	11:00 AM – 10:00 PM	2	6 min	12 min
44	Cargo Area	5:00-7:00 AM & 11:00 PM – 1:00 AM	1	20 min	20 min
55	All Terminals & Blue Line	Monday-Friday 4:00-5:00 AM 5:00 AM - 11:00 AM 10:00 PM - Midnight Midnight - 1:00 AM	 2 4 4 3	 6 min 4 min 4 min 5 min	 12 min 16 min 16 min 15 min
		Saturday 4:00-5:00 AM 5:00 - 11:00 AM 8:00 – 10:00 PM 10:00 PM - Midnight	 2 3 4 3	 6 min 5 min 4 min 5 min	 12 min 15 min 16 min 15 min
		Sunday 4:00-5:00 AM 5:00 - 11:00 AM 10:00 PM – 1:00 AM	 2 3 4	 6 min 5 min 5 min	 12 min 15 min 20 min
66	Logan Boat Dock Concentra Medical Center	7:00 AM - 11:00 PM	2	24 min	48 min
77 split route	Employee Parking (Chelsea Garage)	2:00-6:00 AM 11:00 AM – 2:00 PM 7:00-10:00 PM	6	8 min	48 min
77	Employee Parking (Chelsea Garage)	6:00-11:00 AM 2:00-7:00 PM 10:00 PM – 2:00 AM	4	6 min	24 min
88	Economy Parking	6:00-2:30 AM 2:30-6:00 AM	3 2	8 min 24 min	24 min 48 min
OFP	Overflow/Economy Parking	7:00 AM – 6:00 PM	1	As Needed	
LOC	Logan Office Center	7:30-9:45 AM 2:00-6:00 PM	1	18 min	18 min

*Data from Paul Revere Operating Contract with Massport, October 1, 2012

As indicated, different shuttles connect Airport Station and Logan Airport depending on the time of day:

- During the early morning and evening, Shuttle 55 loops through all terminals and Airport Station.
- During the peak hours, Massport runs two branch routes:
  - Shuttle 22 loops through Airport Station, Terminal A and stops 1 and 2 at Terminal B
  - Shuttle 33 loops through Airport Station, Terminal C and Terminal E
- Route 66 connects the water taxi docks, Logan airport terminals and Airport Station. It is therefore another connection between the terminals and Airport Station

Users can board free at any terminal and at airport station. The advantage of the branch routes is that transit users do not need to wait for the shuttle to travel through and stop at as many terminals when traveling between Airport Station and the airport. The disadvantage is that passengers at Airport Station must determine the correct shuttle to board, and may need to wait for the appropriate shuttle to arrive.

Data has been collected during field visits to assess the headways and cycle times for Massport shuttle routes 22, 33 and 55:

Table 3-13: Observed Massport Shuttle Headways and Cycle Times

Date	Friday, February 1st, 2013	Thursday, January 31, 2013	Thursday, January 31, 2013
Period of Day	AM: 9:15-10:45 AM	PM: 12:30-3:30 PM	PM: 12:30-3:30 PM
Route	55	22	33
Scheduled Number of Buses	4	3	2
Observed Number of Buses	4	3	2
Scheduled Headway	4:00	6:00	6:00
Average Measured Headway	3:47	5:16	7:25
Standard Deviation of Headways	1:04	1:36	0:43
Estimated Cycle Time	16:00	18:00	12:00
Average Measured Cycle Time	14:57	15:41	15:39
Standard Deviation of Cycle Time	01:19	3:28	3:43

The observed headway for Route 55 during the AM period is slightly less than 4 minutes. The bus operator runs 3 buses on Route 22 (which must serve Terminal A and the two stops at Terminal B) and 2 buses on Route 33 (which serves Terminals C and E). With three buses on Route 22, a headway of 5:16 – more frequent than the scheduled headway of six minutes – can be achieved. The average cycle time is 15:41, indicating that the full 18 minutes are not required for this route.

The scheduled headway for Route 33 is also 6 minutes, although only 2 buses are run on this route. The average cycle time of 15:39 for this route is nearly equivalent to the average cycle time for Route 22 (15:41). The average headway is 7:25, which exceeds the scheduled headway of 6 minutes.

Once users arrive at Airport Station, the Blue Line provides access to Boston. Headways on the Blue Line are summarized in **Table 3-14**.

Table 3-14: Blue Line Headways

Weekday	AM Peak	6:30 AM to 9:00 AM	5 minutes
	Midday	9:00 AM to 3:30 PM	9 minutes
	PM Peak	3:30 PM to 6:30 PM	5 minutes
	Evening	6:30 PM to 8:00 PM	9 minutes
	Late Night	8:00 PM to Close	13 minutes
Saturday	AM Peak	6:30 AM to 9:00 AM	9 minutes
	PM Peak	3:30 PM to 6:30 PM	9 minutes
	Evening	6:30 PM to 8:00 PM	9 minutes
	Late Night	8:00 PM to Close	13 minutes
Sunday	AM Peak	6:30 AM to 9:00 AM	13 minutes
	PM Peak	3:30 PM to 6:30 PM	9 minutes
	Evening	6:30 PM to 8:00 PM	9 minutes
	Late Night	8:00 PM to Close	13 minutes

http://www.mbta.com/templates/popup.asp?eid=9792

3.2.3 Massport Shuttle Travel Times

Massport recently purchased new NABI buses for its operations at Logan Airport. These buses are AVL-equipped, and AVL data will be available once Massport's new Ground Operation Centre is operational. Travel time runs were completed on Thursday, January 10, Thursday, January 31st and Friday, February 1st, 2013, to assess average travel times for Routes 22, 33 and 55 which connect Logan Airport and Airport Station. The results are shown in **Table 3-15** and **Table 3-16**.

Table 3-15: Massport Shuttle Inbound Travel Times from Airport Station to Logan Airport Terminals

From Airport Station to:	Route 22	Route 33	Route 55
Terminal A	2:58		3:09
Terminal B1	4:54		5:06
Terminal B2	6:31		6:36
Terminal C		3:48	8:13
Terminal E		5:47	9:56

Table 3-16: Massport Shuttle Outbound Travel Times from Logan Airport to Airport Station

To Airport Station From:	**Route 22**	**Route 33**	**Route 55**
Terminal A	7:45		9:44
Terminal B1	5:50		7:47
Terminal B2	4:12		6:17
Terminal C		5:41	4:40
Terminal E		3:42	2:57

The introduction of the branch routes 22 and 33 result in in-vehicle travel time savings for inbound passengers on Route 33 going to Terminals C and E and outbound passengers on Route 22 going to Terminals A, B1 and B2. However, the longer headways increase the waiting time once these routes are introduced. **Table 3-17** shows the results of a comparison of wait times and travel times, demonstrating that the in-vehicle travel time savings on Route 22 and Route 33 outweigh the increase in wait time. Massport runs 4 buses for Route 55, but 5 buses when Route 22 and Route 33 run concurrently; these findings indicate that the additional bus does translate into travel time savings for passengers.

Table 3-17: Massport Shuttle Travel Time Savings

Travel Time Comparison: Inbound Trip to Logan Airport Terminals from Airport Station					
Route	Headway	Average Wait Time	Average Travel Time to Terminal E	Total Travel Time	Time Savings
33	7:25	3:44	5:47	9:31	
55	3:47	2:02	9:56	11:58	**2:26**
Travel Time Comparison: Outbound Trip from Logan Airport Terminals to Airport Station					
Route	Headway	Average Wait Time	Average Travel Time from Terminal A	Total Travel Time	Time Savings
22	5:16	2:52	7:45	10:37	
55	3:47	2:02	9:44	11:46	**1:08**

3.2.4 Airport Station Ridership

Data from 2010 indicate that there were 2.27 million entrances and 1.359 million exits at Airport Station. The large difference between entrances and exits may be a result of the fare array measurements: when the fare array opens, it is possible for multiple riders to exit the station. Total fare array counts have increased by 44% from 2007 to 2010. While these data are not broken down by fare array and include all entrances and exits to Airport Station, they do indicate the overall growth in traffic at this station.

Airport Station entrances subdivided by fare array for April and May 2012 have been provided by the MBTA. In order to estimate the number of air passengers and airport employees using Airport Station, the entrances at the fare arrays on the airport-facing side were extracted from the full data set. As noted above, some members of the community and users of courtesy shuttles also use the airport-side fare arrays. Data was collected at Airport Station on Thursday, January 10th between 7 AM and Noon and 2:00 PM and 7:00 PM to estimate the proportion of airport-side users from the community and from courtesy shuttles:

- Air Travelers and Airport Employees: 82%
- Courtesy Shuttles: 6%
- Local Community: 12%

Based on these observations, an 18% reduction in trips has been applied to the fare array counts on the airport side to estimate airport-related entrances in **Table 3-18**. Of all weekdays, the most boardings are on Mondays and Fridays and the fewest boardings are on Tuesdays and Wednesdays.

Table 3-18: Average Estimated Daily Airport-Related Entrances at Airport Station

Day of Week	Average Airport Entrances
Monday	3247
Tuesday	2724
Wednesday	2868
Thursday	3050
Friday	3374
Average Weekday	**3045**
Saturday	3696
Sunday	3250

Massport provided ridership counts for the Massport shuttles that serve Airport Station, measured in May and June 2011 and 2012. These counts were measured between 6:00 AM and 8:00 PM. The 2011 and 2012 data was collected prior to the introduction of free Silver Line boardings, so the difference in fare between the Blue Line and Silver Line does not influence this data. The results are summarized in **Table 3-19** and **Figure 3-8**.

Table 3-19: Massport Shuttle Counts, May and June 2011/2012

	Inbound: From Airport Station to Logan Airport	Outbound: From Logan Airport to Airport Station	Ratio of Inbound to Outbound
Tuesday, June 17, 2011	3076	2396	1.28
Friday, June 17, 2011	3727	2707	1.38
Sunday, June 19, 2011	2470	2002	1.23
Tuesday, May 22, 2012	2964	2023	1.47
Friday, June 1, 2012	3515	2574	1.37
Sunday, June 3, 2012	2180	1949	1.12

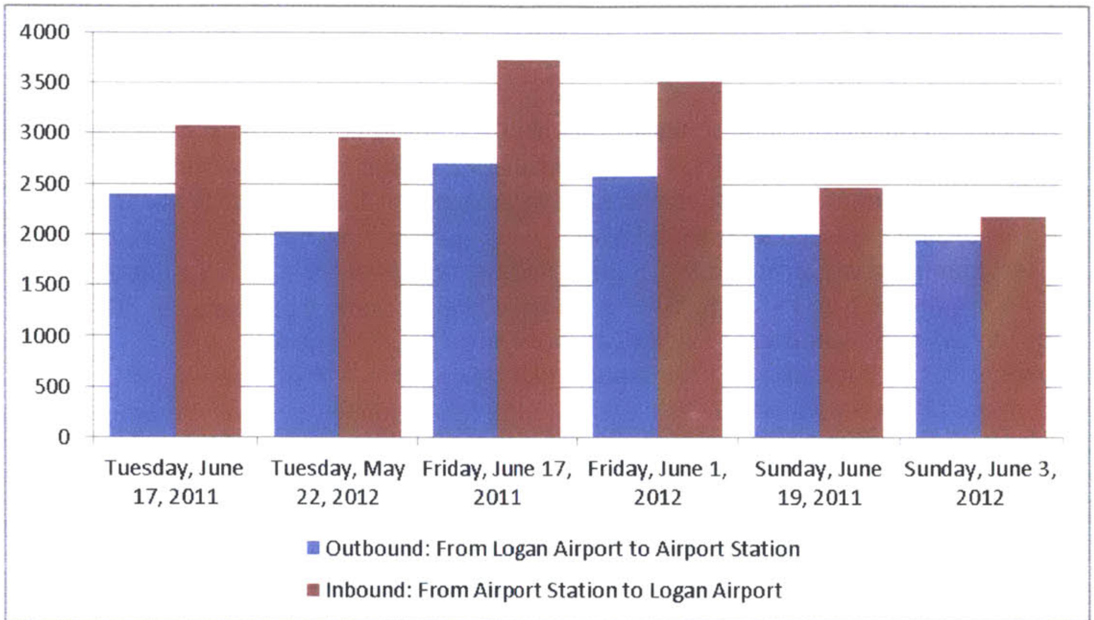


Figure 3-8: Massport Shuttle Ridership to and from Airport Station

These Massport shuttle ridership can be used to estimate the total daily airport-related ridership at Airport Station on the Blue Line. The estimated inbound and outbound passenger and employee volumes at Airport Station are presented in **Table 3-20**.

Table 3-20: Airport Related Entrances and Exits at Airport Station

		Inbound to Logan: Airport Station Exits			Outbound from Logan: Airport Station Entrances			Inbound / Outbound Split
		Employees	Passengers	Total	Employees	Passengers	Total	
Tuesday	Empl Low	767	2555	**3322**	767	2016	**2783**	**1.19**
	Empl High	1023	2299		1023	1760		
Friday	Empl Low	767	3216	**3983**	767	2559	**3326**	**1.20**
	Empl High	1023	2960		1023	2303		
Sunday	Empl Low	767	1790	**2558**	767	1758	**2525**	**1.01**
	Empl High	1023	1535		1023	1502		

The following methodology was used to generate the ridership numbers in **Table 3-20**:

- Massport shuttle data was only collected until 8:00 PM. To convert the data into full-day measurements, expansion factors were applied to the Massport Shuttle alighting data (which correspond to entrances at Airport Station). The expansion factors were **1.26** for Tuesday and Friday, and **1.28** for Sunday. The factors were determined from fare array data by calculating the proportion of entrances at Airport Station that take place after 8:00 PM (20-21% of entrances on weekdays and 22% of entrances on Sundays).

Employees returning from work and air passengers landing on evening flights comprise this block of transit passengers.

- Massport shuttle boardings (which correspond to exits from Airport Station) also required expansion factors to account for the fact that data collection did not extend past 8:00 PM. An expansion factor of **1.1** was applied – somewhat lower than the value of 1.26 applied for Massport Shuttle alightings – to account for the fact that fewer trips **to** Logan Airport are expected after 8:00 PM.
- Based on team observation at Airport Station and the results of the "2007 Logan Airport Employee Commute Survey", employee trips have been estimated to represent **30% to 40%** of Sunday trips inbound to Logan Airport from Airport Station.
- The average of the Tuesday and Friday outbound ridership to Airport Station on the Massport shuttles is 3,054, which is consistent with the estimated weekday average of 3,045 determined from the fare array data. This shows that there is consistency between the fare array estimates and the Massport shuttle weekday point checks.
- The Saturday and Sunday fare array values are much higher than the corresponding Massport shuttle point load counts, potentially as a result of a larger proportion of community trips and courtesy shuttle trips on the weekends. The Massport shuttle values have been used as they directly measure trips to and from the airport.

The 2011 Point Check ridership data on Massport shuttles to and from Airport Station and the economy parking lot have also been analyzed by time period. Loads from Airport Station to Logan Airport exceed flows from Logan Airport to Airport Station during all time periods except for the evening period from 6:00 PM to 8:00 PM. Data from a Tuesday, Friday and Sunday in June 2011 are presented in **Figure 3-9**, **Figure 3-10** and **Figure 3-11**.

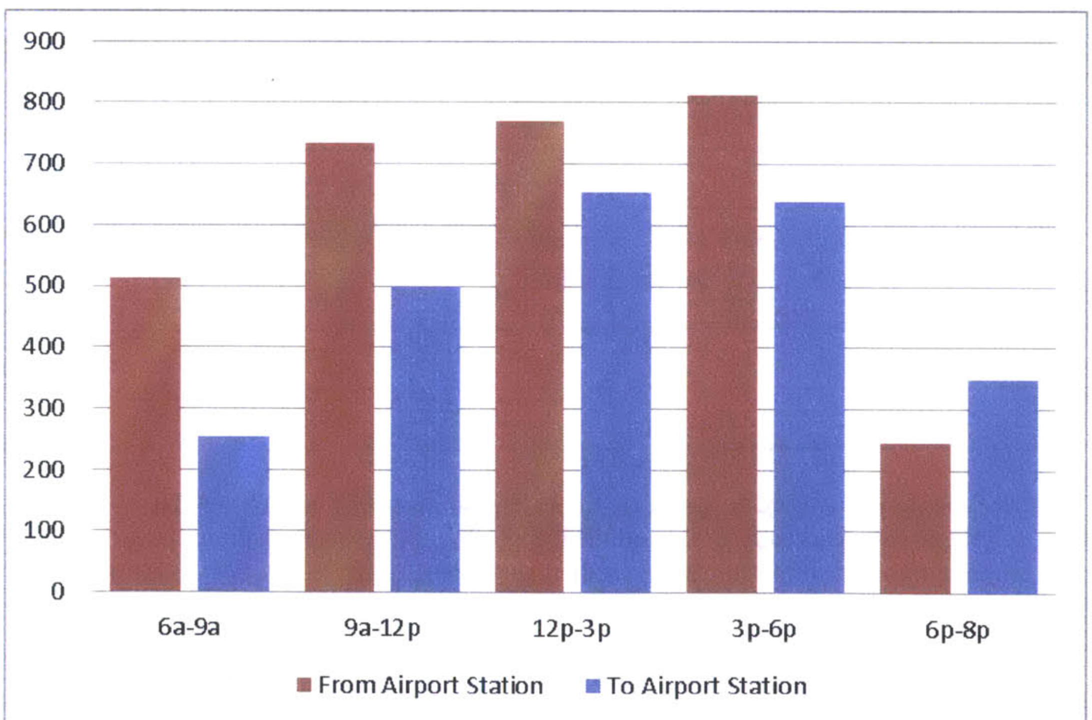


Figure 3-9: Massport Shuttle Ridership – Tuesday, June 14th, 2011

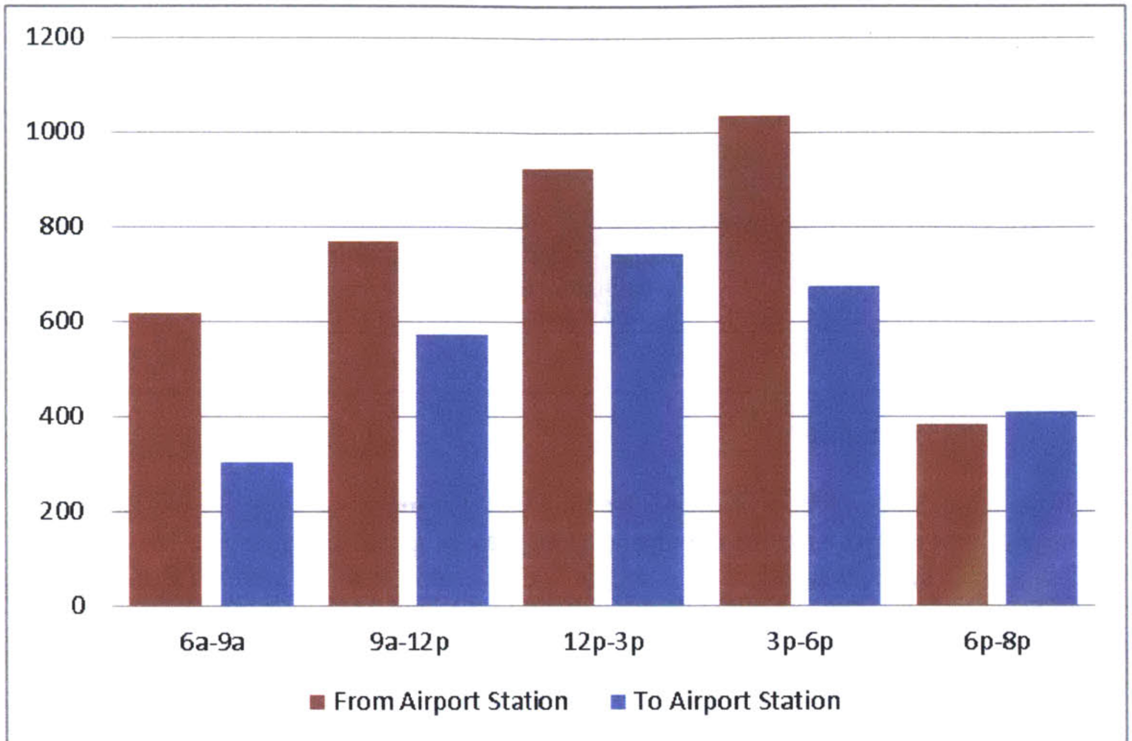


Figure 3-10: Massport Shuttle Ridership – Friday, June 17th, 2011

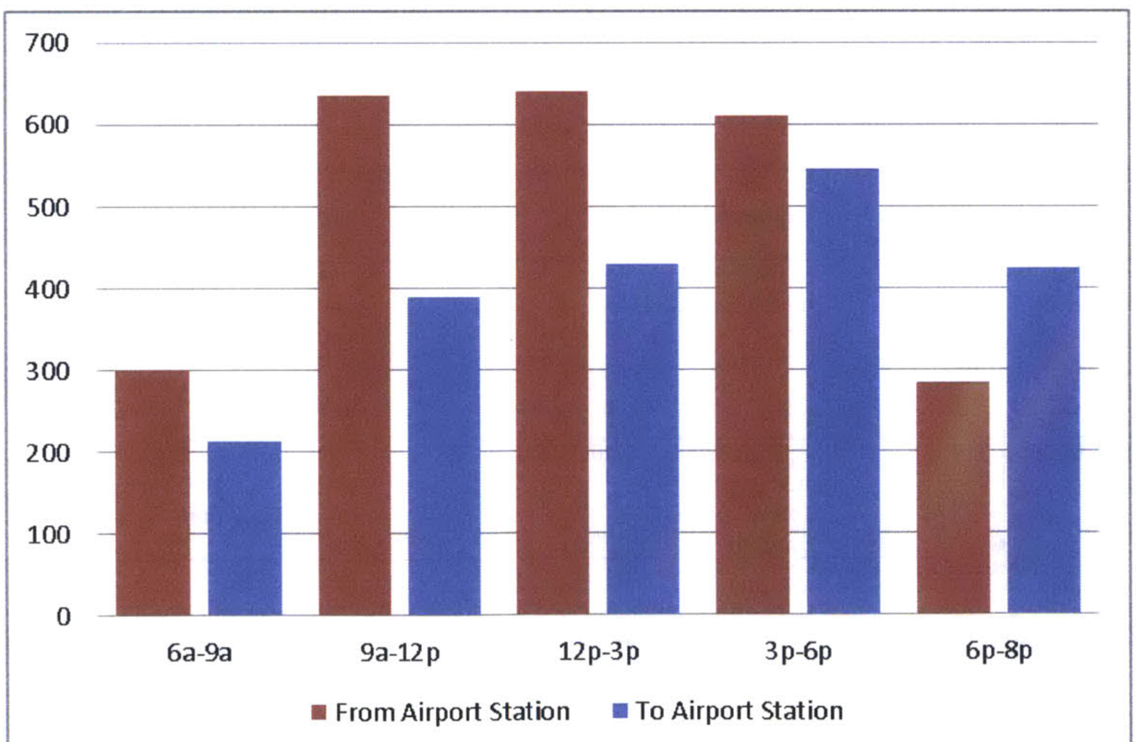


Figure 3-11: Massport Shuttle Ridership – Sunday, June 19th, 2011

This data shows that there is an imbalance between the outbound trips and the inbound trips: more airport travelers use the Blue Line to **go to** the airport than to **come from** the airport. In order to verify these results, data was collected at Airport Station to assess the split between inbound and outbound trips and verify the significant imbalance implied by the Massport Shuttle Point Checks. The results are shown in **Table 3-21**.

Table 3-21: Data Collection at Airport Station

Date	Time Period	Inbound: from Airport Station to Logan Airport	Outbound: from Logan Airport to Airport Station	Ratio
Friday, November 16, 2012	8:15 AM to 10:15 AM	258	232	1.11
Thursday, January 10, 2013	7:15 AM to Noon; 2:15 PM to 7:00 PM	1640	1270	1.29

The results of the team data collection corroborate the trend that more travelers use the Blue Line to **go to** the airport than to **return from** the airport. This may be because the transfer from Airport Station to the Massport shuttles is more efficient and direct than the transfer from the shuttles to the Station. Users may also find it challenging to find the Massport shuttle pick-up location at the terminal curbside upon arrival at Logan Airport. Return trips may also dominate after 8 PM, although data is not available for this time period.

3.3 Other MBTA Buses to the Airport

The MBTA runs three other bus routes to Terminal C at Logan Airport:

Bus Route 448/449: These routes provide service between Marblehead and Downtown Crossing, with stops at Terminal C.

Bus Route 459: This route provides service between Salem and Downtown Crossing, with a stop at Terminal C.

Route	Average Weekday Inbound	Inbound Schedule	Average Weekday Outbound	Outbound Schedule	Total Trips
448: Marblehead to Downtown Crossing	72	5 AM Peak trips, 30 minute headway	58	2 AM Peak trips, 4 PM Peak trips, 30 minute headway	130
449: Marblehead to Downtown Crossing	99		78		177
459: Salem Depot to Downtown Crossing	517	12 trips between 5:40 AM and 5:30 PM, approx. 60 minute headway	431	13 trips between 6:30 AM and 7:10 PM, approx. 65 minute headway	948

Ridership numbers from MBTA 2010 Blue Book

These low-frequency services have limited impact on transit access to Logan Airport.

3.4 Logan Express

Massport operates express buses between suburban locations and Logan Airport on four routes:

- Braintree
- Framingham
- Peabody
- Woburn

Each location includes a full service bus terminal and park and ride lot. The full round-trip fare is $22, but there are subsidies for employees. The daily parking rate at the parking lots is $7. The schedule for each route is shown in **Table 3-22** and **Table 3-23**.

Table 3-22: Logan Express Schedule: Inbound Trips to Logan Airport

Route	Service	Weekday	Saturday	Sunday
Braintree	Early Bird	-3:00 AM, 3:15 AM, 3:30 AM	-3:00 AM, 3:30 AM, 4:00 AM, 4:30 AM, 5:30 AM	-3:00 AM, 3:30 AM, 4:00 AM, 4:30 AM, 5:30 AM
	Regular	-4:00 AM to 11:00 PM every 30 minutes	-6:00 AM to 10:00 PM, every hour	-6:00 AM to Noon every hour -Noon to 11:00 PM every half hour
Framingham	Early Bird	-3:15 AM	-3:15 AM, 4:00 AM, 4:30 AM, 5:30 AM	-3:15 AM, 4:00 AM, 4:30 AM, 5:30 AM
	Regular	-4:00 AM to 11:00 PM every half hour	-6:00 AM to 10:00 PM every hour	-6:00 AM to Noon every hour -Noon to 11:00 PM every half hour
Peabody	Early Bird	-3:15 AM	-3:15 AM, 4:15 AM	-3:15 AM, 4:15 AM
	Regular	-4:15 AM to 9:15 PM every hour -10:45 PM	-5:15 AM to 9:45 PM, every 90 minutes	-5:15 AM to 9:45 PM, every 90 minutes
Woburn	Early Bird	-3:00 AM, 3:30 AM	-3:00 AM, 3:30 AM, 4:00 AM, 4:30 AM, 5:30 AM	-3:00 AM, 3:30 AM, 4:00 AM, 4:30 AM, 5:30 AM
	Regular	-4:00 AM to 11:00 PM every 30 minutes	-6:00 AM to 10:00 PM every hour	-6:00 AM to Noon every hour -Noon to 11:00 PM every 30 minutes

Table 3-23: Logan Express Schedule: Outbound Trips from Logan Airport

Route	Weekday	Saturday	Sunday
Braintree	-6:30 AM to midnight every 30 minutes -1:15 AM	-7:00 AM to 11:00 PM every hour -12:15 AM	-7:00 AM to 1:00 PM every hour -1:00 PM to Midnight every 30 minutes -1:15 AM
Framingham	-6:30 AM to midnight every 30 minutes -1:15 AM	-7:00 AM to 11:00 PM every hour -12:15 AM	-7:00 AM to 1:00 PM every hour -1:00 PM to Midnight every 30 minutes -1:15 AM
Peabody	-6:15 AM – 12:15 AM every hour -1:15 AM	-6:00 AM to 10:30 PM every 90 minutes -12:15 AM	-6:00 AM to 10:30 PM every 90 minutes -12:15 AM
Woburn	-6:30 AM to midnight every 30 minutes -1:15 AM	-7:00 AM to 11:00 PM every hour -12:15 AM	-7:00 AM to 1:00 PM every hour -1:00 PM to Midnight every 30 minutes -1:15 AM

On weekdays buses generally run every 30 minutes on the Braintree, Framingham and Woburn routes, and every 60 minutes on the Peabody route. Saturday and Sunday mornings have slightly less service, with service every hour on the Braintree, Framingham and Woburn routes and every 90 minutes on the Peabody route. Headways increase to 30 minutes on Sunday afternoons for the Braintree, Framingham and Woburn routes. Based on these schedules the number of bus trips by route and by day of week is shown in **Table 3-24**.

Table 3-24: Number of Logan Express Buses by Day of Week and Route

		Weekday	Saturday	Sunday
Inbound	**Braintree**	42	22	35
	Framingham	40	21	33
	Peabody	20	14	14
	Woburn	41	22	34
Outbound	**Braintree**	37	18	30
	Framingham	37	18	30
	Peabody	20	13	13
	Woburn	37	18	30

Fleet characteristics for the Logan Express are shown in **Table 3-25**.

Table 3-25: Logan Express Fleet Size

Route	Number of Buses	Number of Spares
Braintree	5	2
Framingham	6	2
Peabody	2	2
Woburn	6	2

The bus operators have additional buses which can be called into service if required, although these buses are not branded as "Logan Express"[19]

Annual ridership for each of these routes is shown in **Table 3-26.**

Table 3-26: Annual Logan Express Ridership by Route, 2007-2011

Route	2007	2008	2009	2010	2011
Braintree	497,670	473,880	466,059	482,865	519,036
Framingham	368,551	333,909	324,073	334,416	340,529
Peabody	63,316	61,483	60,076	51,744	57,296
Woburn	272,215	252,162	235,240	242,377	269,261
Total	**1,201,752**	**1,121,434**	**1,085,448**	**1,111,402**	**1,186,122**

2007-2010 data from Appendix G of Massport 2010 EDR; 2011 data from communication with L. Dantas

The Braintree route consistently has the highest ridership, followed by Framingham, Woburn and Peabody. The 2011 annual ridership is illustrated in **Figure 3-12.**

[19] L Dantas, personal communication, November 8, 2012

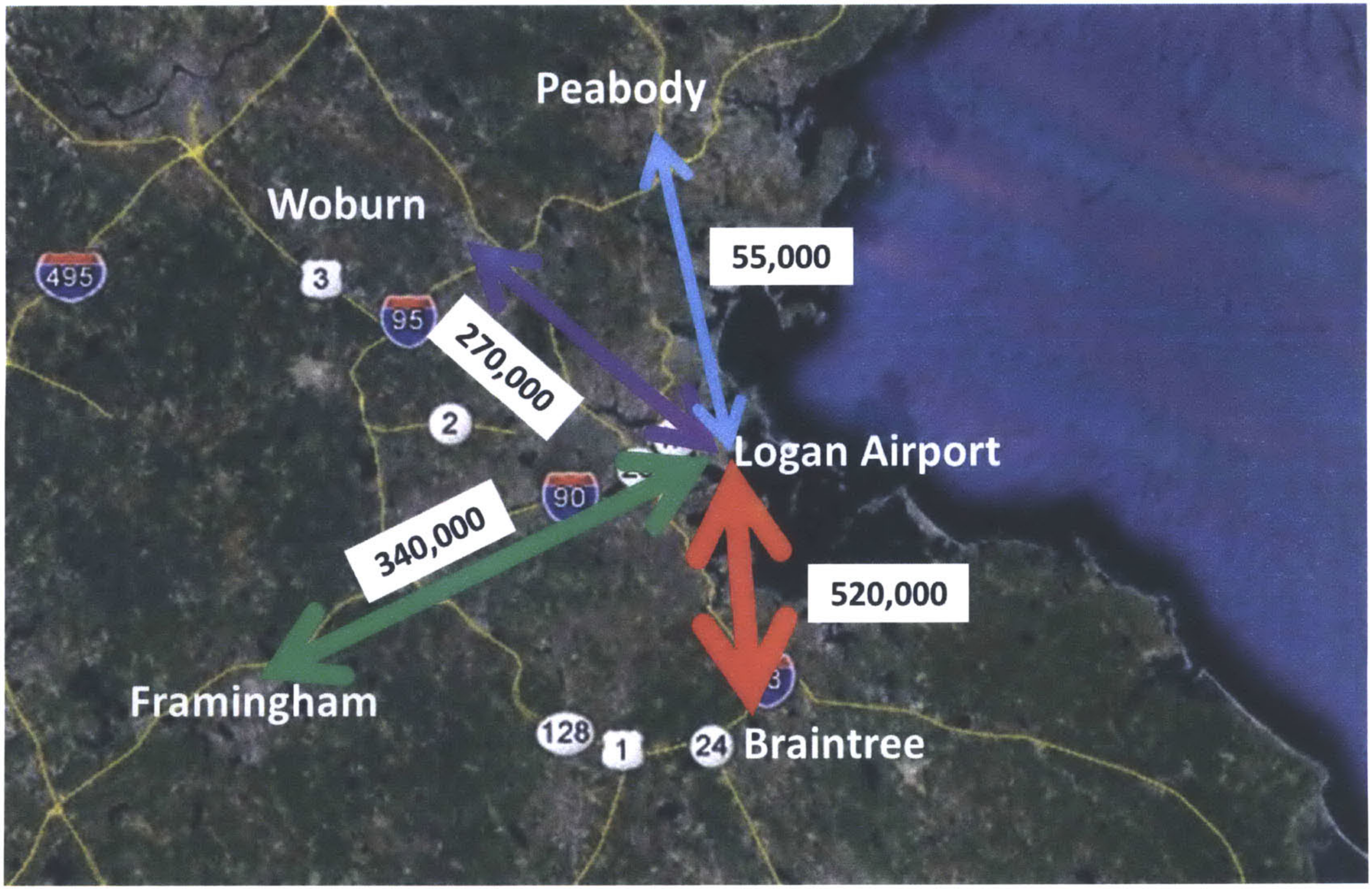


Figure 3-12: Logan Express Route Annual Ridership, Inbound and Outbound Trips, 2011

Annual Logan Express trips between 2001 and 2011 are shown in **Table 3-27**. Annual ridership in both directions (inbound and outbound) on the Logan Express routes has exceeded 1 million for every year since 2001. Total ridership peaked in 2006, with 1.3 million riders. The lowest ridership between 2001 and 2011 occurred in 2009 (1.085 million), likely a consequence of the economic downturn that resulted in less travel. As shown in the table, changes in the number of Logan Express trips generally mirror changes in total air passenger volumes at Logan Airport.

Table 3-27: Annual Logan Express Trips, 2001-2011

Service Year	Number of Passenger Trips	Number of Employee Trips	Total Logan Express Trips	Total Air Passenger Volumes at Logan Airport[1]
2001	885,296	236,395	1,121,691	--
2002	855,632	326,707	1,182,339	--
2003	808,335	400,132	1,208,467	--
2004	857,530	408,297	1,265,827	--
2005	837,034	397,660	1,234,694	27,087,905
2006	891,918	418,051	1,309,969	27,725,443
2007	797,530	404,222	1,201,752	28,102,455
2008	688,673	432,761	1,121,434	26,102,651
2009	636,847	448,601	1,085,448	25,512,086
2010	644,412	467,020	1,111,432	27,428,962
2011[2]	649,609	536,513	1,186,122	28,800,000

[1]From Chapter 1 of Massport's 2010 Environmental Data Report
[2]2001-2010 data from Appendix G of Massport 2010 EDR; 2011 data from communication with L. Dantas

The number of passenger and employee trips on the Logan Express between 2001 and 2011 are shown in **Figure 3-13**. The proportion of employees using the service has been steadily increasing, while the number of air passenger trips has slightly. In 2011, there were approximately 650,000 passenger trips and 535,000 employee trips, representing a split of 55% to 45%. The employee subsidies for parking and tickets for the Logan Express are likely causes of the increasing share of employee trips. The number of passenger trips, however, has been decreasing: there were approximately 236,000 fewer passenger trips in 2011 than in 2001.

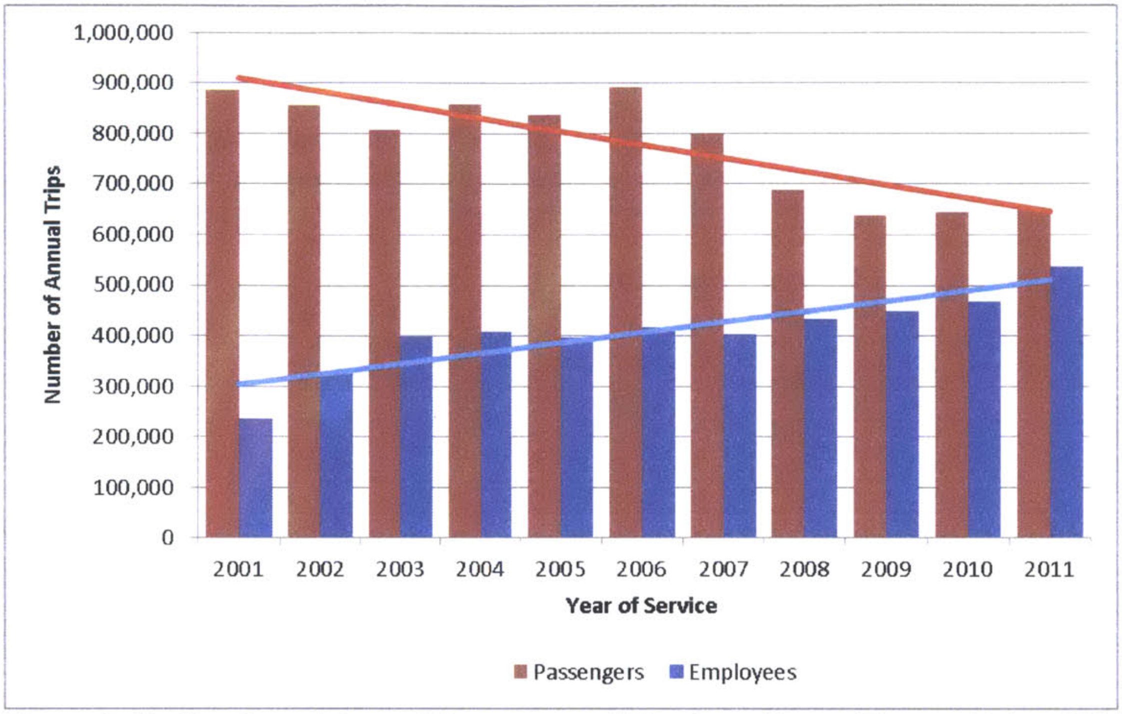


Figure 3-13: Number of Annual Passenger and Employee Logan Express Trips, 2001 to 2011

Employees who use the Logan Express tend to have higher incomes than employees who use other modes. Further, according to the 2007 employee commute survey, 60.8% of employees using the Logan Express are employed by the government (Massport, TSA, etc.) and 35.9% are employed by airlines.

3.5 Sunrise Shuttle

The Sunrise Shuttle provides early-morning access for employees in East Boston who need to arrive at work before MBTA services begin. The fare for the shuttle is $1, and ridership has grown steadily to over 1,300 riders per month (with approximately 1,040 riders on the Southern Route and the 260 riders on the Northern Route[20]). Route characteristics are shown in **Table 3-28** and **Table 3-29**.

[20] L. Dantas, personal communication, November 20, 2012

Table 3-28: Sunrise Shuttle Southern Route Service

Stop	Run #1	Run #2	Run #3	Run #4	Run #5	Run #6
Day Square	3:00 AM	3:30 AM	4:00 AM	4:30 AM	5:00 AM	5:30 AM
Maverick	3:08 AM	3:38 AM	4:08 AM	4:38 AM	5:08 AM	5:38 AM
Terminal E	3:20 AM	3:50 AM	4:20 AM	4:50 AM	5:20 AM	5:50 AM

Sunrise Shuttle Flyer, Logan TMA, sent by L. Dantas, November 20, 2012

The Southern Route of the Sunrise Shuttle makes 6 runs per day, 7 days a week with an approximate ridership of 1040/month, resulting in an average of 5.7 riders per run.

Table 3-29: Sunrise Shuttle Northern Service Schedule

Stop	Run #1	Run #2	Run #3	Run #4	Run #5	Run #6
Waldamar Avenue	3:00 AM	3:30 AM	4:00 AM	4:30 AM	5:00 AM	5:30 AM
Bennington Street	3:07 AM	3:37 AM	4:07 AM	4:37 AM	5:07 AM	5:37 AM
Terminal E	3:20 AM	3:50 AM	4:20 AM	4:50 AM	5:20 AM	5:50 AM

Sunrise Shuttle Flyer, Logan TMA, sent by L. Dantas, November 20, 2012

The Northern Route of the Sunrise Shuttle also makes 6 runs per day, 7 days a week, with an approximate ridership of 260/month resulting in an average of 1.4 riders per run.

3.6 Conclusions

The following conclusions can be drawn from the review of existing transit services to Logan Airport:

- The Silver Line's lowest speeds are for the portion between World Trade Center and Silver Line Way, suggesting that there are opportunities to decrease the running time for this segment of the trip
- The airport shuttles are an important connection between Logan Airport and Airport Station on the Blue Line and should be planned to maximize efficiency for air passengers and employees
- Logan Express and charter buses provide connectivity to areas well outside Boston, and the causes for the decreasing passenger volume should be investigated

4 MBTA Network Connectivity

While **Chapter** 3 reviewed the Silver Line and Blue Line as separate entities, this chapter reviews how the Silver Line and Blue Line are integrated with and provide connectivity to the larger MBTA rapid transit system.

4.1 Comparison of Silver Line and Blue Line to Boston

Transit travelers to (and from) Logan Airport choose either the Blue Line or the Silver Line. Travel times from each terminal at Logan Airport to various locations in Boston have been estimated along two primary paths:

- **Blue Line**: Massport Shuttle to Airport Station; Blue Line (inbound) to Boston
- **Silver Line:** Silver Line to South Station; Red Line from South Station

The two routes are illustrated in **Figure 4-1**.

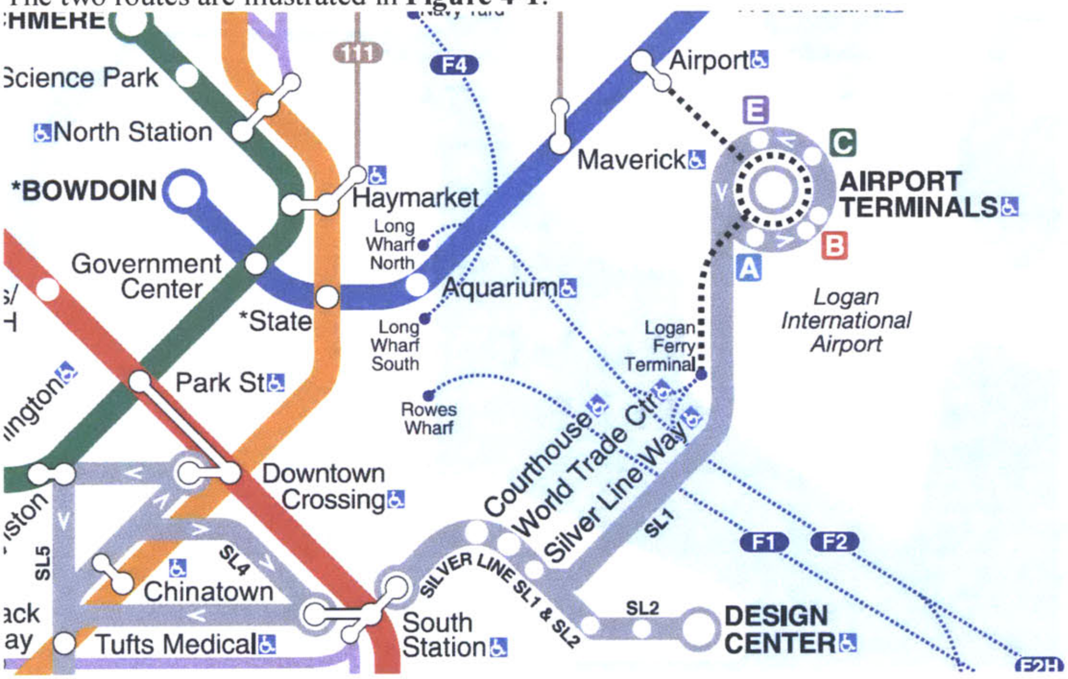


Figure 4-1: Transit Routes from the Airport to Boston

The travel time comparison was completed for the following journeys:

- Logan Airport to Downtown Boston (Park or Government Center)
- Logan Airport to Alewife
- Logan Airport to JFK/UMass
- Logan Airport to Forest Hills
- Logan Airport to Oak Grove
- Green Line EB at Park to Logan Airport

The time period for the comparison is midday. During this time period the Massport shuttles run dual routes to the terminals:

- Route 22: Airport Station – Terminal A – Terminal B1 – Terminal B2 – Airport Station
- Route 33: Airport Station – Terminal C – Terminal E – Airport Station

4.1.1 Logan Airport to Downtown Boston: Park or Government Center

Government Center and Park were selected as the stations for comparison because each is located centrally in downtown Boston, and each allows riders to transfer to the Green Line. The results are shown in **Table 4-1**.

Table 4-1: Mid-Day Travel Times from Logan Airport to Park and Government Center

Silver Line	**To Park Street Station**				
Departing From:	**Terminal A**	**Terminal B1**	**Terminal B2**	**Terminal C**	**Termina l E**
Wait Time for Silver Line	361	361	361	361	361
Travel Time to South Station	1488	1341	1241	1114	991
Transfer Time to Red Line Platform	55	55	55	55	55
Wait Time: Red Line	220.1	220.1	220.1	220.1	220.1
Travel Time to Park	189	189	189	189	189
Total (Seconds)	2313.1	2166.1	2066.1	1939.1	1816.1
Total (Minutes)	**38.6**	**36.1**	**34.4**	**32.3**	**30.3**
Blue Line	**To Government Center**				
Departing From:	**Terminal A**	**Terminal B1**	**Terminal B2**	**Terminal C**	**Termina l E**
Wait Time for Massport Shuttle	172	172	172	224	224
Travel Time to Airport Station	465	350	252	341	222
Transfer Time to Blue Line Inbound Platform	100	100	100	100	100
Wait Time for Blue Line	254.2	254.2	254.2	254.2	254.2
Travel Time to Government Centre	459	459	459	459	459
Total (Seconds)	1450.2	1335.2	1237.2	1378.2	1259.2
Total (Minutes)	**24.2**	**22.3**	**20.6**	**23.0**	**21.0**

These results show that it is faster for a traveler to access Government Center via the Blue Line than it is to access Park Street via the Silver Line and Red Line. The key differences in the travel times between the two routes are as follows:

- Longer wait time for Silver Line than for Massport Shuttle
- The travel time to South Station using the Silver Line is greater than the combined travel time for the Massport Shuttle to Airport Station and for the Blue Line to Government Center

4.1.2 Logan Airport to Alewife

The travel time comparison to Alewife, the northern terminus of the Red Line, is shown in **Table 4-2**.

Table 4-2: Midday Travel Time Comparison from Logan Airport to Alewife

Silver Line	**To Alewife, via Red Line**				
Departing From:	**Terminal A**	**Terminal B1**	**Terminal B2**	**Terminal C**	**Terminal E**
Wait Time for Silver Line	361	361	361	361	361
Travel Time to South Station	1488	1341	1241	1114	991
Transfer to Red Line Platform	55	55	55	55	55
Wait Time for Red Line	220.1	220.1	220.1	220.1	220.1
Travel Time South Station to Alewife	1443	1443	1443	1443	1443
Total in Seconds	3567.1	3420.1	3320.1	3193.1	3070.1
Total in Minutes	**59.5**	**57.0**	**55.3**	**53.2**	**51.2**
Blue Line	**To Alewife, via Green and Red Lines**				
Departing From:	**Terminal A**	**Terminal B1**	**Terminal B2**	**Terminal C**	**Terminal E**
Wait Time for Massport shuttle	172	172	172	224	224
Travel Time to Airport Station	465	350	252	341	222
Transfer Time at Airport Station	100	100	100	100	100
Wait Time for Blue Line	254.2	254.2	254.2	254.2	254.2
Travel Time Airport Station to Government Center	459	459	459	459	459
Transfer Time at Government Center	60	60	60	60	60
Wait Time for Green Line*	180	180	180	180	180
Travel Time Government Center to Park*	107	107	107	107	107
Transfer Time at Park Station	52	52	52	52	52
Wait Time for Red Line	223.6	223.6	223.6	223.6	223.6
Travel Time Park to Alewife	1235	1235	1235	1235	1235
Total in Seconds	3308	3193	3095	3236	3117
Total in Minutes	**55.1**	**53.2**	**51.6**	**53.9**	**51.9**

*Wait time and travel time for the Green Line are approximate values as a result of the unavailability of comprehensive data

These results are notable, as they show similar travel times for both paths. The Silver Line is generally considered the better option to access locations on the Red Line. It is important to note that using the Blue Line route involves several transfers and changes of level (stairs, escalators). The greater number of transfers also increases the variability of the travel time – an unlucky traveler may have to wait the maximum transfer time for each location. As a result, the Red Line path retains some advantages over the Blue Line path, even if the travel times are similar. Regardless, this highlights the need for both continued support for the Blue Line and measures to improve the Silver Line travel time (as will be discussed in **Chapter 6** of this report).

4.1.3 Logan Airport to JFK / UMass

The travel time comparison to JFK/UMass, one of the southern stations on the Red Line, is shown in **Table 4-3**.

Table 4-3: Midday Travel Time Comparison from Logan Airport to JFK / UMass

Silver Line	**To JFK/UMass, via Red Line**				
Departing From:	**Terminal A**	**Terminal B1**	**Terminal B2**	**Terminal C**	**Terminal E**
Wait Time for Silver Line	361	361	361	361	361
Travel Time to South Station	1488	1341	1241	1114	991
Transfer to Red Line Platform	45	45	45	45	45
Wait Time for Red Line	219	219	219	219	219
Travel Time South Station to JFK/UMass	487	487	487	487	487
Total in Seconds	2600	2453	2353	2226	2103
Total in Minutes	**43.3**	**40.9**	**39.2**	**37.1**	**35.1**
Blue Line	**To JFK/UMass, via Green and Red Lines**				
Departing From:	**Terminal A**	**Terminal B1**	**Terminal B2**	**Terminal C**	**Terminal E**
Wait Time for Massport shuttle	172	172	172	224	224
Travel Time to Airport Station	465	350	252	341	222
Transfer Time at Airport Station	100	100	100	100	100
Wait Time for Blue Line	254.2	254.2	254.2	254.2	254.2
Travel Time Airport Station to Government Center	459	459	459	459	459
Transfer Time at Government Center	60	60	60	60	60
Wait Time for Green Line*	180	180	180	180	180
Travel Time Government Center to Park*	107	107	107	107	107
Transfer Time at Park Station	38	38	38	38	38
Wait Time for Red Line	207	207	207	207	207
Travel Time Park to JFK/Umass	682	682	682	682	682
Total in Seconds	2724	2609	2511	2652	2533
Total in Minutes	**45.4**	**43.5**	**41.9**	**44.2**	**42.2**

*Wait time and travel time for the Green Line are approximate values as a result of the unavailability of comprehensive data

The results show that the Silver Line is the faster route to use to access South Station and southern stations on the Red Line.

4.1.4 Logan Airport to Forest Hills

The travel time comparison to Forest Hills, the southern terminus of the Orange Line, is shown in **Table 4-4**.

Table 4-4: Midday Travel Time Comparison from Logan Airport to Forest Hills

Silver Line	**To Forest Hills, via Red Line and Orange Line**				
Departing From:	**Terminal A**	**Terminal B1**	**Terminal B2**	**Terminal C**	**Terminal E**
Wait Time for Silver Line	361	361	361	361	361
Travel Time to South Station	1488	1341	1241	1114	991
Transfer Time to Red Line Alewife Platform	55	55	55	55	55
Wait Time for Red Line	220.1	220.1	220.1	220.1	220.1
Travel Time South Station to Downtown Crossing	91	91	91	91	91
Transfer Time to Orange Line Forest Hills Platform	72	72	72	72	72
Wait Time for Orange Line	262.8	262.8	262.8	262.8	262.8
Travel Time Downtown Crossing to Forest Hills	1070	1070	1070	1070	1070
Total in Seconds	3619.9	3472.9	3372.9	3245.9	3122.9
Total in Minutes	**60.3**	**57.9**	**56.2**	**54.1**	**52.0**
Blue Line	**To Forest Hills, via Orange Line**				
Departing From:	**Terminal A**	**Terminal B1**	**Terminal B2**	**Terminal C**	**Terminal E**
Wait Time for Massport shuttle	172	172	172	224	224
Travel Time to Airport Station	465	350	252	341	222
Transfer Time at Airport Station	100	100	100	100	100
Wait Time for Blue Line	254.2	254.2	254.2	254.2	254.2
Travel Time to State Station	374	374	374	374	374
Transfer Time to Orange Line Forest Hills Platform	185	185	185	185	185
Wait Time for Orange Line	258.9	258.9	258.9	258.9	258.9
Travel Time State to Forest Hills	1151	1151	1151	1151	1151
Total in Seconds	2960.1	2845.1	2747.1	2888.1	2769.1
Total in Minutes	**49.3**	**47.4**	**45.8**	**48.1**	**46.2**

These results show that the Blue Line is the faster path to access Forest Hills station on the Orange Line.

4.1.5 Logan Airport to Oak Grove

The travel time comparison to Oak Grove, the northern terminus of the Orange Line, is shown in **Table 4-5**.

Table 4-5: Midday Travel Time Comparison from Logan Airport to Oak Grove

Silver Line	**To Oak Grove, via Red Line and Orange Line**				
Departing From:	**Terminal A**	**Terminal B1**	**Terminal B2**	**Terminal C**	**Terminal E**
Wait Time for Silver Line	361	361	361	361	361
Travel Time to South Station	1488	1341	1241	1114	991
Transfer Time to Red Line Alewife Platform	55	55	55	55	55
Wait Time for Red Line	220.1	220.1	220.1	220.1	220.1
Travel Time South Station to Downtown Crossing	91	91	91	91	91
Transfer Time to Orange Line Oak Grove Platform	70	70	70	70	70
Wait Time for Orange Line	267.4	267.4	267.4	267.4	267.4
Travel Time Downtown Crossing to Oak Grove	1118	1118	1118	1118	1118
Total in Seconds	3670.5	3523.5	3423.5	3296.5	3173.5
Total in Minutes	**61.2**	**58.7**	**57.1**	**54.9**	**52.9**
Blue Line	**To Oak Grove, via Orange Line**				
Departing From:	**Terminal A**	**Terminal B1**	**Terminal B2**	**Terminal C**	**Terminal E**
Wait Time for Massport shuttle	172	172	172	224	224
Travel Time to Airport Station	465	350	252	341	222
Transfer Time at Airport Station	100	100	100	100	100
Wait Time for Blue Line	254.2	254.2	254.2	254.2	254.2
Travel Time to State Station	374	374	374	374	374
Transfer Time to Orange Line Oak Grove Platform	52	52	52	52	52
Wait Time for Orange Line	271.1	271.1	271.1	271.1	271.1
Travel Time State to Oak Grove	1012	1012	1012	1012	1012
Total in Seconds	2700.3	2585.3	2487.3	2628.3	2509.3
Total in Minutes	**45.0**	**43.1**	**41.5**	**43.8**	**41.8**

The Blue Line is the faster path to access Oak Grove.

4.1.6 Green Line Eastbound at Park to Logan Airport

This comparison investigates whether a traveler on an eastbound Green Line train should alight at Park and transfer to the Red Line and then Silver Line, or stay on the train to transfer at Government Center to the Blue Line. The results are shown in **Table 4-6**.

Table 4-6: Midday Travel Time Comparison from Green Line to Logan Airport

Green Line EB at Park	**To Logan Airport, via Red Line and Silver Line**				
Destined To:	**Terminal A**	**Terminal B1**	**Terminal B2**	**Terminal C**	**Terminal E**
Transfer Time at Park to Braintree/Ashmont Platform	38	38	38	38	38
Wait Time for SB Red Line	207	207	207	207	207
Travel Time to South Station	195	195	195	195	195
Transfer Time to Silver Line Platform	36	36	36	36	36
Wait Time for Silver Line	361	361	361	361	361
Travel Time to Logan Airport	859	1007	1106	1233	1356
Total in Seconds	1696	1844	1943	2070	2193
Total in Minutes	**28.3**	**30.7**	**32.4**	**34.5**	**36.6**
Green Line EB at Park	**To Logan Airport, via Blue Line**				
Destined To:	**Terminal A**	**Terminal B1**	**Terminal B2**	**Terminal C**	**Terminal E**
Green Line Travel Time to Government Center*	80	80	80	80	80
Transfer Time to Blue Line Platform	60	60	60	60	60
Wait Time for Blue Line	257.9	257.9	257.9	257.9	257.9
Travel Time to Airport Station	455	455	455	455	455
Transfer Time to Shuttle Area	67	67	67	67	67
Wait Time for Massport Shuttle (22 or 33)	172	172	172	224	224
Travel Time to Airport Terminal	178	294	391	228	347
Total in Seconds	1269.9	1385.9	1482.9	1371.9	1490.9
Total in Minutes	**21.2**	**23.1**	**24.7**	**22.9**	**24.8**

*Travel time for the Green Line is an approximate values as a result of the unavailability of comprehensive data

These results show that a passenger on an eastbound Green Line train at Park should stay on the Green Line and transfer to the Blue Line at Government Center. In the reverse direction, travelers destined to the Green Line should use the Blue Line and transfer at Government Center. These results also imply that a traveler on a westbound Green Line train from Lechmere should also alight at Government Center (which they will encounter before Park Street).

4.1.7 Additional Considerations

The previous sections have focused on the differences in travel times, wait times and transfer times. Further, it is important to note that the midday period was selected, when Massport runs branch shuttles that reduce the in-vehicle travel time on airport roadways. Additional characteristics of each route are compared in **Table 4-7**.

Table 4-7: Comparison of Silver Line and Blue Lines Routes to Boston

	Silver Line	**Blue Line**
Outbound Trip from Logan Airport to Downtown Boston		
Cost	-Free	-$2 with a Charlie Card, $2.50 with a Charlie Ticket
Number of Transfers to Red Line	1	3
Number of Transfers to Blue Line	3	1
Number of Transfers to Green Line and Orange Line	2	2
Convenience	-Silver Line stop not centrally located at most Logan terminals -Convenient and direct transfer to Red Line at South Station	-Massport shuttle stops located at second curb -Awkward connection to westbound trains at Airport Station: must go outside, obtain fare media / pay fare, go up one level to cross tracks and then return down to track level
Travel Time Variability	-Fewer transfers reduces variability in total travel time	-More transfers increases variability in total travel time
Comfort	-Airport terminal curb inhospitable waiting environment -Real-time information provides next bus arrival time	-Airport terminal curb an inhospitable waiting environment -No real-time information on next bus arrival time
Wayfinding / User Awareness of Service	-Good signage advertising "Free Silver Line" alerts users to the service	-Confusing signage, multiple bus routes and second curb location can be confusing for users arriving at the airport -Little signage in some terminals; arriving passengers potentially unaware of Blue Line option
Inbound Trip from Downtown Boston to Logan Airport		
Cost	-$2 with a Charlie Card, $2.50 with a Charlie Ticket	
Number of Transfers from Red Line	1	3
Number of Transfers from Blue Line	3	1
Number of Transfers from Green Line and Orange Line	2	2

	Silver Line	Blue Line
Convenience and Ease of Use	-Convenient and direct transfer to Silver Line at South Station -Silver Line stop not centrally located at most Logan terminals -Passengers must go up escalators to reach departures level	-Direct transfer for passengers to exit eastbound trains at Airport Station and walk to shuttle pick-up area -Massport shuttle stops at airport terminal located at second curb -Branch routes of the Massport shuttle that only serve some terminals may be confusing or frustrating to users -No information at the stop about headways / service frequency -Passengers must go up escalators to reach departures level
Travel Time Variability	-Fewer transfers reduces variability in total travel time	-More transfers increases variability in total travel time
Comfort	-South Station provides an indoor waiting area with real-time information on next bus arrival	-Outdoor waiting area for Massport shuttles at Airport Station is somewhat barren
Wayfinding / User Awareness of Service	-Silver Line 1 has been branded as the MBTA's airport service -Opportunities to improve signage at South Station	-Station name – "Airport" – clear and self-explanatory

In summary, the Blue Line has a **travel time advantage** for accessing downtown Boston and transfers to the Green Line and the Orange Line, compared to the Silver Line. Depending on the terminal and the time of day, the Blue Line may also have a travel time advantage for stations on the Red Line north of South Station. See **Figure 4-2** for a summary of the travel time advantage for each route.

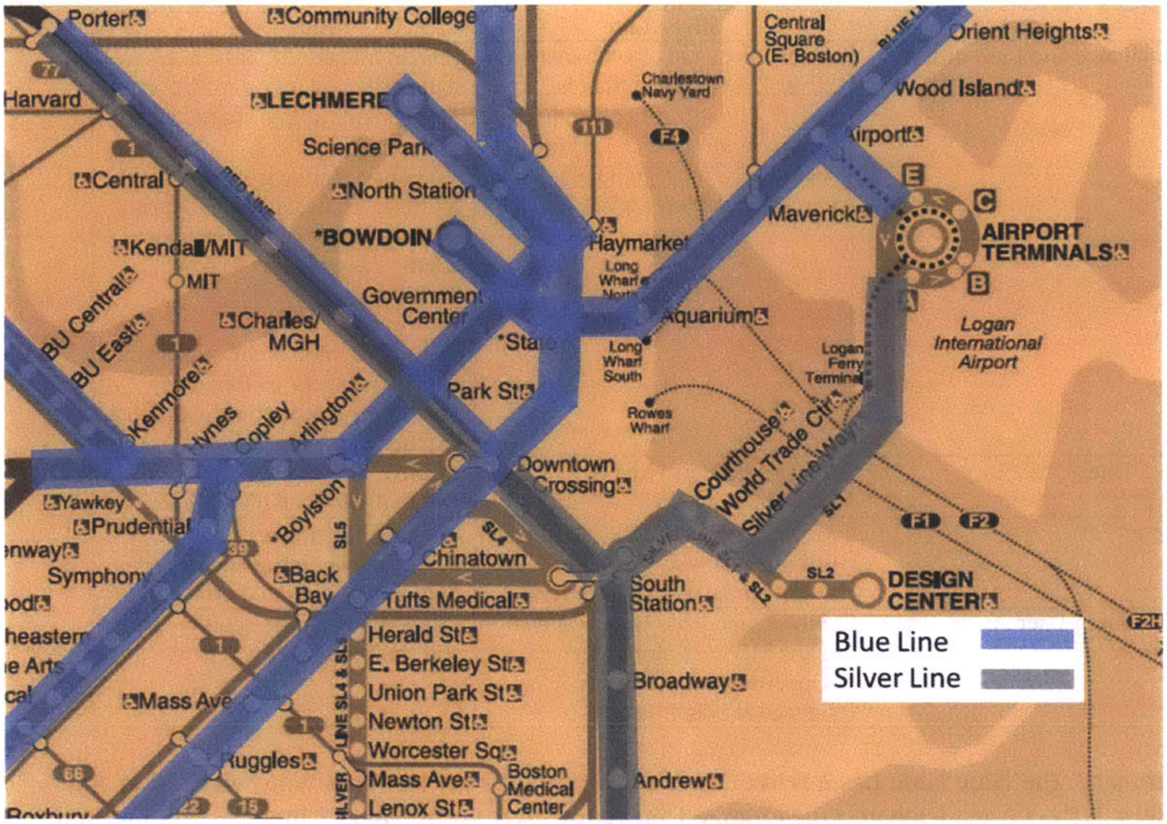


Figure 4-2: Network Connectivity by Silver Line and Blue Line

However, the Silver Line has advantages over the Blue Line in terms of more qualitative elements of the service, such as comfort of waiting area, ease of transfers, directness, clarity of routes (i.e. SL1 goes to all terminals at all times), signage, branding and real-time information systems. This helps explain the comparable Silver Line and Blue Line ridership.

As discussed in **Chapter 3**, the Silver Line and Blue Line carry similar volumes of passengers to and from the airport: regardless of potential travel time advantages to using the Blue Line, many passengers still opt for the Silver Line as a result of the additional characteristics discussed above, such as directness of service, comfort of waiting areas, better travel time reliability and transfer minimization. These results demonstrate that people place different value on different aspects of their trip and make travel choice decisions on more factors than the total travel time alone, thus exemplifying principles of random utility theory.

Although this section has been structured as a comparison between the two services, the Silver Line and the Blue Line should not be thought of as competing transit services. Rather, they should be viewed as complementary services that both serve distinct sub-markets of transit users within the Boston area and provide system resiliency in the event of reduced service on one of the lines (i.e. maintenance, closure, breakdown, congestion, etc.). The comparison reveals potential areas of improvement for each service – namely, the need to reduce travel times on the Silver Line. The results also show that the Blue Line is an important and effective connection to Logan Airport which should continue to be improved. Improvements to the services should be planned with a focus on attracting new riders to the service; measures that result in a shifting of riders between the two services do not increase the overall transit mode share to the airport and thus are not the optimal allocation of resources.

4.2 Impact of Planned Government Center Closure

The MBTA is planning to close Government Center station for renovation and reconstruction for approximately two years, starting in fall 2013. Government Center is a critical transfer station in Downtown Boston, allowing passengers to transfer between the Green Line and the Blue Line.

Many airport passengers use Government Center to transfer from the Green Line to the Blue Line when heading to Airport Station. Passengers can also transfer from the Red Line to the Blue Line via Government Center. For passengers on the Red Line, transferring at Park and Government Center via the Green Line is more direct than transferring at Downtown Crossing and State via the Orange Line, as a result of the transfer distances at Downtown Crossing and State. Airport passengers and employees also use Government Center on the reverse trip, from Airport Station to the Green Line and Red Line. As outlined in the previous section, the Blue Line provides a rapid connection to Logan Airport from several locations throughout the transit system.

Using the MBTA Origin/Destination matrix developed at MIT[21], daily trip totals heading to and from Airport Station through Government Center have been estimated. The total number of trips by time period and day of the week are shown in **Table 4-8**.

[21] Dominick Tribone, MBTA Origin / Destination matrix, MIT

Table 4-8: Number of Airport Station Passengers using Government Center

Week Days		
Time Period	To Airport Station	From Airport Station
5:00 AM to 6:30 AM	78	322
6:30 to 9:30 AM	167	898
9:30 AM to 3:30 PM	805	1136
3:30 PM to 6:30 PM	858	561
6:30 PM to 8:00 PM	272	156
8:00 PM to Close	897	266
Total	**3077**	**3339**
Saturday		
Time Period	To Airport Station	From Airport Station
5:00 AM to7:00 AM	86	285
7:00 AM to Noon	268	1084
Noon to 6:00 PM	1078	1166
6:00 PM to 10:00 PM	770	380
10:00 PM to Close	618	129
Total	**2820**	**3044**
Sunday		
Time Period	To Airport Station	From Airport Station
5:00 to7:00 AM	61	182
7:00 AM to 10:00 AM	116	498
10:00 AM to 6:00 PM	1047	1332
6:00 PM to 10:00 PM	560	352
10:00 PM to Close	376	115
Total	**2160**	**2479**

Many passengers who use Airport Station, however, are not traveling to Logan Airport. Using AFC data at Airport Station, an estimated 51% of weekday entrances, 59% of Saturday entrances and 65% of Sunday entrances are from the airport side of the station. These proportions have been applied to the ridership figures above to estimate the total number of airport passengers who would be affected by the Government Center closure. These figures are presented in **Table 4-9**.

Table 4-9: Estimated Logan Airport Travel through Government Center

Week Days		
Time Period	To Airport Station	From Airport Station
5:00 AM to 6:30 AM	40	164
6:30 to 9:30 AM	85	458
9:30 AM to 3:30 PM	410	579
3:30 PM to 6:30 PM	438	286
6:30 PM to 8:00 PM	139	80
8:00 PM to Close	458	136
Total	**1569**	**1703**
Saturday		
Time Period	To Airport Station	From Airport Station
5-7 AM	51	168
7 AM to Noon	158	639
Noon to 6:00 PM	636	688
6:00 PM to 10:00 PM	454	224
10:00 PM to Close	364	76
Total	**1664**	**1796**
Sunday		
Time Period	To Airport Station	From Airport Station
5-7 AM	40	118
7:00 AM to 10:00 AM	75	324
10:00 AM to 6:00 PM	681	866
6:00 PM to 10:00 PM	364	229
10:00 PM to Close	244	75
Total	**1404**	**1611**

As shown, significant numbers of Logan Airport passengers would be inconvenienced by the proposed closure of Government Center station. Many of these passengers may opt to use the Silver Line to travel to and from Logan Airport. To illustrate the potential impact on Silver Line demand, the week day volumes have been distributed throughout the day and added to the existing Silver Line Friday load profile based upon the ridership data collected by CTPS on Friday, November 16, 2012. The resulting load profile is shown in **Figure 4-3**.

Required headways to support this load profile have been estimated, as shown in **Table 4-10**.

Table 4-10: Silver Line Requirements with Government Center Station Closed

	Friday - Inbound to Logan	Friday - Outbound from Logan
Max Demand	522	609
Planned Capacity per Vehicle	53	53
Headway (minutes)	6.1	5.2
Frequency (trips/hour)	9.8	11.5

These results show that headways of 5 to 6 minutes would be required to accommodate this demand. The maximum demand corresponds to the peak 15 minute period, calculated by multiplying the 95th percentile 15 minute demand by 4. The planned capacity is set at 1.4 times the seating capacity of the buses, accounting for the fact that passengers with luggage require more space.

These results represent a conservative scenario in which all affected passengers transfer to South Station. It is quite likely, however, that passengers presently entering or exiting Government Center from the surface will simply board or alight at State Station instead of transferring to the Silver Line. Further, some passengers may use alternate, non-HOV modes (such as taxi or parking) to access Logan Airport after Government Center closes, which runs contrary to Massport's HOV goal. To encourage airport users to continue using transit, Massport and the MBTA should do the following during the Government Center closure:

- Run Silver Line buses more frequently to accommodate increased demand. Consider reallocating some buses from the SL2 or short-turn shuttle route if an insufficient number of buses are available.
- To complement increased Silver Line service, study potential bus services on surface streets to serve displaced demand, such as a surface route between the Logan Airport terminals and Haymarket Station which has connections to both the Orange and Green Lines and is adjacent to Government Center. Massport's buses could be used on surface routes
- Publicize increased service levels on the Silver Line and new bus routes on surface streets
- Implement a co-ordinated marketing plan to encourage travelers to switch to the Silver Line or buses on surface streets for airport access when Government Center is closed

These measures will support HOV access to Logan Airport during the Government Center closure. As these service improvements are required to mitigate the impact of the MBTA Government Center reconstruction plans, MBTA capital funds might logically be used to finance necessary mitigation.

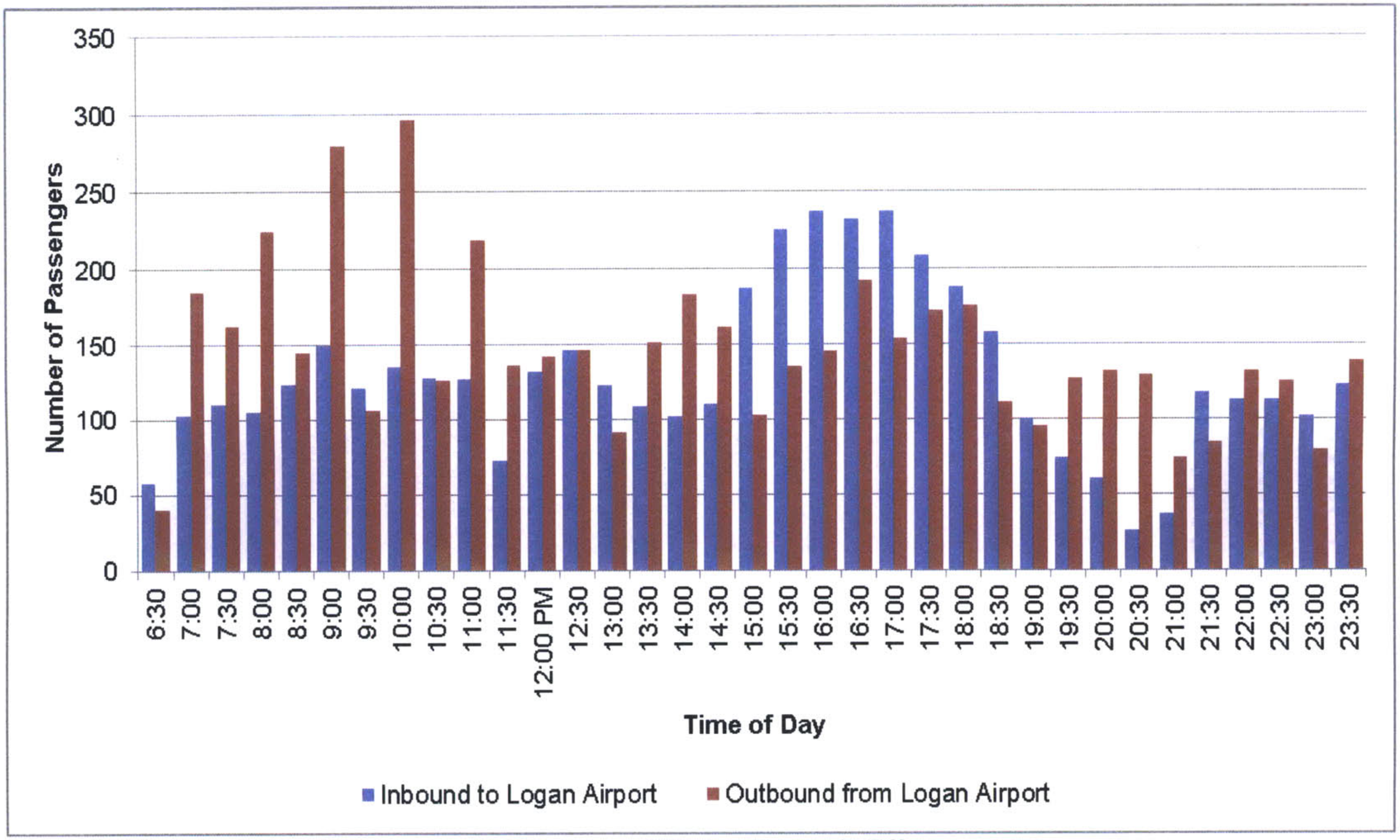


Figure 4-3: Potential Silver Line Loads with Government Center Closure in Effect

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5 Future Vehicle Technology Alternatives

This chapter evaluates potential new vehicle technology alternatives to replace the existing Silver Line buses; alternatives have been assessed with an emphasis on finding a vehicle that can reduce travel time by eliminating the need for a transition from electric to diesel power at Silver Line Way stop.

Boston is presently the only city in the US operating dual propulsion transit buses (diesel-electric dual mode trolleys). The MBTA operates these buses for its Silver Line services to Logan Airport (SL1) and to the waterfront (SL2). Purchased in 2005, the buses run on electric power from overhead catenary wires in the exclusive right of way in the transitway, before switching to conventional diesel fuel for the rest of the trip in mixed traffic on the city streets and highways, including the Ted Williams Tunnel to the airport. This design allows the buses to operate with zero emissions within the transitway tunnel.

The transitway is a one-mile tunnel from South Station to the D Street portal, with three underground stations (South Station, Courthouse, and World Trade Center). Each of the underground stations can accommodate up to three 60-foot buses at the station platforms. The transitway tunnel is passively ventilated, requiring vehicles operations within the tunnel to have zero emissions.

The fleet consists of 32 dual-mode 60-foot articulated buses, powered by diesel from the ICE or by electricity from overhead catenary. Eight of these buses are outfitted with luggage racks and designated for service to and from the Airport. Manufactured by Neoplan USA, the buses are low-floor, air-conditioned, and equipped with AVL and PA/VMS (Public Address/Variable Message Signs) systems, with the additional length providing more room for passengers and their luggage. Massport purchased the Logan Airport service buses, which along with the remainder of the fleet are operated and maintained by the MBTA. The fleet is currently serviced at the Southampton facility.

Neoplan USA declared bankruptcy and ceased production in 2006. This means that the MBTA has to find an alternative supplier if it chooses to renew the dual-mode technology. The dual-mode fleet is now at the point of its midlife rebuild, at which the MBTA may choose to supplement the fleet or purchase replacements. There is however no North American bus company currently focusing on this type of dual-mode technology, raising cost and availability concerns for maintaining the vehicles. This however provides an opportunity for Massport and the MBTA to consider other technologies that may be superior to the dual-mode option, bearing in mind that it may be cheaper in the long run to invest in a new vehicle technology than to maintain the dual mode technology vehicles.

This chapter examines the feasibility of both continuing with the dual-mode technology on this corridor as well as alternative technologies, based on the following criteria:

- Environmental impacts (in particular emissions within the tunnel)
- Vehicle availability and reliability
- Passenger carrying capacity
- Infrastructure constraints

- Capital and Operating costs

The chapter is organized as follows:

- Section 5.1: Corridor Characteristics
- Section 5.2: Tunnel Ventilation and Air Quality Measurements
- Section 5.3: Selection Process
- Section 5.4: Dual Mode Bus Technology
- Section 5.5: Hybrid Bus Technology
- Section 5.6: Battery Electric Bus Technology
- Section 5.7: Financial Implications
- Section 5.8: Conclusions

5.1 Corridor Characteristics

The Silver Line service to Logan airport runs a (round trip) distance of about 10 miles – slightly over 2 miles in the transitway tunnel and about 7.5 miles above ground. The three underground stations are South Station, Courthouse and World Trade Center, as shown in **Figure 5-1**. After an additional 1,250 feet the buses come to the D Street portal after which they switch to diesel power. Average speeds in the transitway range from 8 to 25 mph (see **Figure 5-2**).

The rest of the trip (on diesel power) is characterized by higher operating speeds (12 to 33 mph) and frequent stops, with the buses sharing the roadway with other traffic. On reaching the airport, SL1 buses stop at each of the five terminals (A, B-Stop 1, B-Stop 2, C and E). **Figure 3-2** in **Chapter 3** shows the travel time and dwell time profiles for each segment on the SL1 route.

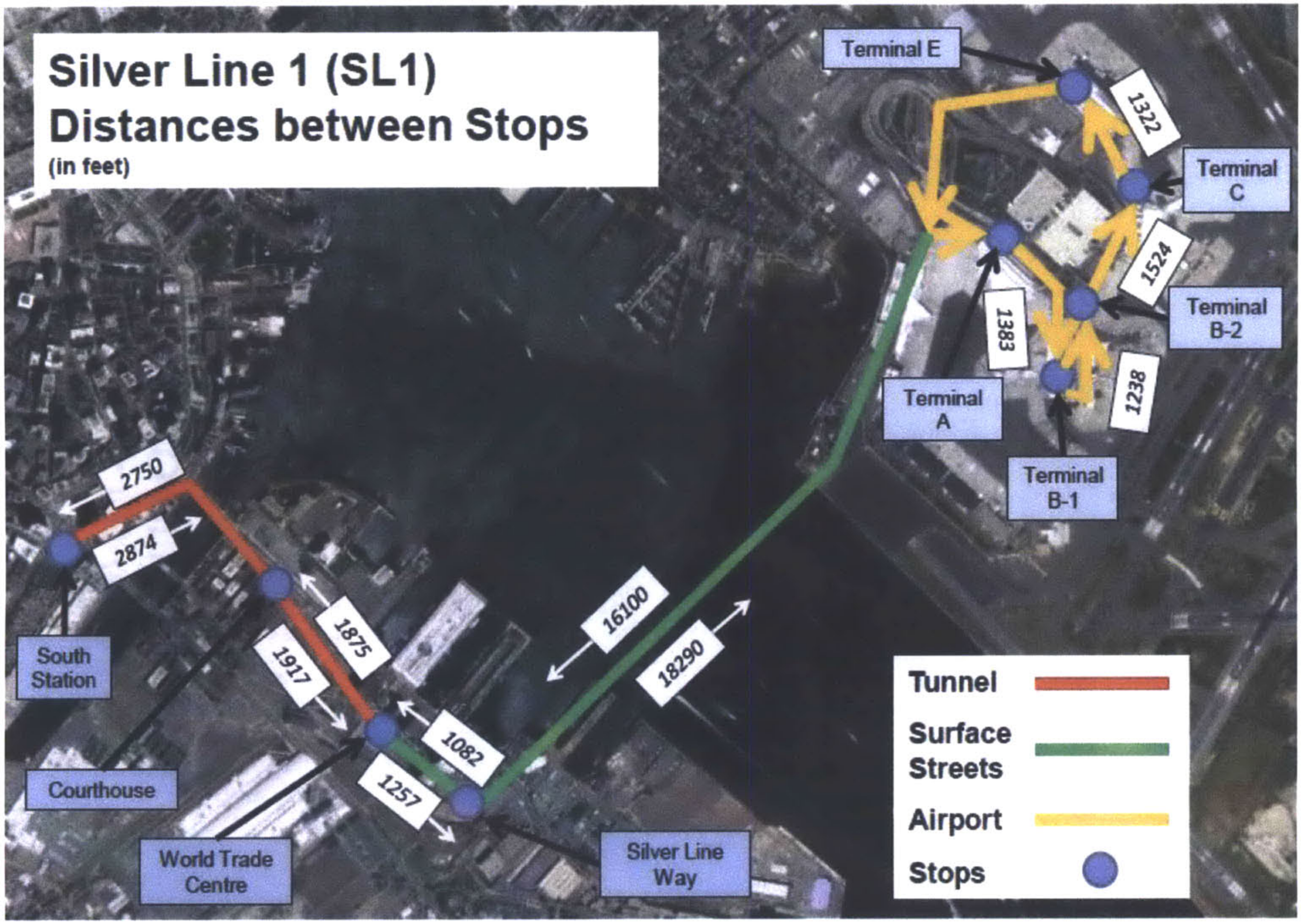

Figure 5-1: Distances between Stops on the Silver Line

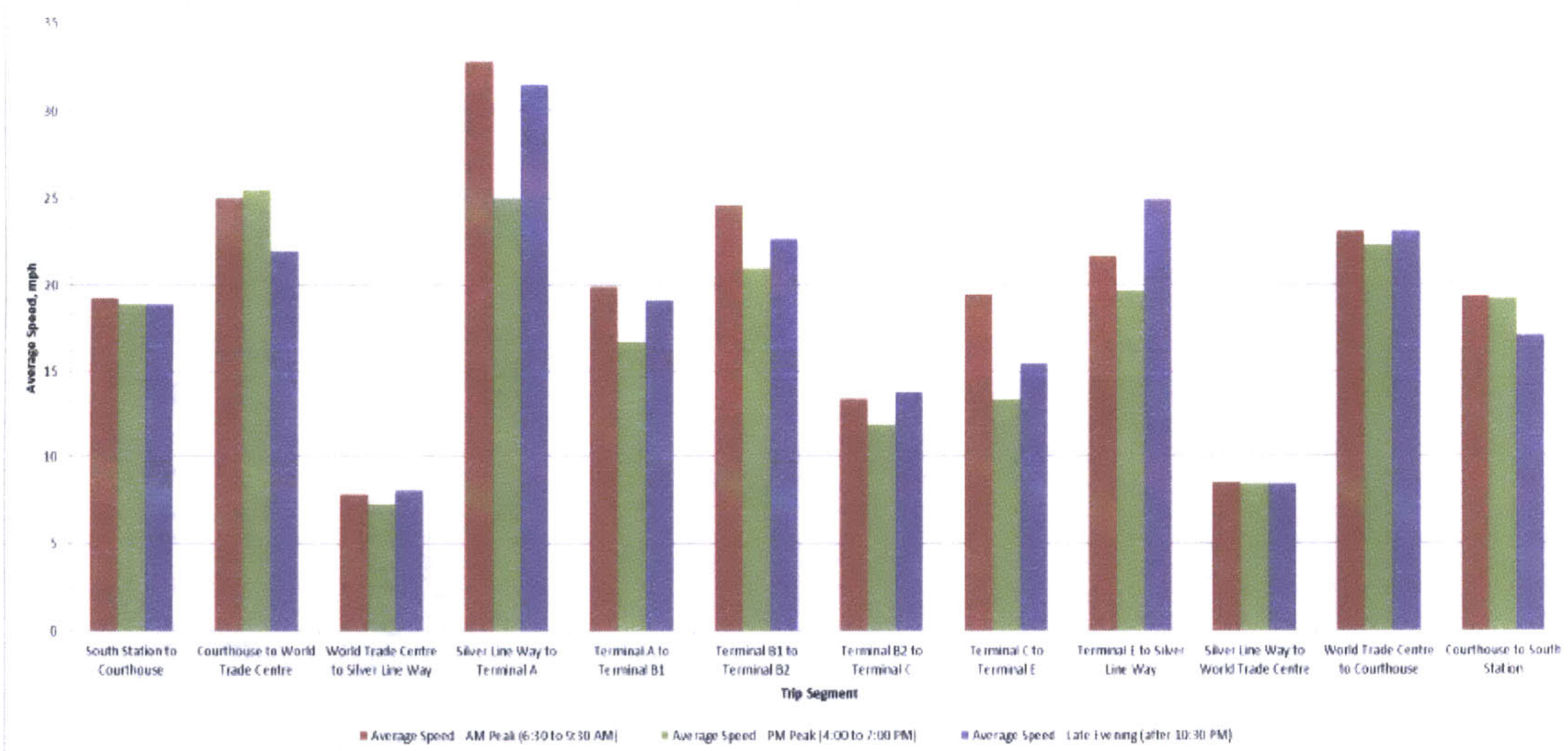

Figure 5-2: Average Travel Speed per Route Segment[22]

[22] See Chapter 3 for additional details

5.2 Tunnel Ventilation and Air Quality Measurements

Information on the ventilation/air exchange system in the South Boston Transitway tunnel is currently unavailable. The tunnel is open only at one end, and aside from emergency fans located at each station, the tunnel is only passively ventilated (i.e. by the piston effect on air flow from bus movements through the small diameter tunnel sections, by convection at the station and tunnel entrances, and by other atmospheric influences).

The Downtown Seattle Transit Tunnel (DSTT) provides an interesting comparison for tunnel ventilation and air exchange. This tunnel is equipped with mechanical ventilation in the form of intake and exhaust fans with "low" and "high" settings. Both sets of fans are operated on the "low" setting during regular operations, with the exhaust fans switched to the "high" setting when diesel buses operate during the evening peak period.

The intake fans draw air from vents located on the surface streets, while the exhaust fans draw air from the tunnel out through ceiling vents where it is expelled. Before being introduced into the tunnel, the air is filtered to remove particles. The filters are designed to remove 90% of particles larger than 5 microns, 48% of particles between 1 and 5 microns, and 18% of particles between 0.7 and 1 micron[23], so do not effectively remove the smaller particles created by combustion. The filters are only used for the supply air (intake).

The DSTT is also affected by passive ventilation.

An air quality assessment of the DSTT was carried out in May 1998. Leading to this assessment, King County Metro (KCM) had been experiencing problems with the dual mode diesel electric buses that had been operating in the tunnel for over 8 years. The electric units of the buses occasionally malfunctioned, leading to operation of the dual mode buses in diesel engine mode even in the tunnel. Additionally, conventional diesel buses were frequently being used on this route in place of the dual mode buses due to reliability problems with the dual mode buses.[24]

The goal of the air quality study was to evaluate the possibility (and air quality implications) of routine use of a small number of "clean" diesel buses in the tunnel. In light of this goal, tunnel air quality measurements were made during regular revenue operations (using dual mode buses, at times operating in diesel engine mode and at times substituted with "clean" diesel buses) as well as during test runs that simulated alternative future operating scenarios.

University Station was chosen as the study location since it is smaller and not as well ventilated naturally compared to the other underground stations, and so was considered the worst-case situation. Measurements were taken from the platform of this station since the platform was considered to be closest to the vehicle exhaust and to represent the greatest exposure to patrons.

Some results of the simulated operation tests are summarized in **Table 5-1**.

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[23] Downtown Seattle Transit Tunnel Air Quality Assessment (1998)

[24] Downtown Seattle Transit Tunnel Air Quality Assessment (1998)

Table 5-1: Emissions Concentrations during Various Test Scenarios[25]

Scenario	$PM_{2.5}$ Test 1 (µg/m^3)	$PM_{2.5}$ Test 2 (µg/m^3)	$PM_{2.5}$ Test 3 (µg/m^3)	CO (ppm)	NO_2 (ppm)
I) 6 Diesel Bus Round Trips	26,26,26	27,29,28	N/A	< 2	< 0.2
II) 20 Diesel Bus Round Trips	41,67,54	N/A	41,74,58	< 2	< 0.3
III) 6 Dual Mode Bus Round Trips	24,34,29	24,48,38	28,44,31	< 2	< 0.12

Each PM2.5 cell entity indicates the 1st 30-minute concentration level, the 2nd 30-minute concentration, and the 60-minute concentration

The diesel buses used in the tests were Gillig buses powered by Cummins M11 engines, equipped with catalytic oxidizers to reduce carbon monoxide, hydrocarbon and particulate matter emissions. The dual mode Breda buses were also equipped with catalytic oxidizers to reduce particulate matter emissions.

Scenario I simulated the operation of diesel buses during peak hours to supplement the existing dual mode fleet, with up to 12 diesel bus trips (6 round trips) per hour. Scenario II simulated the use of a 100% diesel bus fleet for new extended evening services (7-10pm), with up to 40 diesel bus trips (20 round trips) per hour. These two scenarios were compared against a 3rd scenario, which involved running 12 dual mode bus trips (6 round trips) in one hour through the tunnel.

The results in **Table 5-1** indicate that $PM_{2.5}$ concentrations increase with bus volumes, and that the tunnel ventilation was unable to maintain "acceptable" station air quality in Scenario II (The study reported that strong sustained diesel odors were evident during testing with this scenario).

Measured $PM_{2.5}$ concentrations were slightly lower with the diesel buses than with the Breda dual mode buses, suggesting that engine exhaust may not be the main source of $PM_{2.5}$ emissions.

Results from measurements during regular revenue operations are summarized in **Figure 5-3**. The figure illustrates weekday average $PM_{2.5}$ concentrations as well as average bus volumes in the tunnel and on the surface street above the underground station in which the measurements were being made (Third Avenue, above University Station).

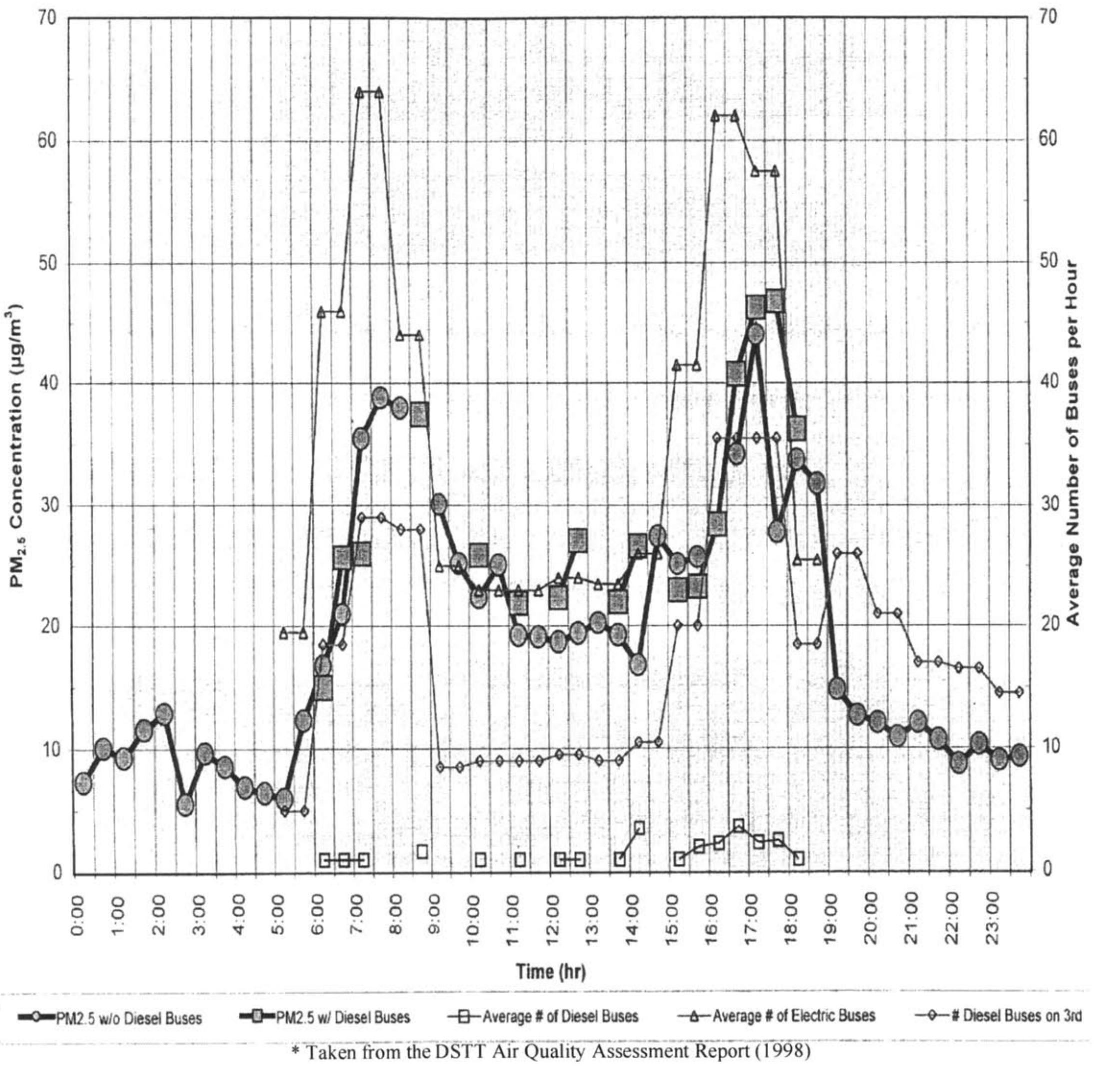
Figure 5-3 shows that PM emissions are correlated with bus volumes in the tunnel, as expected, and are much lower (often around 10µg/m^3) at night when the tunnel is closed.
The results show high PM concentration during peak service times even when there are no diesel buses in the tunnel, again indicating that engine exhaust may not be the dominant source of PM emissions in the tunnel. The study speculated that the measured PM may have been entering the tunnel either via the air that was being drawn in from supply vents on the surface street (Third Avenue) or from re-suspended road dust carried from surface streets into the tunnel on the bus tires and/or frames.

The second source (i.e. activity in the tunnel) was determined to be more plausible since PM concentrations decreased after 7pm when the tunnel was closed to bus operations but there was still significant diesel bus activity on Third Avenue. In this case, the tunnel ventilation system

[25] Downtown Seattle Transit Tunnel Air Quality Assessment (1998)

may not have been able to prevent a buildup of the dust and small particles, hence the high PM measurements even without diesel bus operations.

The study also experimented with switching the station intake ventilation fans to the maximum setting, and determined that this did not have a significant effect on measured tunnel emissions.



* Taken from the DSTT Air Quality Assessment Report (1998)

Figure 5-3: Average $PM_{2.5}$ Concentrations During Routine Operations

Results from the above measurements indicate that occasional operation of diesel buses (equipped with catalytic oxidizers) within the DSTT only slightly increased the level of emissions in the tunnel above that created by the electric operation of dual mode buses. The tunnel ventilation system was however incapable of providing "acceptable" station air quality for operation of a larger number of diesel buses through the tunnel, even with the fans operating at their capacity.

Measured Carbon Monoxide concentration levels in all scenarios (< 2ppm) were less than specified health standards (see **Table 5-2**). NO_2 concentrations were also below OSHA standards, as were PM concentrations (lower than the most restrictive standard - 150 $\mu g/m^3$ for the 8-hour ACGIH standard).

Table 5-2: Pollutant Concentration Standards[26]

	$PM_{2.5}$ ($\mu g/m^3$)	CO (ppm)	NO_2 (ppm)
EPA			
1-hour		35	
ACGIH			
8-hour	150	25	3
15-minute			5
OSHA			
Ceiling			5
8-hour	5,000	50	

*ACGIH = American Conference of Governmental Industrial Hygienists

Newer technology hybrid buses should show even better performance (fewer emissions) than the 1990s Gillig diesel buses used in these tests. Partial or full battery-only operations of the hybrid buses should also greatly reduce diesel engine emissions.

It is however quite clear from Seattle's experience that upgrading of the existing ventilation fans (e.g. by operating both sets of fans at their capacity) does not have a significant effect on the tunnel emissions.

5.3 Selection Process

This section covers the factors influencing vehicle selection; and includes an evaluation of the present dual-mode technology as well as other vehicle technology options. The key factor in this evaluation is the vehicle propulsion system, which affects the emissions, purchase and operating costs of the vehicle, the vehicle's range of operations as well as its reliability. Another important attribute is the vehicle size, which governs its passenger carrying capacity as well as the capacity of the service (i.e. how many vehicles would be needed to meet the transit demand in this corridor).

Currently only electric propulsion is allowed within the tunnel due to ventilation concerns, hence only bus technologies that can potentially meet this constraint (i.e. technologies that allow the vehicle to operate on electricity within the transitway) are considered in this evaluation, including the following propulsion technologies:

- Electric (Trackless) Trolley
- Dual Mode Trolley
- Hybrid Electric bus with "battery only" capability
- Battery Electric bus

[26] Downtown Seattle Transit Tunnel Air Quality Assessment (1998)

An evaluation of these alternatives based on the evaluation criteria outlined at the start of this chapter follows.

5.3.1 Electric (Trackless) Trolley

This technology allows buses to operate in a purely electric mode primarily by drawing electricity from overhead catenary wires. Some bus designs include battery packs on board to allow for limited "off-wire" operations, primarily for short distances at low speeds in areas where catenary cannot be installed (e.g. due to physical constraints).

For the South Boston transitway application, this would mean that catenary would need to be installed beyond the transitway tunnel, which would significantly increase the infrastructure costs of this alternative. Moreover, past studies have found that low clearance requirements in the Ted Williams tunnel and at the airport may make installation of catenary along these routes infeasible or impractical[27].

This option is therefore not considered further for this application.

5.3.2 Dual Mode Trolley

This is the propulsion technology currently used on the Neoplan buses now serving this corridor. A dual-mode trolley uses an electric drive train powered either by electricity through overhead catenary or by an internal combustion engine (ICE), and can run exclusively on either of these sources. The ICE in a dual-mode trolley can be fueled either by diesel fuel or Compressed Natural Gas (CNG), but catenary sparks within the transitway tunnel prohibit use of CNG. The electric component allows the bus to operate with zero emissions within the transitway, while the ICE component provides the flexibility for the bus to operate on streets with no catenary.

Section 5.4 further explores dual-mode systems and the possibility (and implications) of the technology's continued use on the Silver Line.

5.3.3 Hybrid Electric bus with "Battery Only" Capability

A hybrid electric bus has an electric drive train that propels the bus and an ICE attached to a generator for generating electricity. A battery pack included in the system provides the electricity required for operations on-board (instead of pulling power from overhead catenary). The battery pack also acts as a "load leveler" that allows the system to better manage energy use throughout the drive cycle.

The battery pack in hybrid buses allows them to operate in a "battery only" mode, with the ICE turned off, for limited stretches. This pure electric propulsion mode can potentially ensure zero emissions, which would make these buses applicable for use in the South Boston Transitway. **Section 5.5** includes a discussion of the different hybrid electric bus configurations as well as the possibility of the technology's use for this application.

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[27] South Boston Piers Transitway Peer Review (2000)

5.3.4 Battery Electric Bus

These buses are equipped with batteries that provide the energy needed for propulsion; so do not require overhead catenary. The batteries need to be periodically recharged (from the electric grid), or swapped out for new batteries once depleted. The size of the battery determines the time between charges as well as the recharge time. The battery size also determines the size, and hence carrying capacity of the bus.

Most of the battery electric transit buses currently in use in the US are 22 ft long (carrying capacity of 30-36 passengers). Even with more advanced battery technology, the newer battery electric transit buses (e.g. the New Flyer electric bus prototype) are only 40ft long, much less than the carrying capacity of the 60ft Neoplan buses currently in use for the Silver Line.

Deploying these buses would therefore mean higher operating costs if more buses are required (to provide the same transit service capacity as the Neoplan buses), hence more drivers. Additionally, charging stations would be required at strategic locations to ensure that the buses can be re-charged and resume service without major disruptions.

Section 5.6 will further explore the battery electric bus technology alternative, and the feasibility of the technology's use for the Silver Line service.

5.4 Dual-Mode Technology

Dual-mode technology was first introduced for mass transit systems in the 1990s to increase inner-city travel efficiency. A dual-mode bus can run independently on either electric power or on conventional fossil fuel. A typical diesel-electric dual-mode bus has a diesel engine and an electric drive train that gets its electricity supply from overhead catenary or on board from batteries. Dual-mode buses can run in full electric mode as long as there is a continuous electric power supply.

5.4.1 Current Deployments

Dual-mode buses are currently in limited use in both the US and Europe. The MBTA purchased dual-mode buses from Neoplan in 2005 to allow for full electric (zero emission) operation within the transitway tunnel, where the electrical power is supplied by overhead catenary. The dual-mode buses switch to diesel engine operation on city streets and highways, including in the Ted Williams Tunnel and at Logan Airport.

Neoplan also supplied the 28 dual-mode buses for Lausanne's trolleybus fleet in 2001-2002.These buses were eventually sold in 2010, and there are no remaining dual mode buses in this fleet[28].

King County Metro in Seattle deployed 236 dual-mode buses within the Downtown Seattle Transit Tunnel (DSTT) from 1990 till late 2004[29]. The buses were supplied by Breda, an Italian

[28] http://en.wikipedia.org/wiki/Trolleybuses_in_Lausanne

company that has since merged with Ansaldo (in 2001) to form AnsaldoBreda. The original bus production division of Breda ceased bus production after the merger, and the company now focuses on production of rail cars, trams, and trains.

All buses supplied used electric power inside the tunnel (supplied by overhead catenary), and then switched to diesel engine out of the tunnel. The entire fleet was replaced with diesel hybrid electric buses in 2005. Fifty-nine of the dual-mode buses were converted into conventional trolley buses with the remaining buses to be used for replacement parts for the trolley bus fleet.

The city of Castellon in Spain deployed 3 dual-mode buses in 2008 for its City Trolleybus Line. These Civis buses, manufactured by French-based Irisbus Iveco, are new generation trolleybuses equipped with medium power diesel engines and technology that allows a switch to diesel engine propulsion when the trolley poles are not connected to overhead power lines. The buses are about 12m long (40 ft), and have 22 seats.

The Bergen trolleybus system in Norway runs a fleet that includes 2 dual-mode buses, manufactured by German NEOPLAN Bus GmbH.

Other dual mode bus manufacturers in Europe include Vossloh Kiepe in Germany and Van Hool in Belgium.

5.4.2 Feasibility for Continued Use in Corridor

Dual-mode buses ensure zero emissions and low noise levels during the purely electric mode operation within the transitway tunnel. However, since Neoplan folded in 2006, most North American bus companies have focused on other bus technologies, so it would be hard to find replacement parts (or order new buses).

Additionally, the catenary within the tunnel would need to be maintained periodically, adding to the maintenance cost for this alternative.

5.4.3 Availability and Reliability

As discussed above, no North American bus companies are currently producing dual-mode buses due to low demand for dual-mode fleets, although it may be possible to make special orders.

Although there are several dual mode bus manufacturers in Europe, none of them have produced a significant number of these buses in recent years.

In terms of reliability, the dual-mode alternative is less desirable, particularly from a maintenance perspective. After King County's (KC) purchase of dual-mode buses from Breda, the Italian manufacturer was unable to provide effective support in the later operations of the fleet. KC faced multiple issues with the dual-mode buses, including insufficient technical support, lack of readily available replacement parts, increased maintenance cost, and the

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[29] http://metro.kingcounty.gov/am/vehicles/bustech.html

scheduled engine/transmission rebuild. KC Metro finally abandoned the Breda dual-mode buses and sought alternative solutions in late 2004.

5.4.4 Passenger Carrying Capacity

Existing 60' dual mode trolleys provide sufficient capacity to meet the Transitway's current and projected demand.

5.4.5 Infrastructure Requirement

This vehicle does not require the installation of any new infrastructure, but periodic maintenance of the overhead catenary is required.

5.5 Hybrid Bus Technology

Hybrid technology can allow buses to operate with minimal emissions within the transitway tunnel and in hybrid mode over the surface streets and within the Ted Williams tunnel, reducing total emissions and potentially even improving reliability (if the buses are sourced from a North American based company, as opposed to buying replacement dual-mode trolleys from abroad).

The hybrid option should be considered for the following reasons:

- Availability of several North American manufacturers of hybrid buses
- Various transit operators within the US, including the MBTA and Massport, have successfully deployed hybrid buses
- Hybrid buses require no additional infrastructure
- Flexibility in route design
- Potentially lower maintenance and operating costs than the dual-mode buses (from lower fuel consumption and less infrastructure maintenance needs)
- Better fuel economy than dual-mode buses

Disadvantages of the hybrid option include:

- Most of the hybrid transit buses currently in use have not been designed for full "battery-only" operation, meaning that some design changes may be needed if this requirement is to be met with existing models for the South Boston Piers Transitway application
- The hybrid technology is most common on smaller buses (22' and 40' hybrid buses), even though some manufacturers have recently introduced 60' diesel electric hybrid buses (e.g. New Flyer for King County in Seattle).

5.5.1 Features

A hybrid-electric bus combines an electric propulsion system with another power plant (typically an ICE fueled by diesel or gasoline, though propane or natural gas can also be used). This hybrid system provides the advantages of an electric system, including better acceleration from a stop and better fuel efficiency, without the reduced-range limitation of a pure battery electric bus. Hybrid buses include a battery pack on board which acts as an energy-storage device as well as a load-leveler that maintains efficient energy use when the bus is in operation. Most hybrid electric transit buses are equipped with either lead-acid or nickel metal hydride batteries. The system is typically designed so that the batteries are never depleted—the batteries are continuously recharged during driving so buses do not have to be taken out of operation for periodic recharging. Regenerative braking is made possible by the electric motor and energy-storage system. The Vehicle accessory systems are powered either electrically or mechanically (from the ICE), or combinations of both.

The two major configurations for hybrid-electric vehicle systems are Series and Parallel. In a series configuration, there is no direct connection between the engine and the drive wheels; the energy produced by the engine is converted to electrical power by a generator, which recharges the batteries and powers the electric motors that turn the wheels of the vehicle. This means that the ICE can be completely switched off for limited all-electric zero-emissions operations at low speeds. The series configuration performs better for stop-and-go urban driving applications.

In a parallel hybrid configuration, both the engine and the electric motors have direct and independent connections with the transmission, and can be used separately or together to drive the wheels. This design can achieve greater fuel efficiency in high, constant speed operations.

5.5.2 Current Deployments

Most hybrid-electric buses in operation today are 40' buses, although some 22' shuttles and 60' articulated buses have also been deployed. Transit agencies tend to introduce hybrid buses in small numbers (fewer than 10 buses) to test them out. New York City and King County in Seattle currently have the largest fleets of hybrid buses[30].

The major hybrid system manufacturers (for full size transit buses) are GM Allison Transmission (parallel configuration), British Aerospace Engineering (BAE) Systems (series configuration), and ISE Corporation (series configuration).

GM Allison has primarily worked with New Flyer to produce hybrid buses, including the 60' articulated hybrids deployed in Seattle's tunnel that are equipped with nickel metal hydride batteries. These buses were delivered between 2004 and 2008, and the fleet size is over 200 buses[31].

The Downtown Seattle Transit Tunnel (DSTT) is 1.3 miles long, with 5 underground stations (see Figure 5-4). Routes operating through this tunnel include Routes 101, 102 and 106, each running a total round trip distance of about 30 miles (including the tunnel segment).

The hybrid fleet operating on these routes was set up to stay predominantly electric at speeds below 15 mph when in "hush mode"; the diesel engine kicks in when the speed exceeds this limit. This set up was the result of a compromise between KC Metro's requirement that the buses operate without any diesel engine operation within the tunnel (in order to reduce tailpipe emissions), and GM Allison's concern that battery-only operation would seriously reduce battery life. The need for low emissions and adequate battery life resulted in the development of the "hush mode".

[30] FTA's 'Analysis of Electric Drive Technologies for Transit Applications' (2005)
[31] FTA's 'Analysis of Electric Drive Technologies for Transit Applications' (2005)

The innovative use of the hybrid drive system in "hush mode" allows for relatively quiet tunnel operations while adhering to air quality standards. The buses operate in a pure electric mode in the station areas of the tunnel, and in reduced engine power mode between the tunnel stations.

The "hush mode" works by first pre-charging the batteries (using engine power), if necessary, to the maximum state of charge at some distance before entering the tunnel. Just before entering the tunnel, the "hush mode" is selected by the bus driver on the shift selector. In this mode, the hybrid buses operate on battery power (with the fuel completely cut off) while in the station areas. The engine is however "motored" (rotated by the motors in the hybrid drive unit) for powering the vehicle accessories, and is only completely turned off when the bus makes a stop and the doors are opened at any of the underground stations.

In the tunnel tube areas, the diesel engine is allowed to operate at reduced power (about 110 hp) for charging the batteries. The bus automatically changes out of "hush mode" at the end of the tunnel.

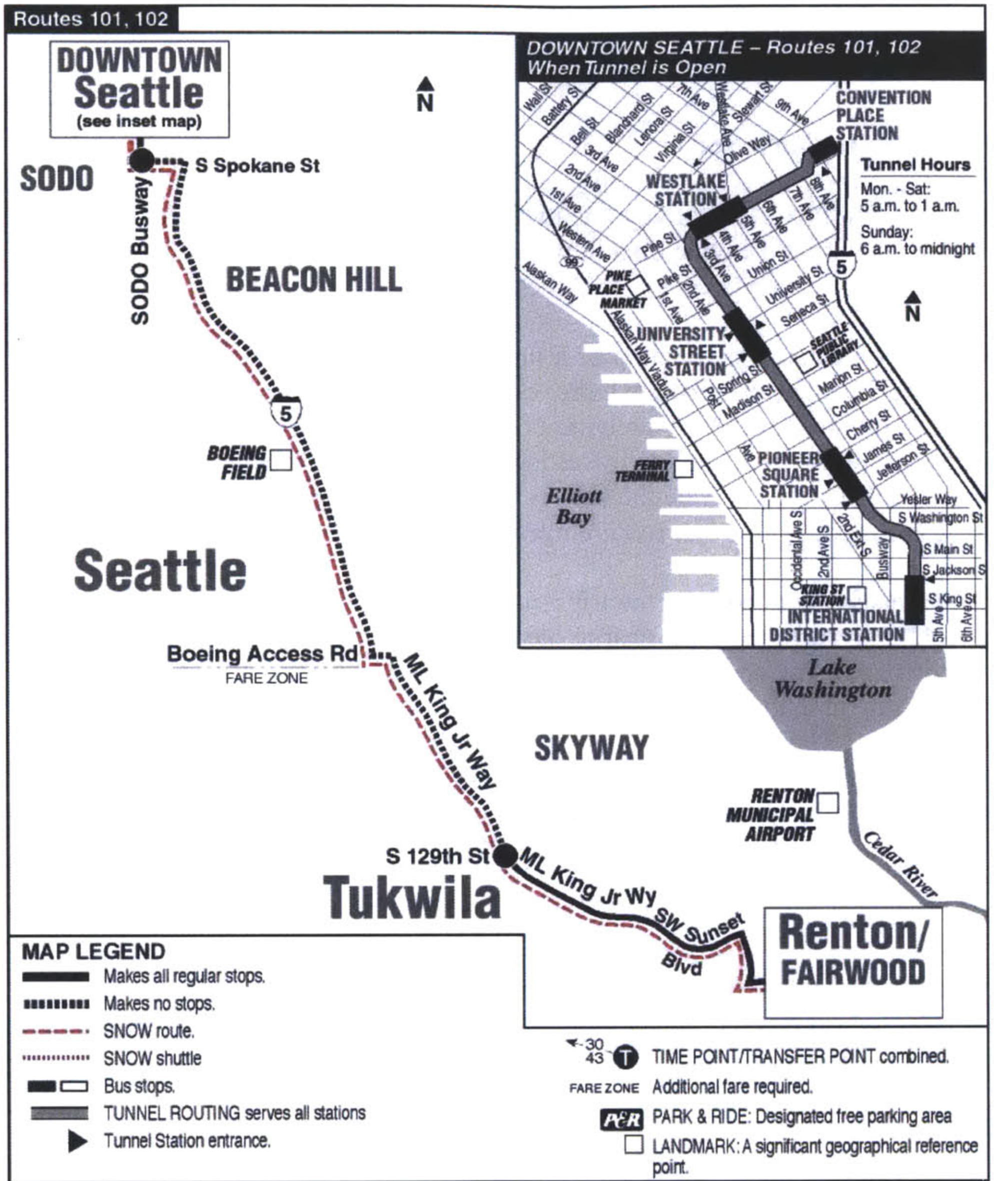

Figure 5-4: Downtown Seattle Routes 101 and 102[32]

The NABI hybrids deployed for the rental car services system at Logan airport also use the GM Allison system. The entire Logan hybrid fleet consists of 32 60' articulated buses, 10 delivered in 2012 and another 22 to be delivered in 2013. These buses are equipped with lead-acid battery packs.

BAE Systems has mainly partnered with Orion Bus Industries, which produced NYCT's hybrid bus fleet. This hybrid fleet consists of over 1,500 buses, all delivered between 2004 and 2010. This hybrid system uses a series configuration, with the buses equipped with lead acid battery packs.

[32] metro.kingcounty.gov

ISE is a smaller company with fewer of its systems currently in operation on buses. The company has incorporated a variety of energy storage options on its buses, including use of ultracapacitors.

5.5.3 Feasibility for Use in Corridor

To be used in the South Boston Piers Transitway, the hybrid buses would need to be set up to run on a "battery-only" mode, or with the engine on at low power (predominantly "battery-only)" if it can be proven that minimal emissions occur within the transitway tunnel in this setting.

The ability to run in a purely electric mode would be a function of how long the tunnel section is, how long the rest of the trip is (to ensure that the batteries are adequately charged by the time the bus returns to the tunnel segment of the trip), the number of stops within the tunnel section, the load (number of passengers) on the bus, and the travelling speed. The main concern with battery-only operation is that it could severely reduce the battery life. The "hush mode" is therefore more likely to be used instead for applications that require minimal emissions, e.g. in Seattle's tunnel.

In South Boston's case, the surface portion of the trip is only about 7.5 miles (round trip). This distance is likely inadequate to sufficiently re-charge the batteries for the tunnel segment of the trip over the course of the day, using conventional hybrid buses (For comparison, the surface portion of the trip in Downtown Seattle is over 25 miles).

The tunnel ventilation/air exchange system is also currently inadequate to handle diesel emissions within the South Boston Transitway Tunnel, and would need to be redesigned if hybrid buses are to operate in the tunnel.

Emissions

Current diesel-electric hybrid bus deployment in NYCT has been tested to determine in-use emissions of the Orion VII hybrid bus (equipped with BAE Systems' series hybrid drive). Some results are summarized in **Table 5-3.**

Table 5-3: Emissions Comparison

Emissions (g/mi)	**CO**	**NOx**	**PM/10**	**Total HC**
Diesel (with DPF)[33]	0.12	2.79	0.2	0.02
Neoplan Dual-mode[34]	N/A	4.3 – 1.2	0.01	N/A
NYCT's BAE – Orion VII diesel hybrid (with DPF)[35]	.03	0.94	0.2	0.02

The hybrids clearly do not provide the zero emissions of pure electric operations, but have emission benefits comparable to or better than clean diesel for the most part.
Official in-use emission data from the GM Allison parallel hybrid buses at King County Metro are not available at this point. Of greater importance is the level of emissions from the "hush

[33] FTA's 'Analysis of Electric Drive Technologies For Transit Applications' (2005)
[34] South Boston Piers Transitway Peer Review (2000)
[35] FTA's 'Analysis of Electric Drive Technologies For Transit Applications' (2005)

mode" operation of the hybrid buses within the DSTT, where there may be insufficient ventilation. This emission profile, once available, should be studied to provide an estimate for potential emissions from running hybrid buses in Boston's transitway tunnel.

Availability and Reliability

Vehicle availability is not foreseen to be an issue since hybrid buses are currently widely commercially available for transit use. Reliability is also not expected to be a big issue since hybrids have advanced significantly over the last few years since their adoption by NYCT and King County.

Durability of the bus components is the bigger concern for diesel-electric hybrids, since not much data is available from agencies that have had hybrids in operation over the 12-year estimated life of a transit bus. Even early adopters have upgraded their fleets with newer buses with improving bus technology and design, making these data even harder to obtain.

The biggest question is the durability of the battery packs, which are currently not expected to last for the entire life of a transit bus (NiMH are estimated to last longer (about 6 years) than lead-acid batteries (about 3 years)[36]. This is a major concern since the battery pack is a major cost component of the hybrid bus.

Passenger Carrying Capacity

60' articulated diesel electric hybrid models exist (e.g. the Allison New Flyer hybrids in King County Metro, and Massport's shuttles at Logan Airport), and should have enough capacity to meet transit demand in the transitway.[37]

Infrastructure Requirement

This vehicle does not require the installation of any new infrastructure, so should be fully usable in the existing corridor.

5.6 Battery Electric Bus Technology

Unlike diesel-electric hybrid buses, battery electric buses are "pure" electric buses, as the propulsion system is powered solely by electric energy stored in the batteries. These buses therefore ensure zero emissions at all times, and may thus be a viable alternative to the existing Neoplan dual mode buses for the South Boston Transitway tunnel.

[36] FTA's 'Analysis of Electric Drive Technologies For Transit Applications' (2005)
[37] Capacity estimates from the South Boston Piers Transitway Peer Review (2000)

The battery electric bus option should be considered for the following reasons:

- Absence of vehicle tailpipe emissions and reduced noise levels within the tunnel as well as on surface streets
- Potentially better availability than dual mode buses (several North American manufacturers of battery electric buses)
- Several bus operators in the US (e.g. Chatanooga, TN; Santa Barbara, CA; and Miami, FL) have deployed battery electric buses on short shuttle routes
- Potentially lower maintenance and operating costs than dual mode buses resulting from reduced brake and engine wear and tear, as well as lower fuel costs.

Disadvantages of the battery electric bus option include:

- Range and size limitations, since most batteries have a lower energy storage capacity than is required for typical transit operations, with reasonable weight and size
- Battery electric buses need to be periodically recharged, requiring costly charging equipment and in some cases impacting transit service schedules

5.6.1 Features

Battery electric buses are powered by batteries, with the electric drive system consisting of an electric motor, a battery pack for energy storage, and a control system that governs the vehicle operation. The electric motor offers more energy efficiency (than an Internal Combustion Engine) by enabling regenerative braking when the vehicle decelerates. The electric drive system also has higher overall efficiency and less noise than Internal Combustion Engines, and enables smoother vehicle operations as well as reduced wear and tear.

Being the sole source of power for the vehicle, the battery is large compared with the storage batteries in hybrid buses, and provides power for all the vehicle accessory systems in addition to providing energy for the vehicle's propulsion system.

Lead acid and nickel cadmium batteries are predominantly used in most battery electric transit buses currently in deployment. At this point in time, neither of these battery types can allow for both a full load of passengers and sufficient travel range for typical transit use (300 – 400 miles), without requiring recharging at some point during the day. For example the 22' battery electric buses currently deployed by most bus service operators with these fleets can only travel 60-80 miles before recharging.

The bus' battery packs are recharged when the batteries get depleted, or can be swapped out and replaced with fully charged packs. Transit operators are more likely to use the recharging option, and must thus purchase charging equipment to recharge their battery electric bus fleets. Buses with depleted batteries could also be replaced with fully charged ones at the recharging station to enable continuous operation of the buses.

Recharging time for the battery packs varies depending on the battery type as well as the charging equipment in use (the capacity and voltage/current output of the charger). Lead acid batteries require longer recharge times, but have a lower upfront cost and need to be replaced earlier. Nickel cadmium batteries on the other hand can be recharged faster and are smaller and lighter than lead acid batteries. These batteries however cost much more to purchase, though they last longer than lead acid batteries.

Most battery electric buses currently in operation (22' buses) are recharged overnight (after their service hours), and can receive a full recharge in 6 hours. Faster charging systems are also available at a higher cost, and can reduce charging time to 2-3 hours depending on the battery type[38]. Proterra Inc is currently offering battery electric fast-charge buses that are able to charge in less than 10 minutes[39].

The recharge time is particularly important since it determines how soon the vehicle can get back into service, hence the total number of buses needed for serving a given route. Bus service operators can implement "opportunity charging" at key locations on fleets' routes to enable the bus batteries to get recharged during regular bus service, reducing the time that buses spend out of service. This however comes with significant infrastructure costs since charging stations have to be installed at the chosen spots. It may also be more challenging and costly for operators to deliver timely and reliable service to their patrons if the buses are to be recharged during their daily service.

5.6.2 Current Deployments

There are few bus companies in the battery electric bus market, including Ebus and Proterra in North America, who mainly target medium duty shuttle transit operators.

For transit use, battery electric propulsion systems have primarily been applied in small transit buses (mostly 22' buses) servicing short low speed and less demanding routes, such as those used for shuttle services. Fleet sizes are generally small (5 - 10 buses), with Santa Barbara and Los Angeles in California having larger fleet sizes (20 and 18 buses, respectively). As of August 2005, the total number of these buses in transit operations in the US was estimated at 90-120 battery electric buses[40].

The Santa Barbara Metropolitan Transit District (MTD) in California initially deployed 20 battery electric buses for their low mileage routes in their downtown shopping district, with plans for an additional 13 buses in 2005. The buses are all 22', 10 of which were supplied by Ebus. All 18 battery electric buses deployed in Los Angeles were supplied by Ebus.

The Chattanooga Area Regional Transportation Authority (CARTA) in Tennessee has deployed a 12-bus fleet of battery electric buses since 1992 that is still in operation as their downtown circulator. The buses were supplied by AVS. Miami Beach, FL, also deployed battery electric buses for its downtown electric shuttle program, with a fleet size of 10 all-electric buses. These 22' buses were also supplied by AVS.

[38] FTA's 'Analysis of Electric Drive Technologies For Transit Applications' (2005)
[39] Personal Communication with Proterra – 04/08/2013
[40] FTA's 'Analysis of Electric Drive Technologies For Transit Applications' (2005)

Ebus is one of the earliest manufacturers of battery electric buses in the US, having supplied a majority of the 22' battery electric buses currently deployed by most transit bus service operators with these fleets in the US. The original 22' buses have now been upgraded for fast charging, and can travel about 45 miles on a single charge, after which they need to be recharged for about 30 minutes. These buses are equipped with nickel cadmium batteries.

Proterra Inc currently offers 35' fast-charge battery electric buses equipped with 72kWh lithium titanate batteries. The batteries are estimated to have a useful life of 6-8 years, so would need to be replaced once in the life of a bus[41]. The bus' travel range is dependent on the battery size, the passenger and air-conditioning load, as well as driving skills. The Proterra buses can charge in under 10 minutes and travel 30-40 miles on a single charge. These EcoRide BE35 buses are lighter than 40' buses, and have almost the same number of seats (up to 37 seats, with a capacity of 64 seating and standing passengers) as 40-ft buses.

The first of Proterra's fast-charge battery electric buses were deployed in Foothill Transit, California in September 2010. The buses currently serve Line 291, an 8-12 mile roundtrip route (similar to the SL1 10-mi round trip route). The buses do not use the full charge of the batteries in one round trip, and so take only 4-6 minutes to be fully recharged at the end of the trip[42].

The current fleet size of Foothill's battery electric buses is 3. The transit operator is however set to release an RFP for 9 more buses this year, indicating their satisfaction with the performance of the bus so far. The buses have been reported to be highly reliable; with few non-propulsion related failures (i.e. failing of typical bus components such as doors and wiper motors)[43]. Fuel and maintenance costs are also reduced for the vehicles.[44]

San Antonio recently purchased 3 Proterra battery electric buses that went into service in February 2013[45]. StarMetro in Tallahassee, FL, also purchased 3 buses, with 2 more to be delivered in June[46]. StarMetro is currently in the final stages of preparation work necessary before revenue service can begin, and expects to place the buses into service in August 2013[47].

Proterra is also supplying 6 buses to Worcester, MA, with 3 already on line while waiting for a Notice to Proceed on the remaining 3. [48]

New Flyer is currently working on a 40' battery electric bus that can run for up to 4 hours (at speeds between 9 and 12.5 mph) before requiring a recharge. In general the longer the bus travels, the more time it will take to be fully recharged, e.g. less than 10 minutes recharge would be required (at a rapid charge station) after running the bus for an hour, 15 minutes recharge after 2 hours of travel, or 30 minutes recharge after 4 hours. 60' buses would require bigger and heavier batteries for similar run / charge times.

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[41] Personal Communication with Proterra – 04/08/2013
[42] Personal Communication with Proterra – 04/08/2013
[43] Personal Communication with Proterra – 04/08/2013
[44] Bus Ride Magazine – April 2013 issue
[45] Bus Ride Magazine – April 2013 Issue
[46] Personal Communication with Proterra – 04/08/2013
[47] Personal Communication with StarMetro – 04/16/2013
[48] Personal Communication with Proterra – 04/08/2013

A 60' bus could be developed given sufficient market demand. This would require an increase of the bus' batteries by 1/3 to ½ and an upsizing of the power equipment. The bus itself would be larger, so should be able to carry the heavier load.[49] The batteries are estimated to have a useful life of 8 years, based on 40,000 miles of usage per year. The batteries have a longer life with less frequent re-charges.[50]

New Flyer's battery electric bus development is progressing well, with good performance in cold weather reported. At the moment only the shop charger is available; there has been a delay in the development of the rapid charger, which is now expected to be online in June 2013.[51]

New Flyer has already received orders for 2 battery electric buses for the city of Chicago, and 4 for the city of Winnipeg, all expected to be delivered in the last quarter of 2013.[52]

Chinese based BYD recently (September 2010) rolled out a 40' battery electric bus that is said to be capable of achieving a travel range of 155 miles on a single charge. This bus is powered by Iron-cell batteries, and takes about 6 hours for full charge using regular charging equipment, or 3 hours for fast charge. Over 200 BYD battery electric buses have been deployed for transit service in China and in other parts of Asia and Europe. The company has dealers in North America with its global headquarters located in Los Angeles, CA.

Advanced Vehicle Systems (AVS), one of the biggest battery electric bus companies from the 1990s has gone out of business.

5.6.3 Feasibility for Use in Corridor

Battery electric bus operations ensure zero tailpipe emissions; so could be used in the Boston transitway tunnel. However, since the MBTA does not currently operate a battery electric bus fleet for any of its service routes, new charging infrastructure would need to be purchased and installed to enable recharging of the bus batteries.

Additionally, recharge time for the buses would need to be incorporated into their daily routine to ensure that the bus batteries are sufficiently charged and available for service as needed.

Newer battery electric buses (Proterra and New Flyer) can travel 30-40 miles on a single charge (3-4 round trips from South Station to Logan Airport), before requiring a recharge of less than 10 minutes, which can be carried out during the bus layover / driver breaks. The dwell time plus layover at South Station is currently 10-11 minutes (see **Chapter 3**), so should provide sufficient recharging time using a rapid charging station.

The lack of sufficient demonstrated deployment of larger battery electric buses means that this may not yet be a credible option for the Silver Line.

[49] Preliminary Estimate from New Flyer
[50] Personal Communication with New Flyer – 04/09/2013
[51] Personal Communication with New Flyer – 04/09/2013
[52] Personal Communication with New Flyer – 04/09/2013

5.6.4 Emissions

There are no tailpipe / in use emissions associated with these vehicles.

5.6.5 Availability and Reliability

Battery electric transit buses are currently available in North America by Ebus, and Proterra, with New Flyer just now starting out in this market.

Based on literature review as well as conversations with manufacturers and operators of battery electric buses, there is no evidence of reliability concerns for this bus propulsion technology. Similar to hybrid buses, however, durability of the battery packs is of greater concern since they are a major cost component of a battery electric bus.

5.6.6 Passenger Carrying Capacity

Proterra's 35' bus and New Flyer's 40' prototype are smaller than the buses currently in use on SL1, so a bigger fleet would be needed to meet the peak transit demand.

There are currently no 60' battery electric buses in the market.

5.6.7 Infrastructure Requirement

This vehicle requires purchase and installment of charging infrastructure, which would also need to be periodically maintained.

5.7 Financial Implications

Financial considerations must be taken into account before an investment is made on a particular vehicle technology. **Table 5-4** provides a comparison of the purchase and selected operation costs for the three technology alternatives evaluated in this chapter.

The purchase scenarios are categorized by propulsion technology, with the number of buses required in each scenario obtained from recommended headways and cycle times given peak demand and bus sizes (see **Section 6.6.5**).

Vehicle purchase costs were obtained from amounts paid by transit agencies in the past. The MBTA purchased its dual mode fleet at about $1.6 million per bus in 2005. A higher price is expected for new purchases since this type of dual mode vehicle is currently not available in the North American market. King County Metro (KCM) in Seattle purchased its hush mode hybrid buses at about $645,000 per bus.[53] Foothill Transit paid $1.2 million for each of the three battery electric Proterra buses in their fleet, though the unit price for these vehicles is currently estimated

[53] http://www.greencar.com/articles/buses-green-hybrid-electric-vehicle-technologies.php

at $950,000[54]. Battery electric buses additionally require a rapid charger unit, which is estimated to cost $500,000[55].

Energy storage costs are estimated at $1,000/kWh[56]. A 60ft hybrid bus requires 8-15kWh batteries, and may be sized to up to 30kWh to provide a safety margin.[57] Our cost estimate includes a battery size range of up to 72 kWh for hybrid buses, to illustrate the cost range if a bigger battery is needed for pure electric operation in the tunnel. Battery electric buses require bigger batteries as the batteries are the only source of energy for these vehicles. The Proterra buses in use at Foothill Transit are equipped with 72kWh batteries[58]. The batteries are estimated to last 6-8 years, so will need to be replaced at least once in the life of the vehicle.

Labor and fuel costs are the two major operating costs for transit providers. A wage rate of $55/hour for drivers is used in this evaluation for comparison purposes, resulting in the annual driver costs shown in **Table 5-4**.

Annual fuel costs are dependent on the vehicle's fuel economy. Reports from Foothill transit indicate that the Proterra battery electric bus has a fuel economy of 18 MPG (Diesel Gallon Equivalent) or approximately 2kWh/mi[59]. In contrast the hybrid buses at KCM have an average fuel economy of 4 MPG, and their diesel buses 3.5 MPG[60]. The diesel bus fuel economy was used as an estimate for dual mode vehicles, since these vehicles run predominantly on diesel on the SL1 route.

Annual fuel consumption was obtained from the expected mileage per year and the fuel economy.

The evaluation results show that hybrid vehicles are the most cost effective in terms of capital costs, followed by battery electric buses. The higher fuel economy and lower fuel costs of battery electric buses result in much lower annual fuel costs than the other two alternatives, almost making up for the additional driver costs from requiring more buses in this scenario.

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[54] http://www.proterra.com/index.php/mediacenter/companynews/proterra_builds_its_case
[55] Personal Communication with Proterra – 05/07/2013
[56] Personal Communication with New Flyer – 11/14/2012
[57] Personal Communication with New Flyer – 11/14/2012
[58] Personal Communication with Proterra – 04/08/2013
[59] Personal Communication with Foothill Transit – 04/30/2013
[60] Clark N., et al, (2008). Assessment of Hybrid-Electric Transit Bus Technology (Prepared for the Transit Cooperative Research Program)

Table 5-4: Comparison of Purchase and Selected Annual Operating Costs

Comparison of Purchase and Operating Costs			
Overall Parameters			
Mileage per year	30,000	Vehicle Life:	12
Purchase Scenario			
Technology	Dual Mode	Hybrid	BEV
Length	60	60	40
Number of Buses Needed	7	7	9
Inputs			
Purchase Scenario Number	1	2	3
One-Time Costs			
Rapid Charger [$/unit]	-	-	500,000
One-Time Costs per Bus			
Vehicle Purchase [$/Bus]	1,600,000	645,000	950,000
Energy Storage Costs			
Battery Size [kWh]	N/A	30 - 72	72
Batteries Needed/Vehicle Life	N/A	2	2
Battery Purchase Cost [$/kWh]	N/A	1,000	1,000
Energy Storage Costs [$/bus]	N/A	60,000-144,000	144,000
Annual Costs per Bus			
Driver Costs			
Labor Rate [$/hr]	55	55	55
Annual Operating Hours [hrs/yr]	6,750	6,750	6,750
Total Driver Costs [$/yr/bus]	371,250	371,250	371,250
Fuel Costs			
Fuel Economy [MPG or kWh/mi]	3.5 MPG	4MPG	2kWh/mi
Gallons per Year per Bus	8,600	7,500	-
kWh per Year per Bus	-	-	60,000
Fuel Cost [$/gallon or $/kWh]	4	4	0.15
Total Fuel Cost [$/bus/year]	34,000	30,000	9,000
Total Comparative Costs			
Purchase Scenario Number	1	2	3
Subtotals			
Rapid Charger	-	-	500,000
Vehicle Purchase	11,200,000	4,500,000	8,600,000
Energy Storage	-	420,000 - 1,000,000	1,300,000
Annual Driver	2,600,000	2,600,000	3,340,000
Annual Fuel	240,000	210,000	81,000
Totals			
Total Capital	11,200,000	4,920,000 - 5,500,000	10,400,000
Annual Driver & Fuel Costs	2,840,000	2,810,000	3,421,000

Other external factors, however, need to be included in the evaluation of the feasibility of a vehicle's use for the SL1 Route. **Table 5-5**, **Table 5-6**, and **Table 5-7** show SWOT analyses for hybrid, battery electric, and dual-mode buses, respectively.

Table 5-5: Hybrid Bus SWOT Analysis

SWOT Analysis - Hybrid Bus	
Strength	**Weakness**
Lowest vehicle costs Proven technology in transit use Readily available Batteries are recharged during driving	No present set up for extended pure electric operation
Opportunity	**Threat**
Hybrid system with extended range capability	Battery only operation would severely reduce battery life Likely to be totally infeasible

Table 5-6: Battery Electric Bus SWOT Analysis

SWOT Analysis - Battery Electric Bus	
Strength	**Weakness**
Lower vehicle costs (than Dual Mode bus) Lowest Fuel Costs (all electric) No diesel emissions Readily available	Newer Technology - Less experience in typical transit use Smaller bus size
Opportunity	**Threat**
More Cost Effective with bigger bus (60')	Unknown future maintenance costs

Table 5-7: Dual Mode Bus SWOT Analysis

SWOT Analysis - Dual Mode Bus	
Strength	**Weakness**
Existing SL1 propulsion technology	Not readily available Highest vehicle cost
Opportunity	**Threat**
-	Inadequate support if purchased from abroad

In addition to cost effectiveness, many transit operators have successfully deployed hybrid buses, and so these buses have a proven performance record. The main weakness of hybrid buses currently in the market is their inability to operate in a pure electric mode for extended periods. There may however be opportunities for developing hybrid systems with extended range capabilities, e.g. by increasing the size of the vehicle's batteries[61], though this would inherently increase the capital cost of these buses.

[61] Personal Communication with New Flyer – 04/09/2013

Battery electric buses on the other hand ensure zero diesel emissions during operations. They are however not as widely used for typical transit service, and are currently only available in 35-ft and 40-ft sizes. This option can be more cost effective if bigger buses are used. Performance reports over the past 2 years also show no evidence of reliability problems, which may encourage more deployment by transit operators.

The dual mode option's main strength is that the MBTA already has experience with this vehicle, so they know its problems and how to fix them. The vehicle is however not readily available, and there may be support issues if an overseas manufacturer is used.

5.8 Conclusions and Recommendations

This report shows that dual mode buses are not readily available in the North American market. Even in Europe where there are several dual mode bus manufacturers, none of these companies has produced a sizeable fleet of these buses in recent years. This means that an order of these buses would be very costly. Moreover there would be maintenance concerns if an overseas manufacturer were to be unable to provide local support. However no proven alternative that is currently available has been found for the dual mode vehicle, so it is recommended that the MBTA proceed with the midlife rebuild of the current Silver Line vehicles.

Preliminary findings show that hybrid buses have lower emissions, quieter operations, and smoother acceleration and performance over dual mode buses on surface streets. The hybrid buses also have better availability and fuel economy, and offer additional route flexibility as compared to their dual mode counterparts.

The feasibility of pure electric operation in the tunnel given the short surface segment of the SL1 route is however still highly questionable, and would be even more problematic if the tunnel were to be extended, e.g. for Silver Line Phase III. It is therefore recommended that further research on new designs to enable extended battery-only operation be carried out before this option can be considered for future use for the Silver Line route.

Battery electric buses currently show the most promise for future procurement options for the Silver Line vehicles. 35' fast charge buses are already available by Proterra, and have shown good reliability since their initial deployment by Foothill Transit in 2010. New Flyer is also developing a 40' battery electric bus.

It is therefore recommended that Massport purchase a few of the currently available models for testing on other routes, before testing can be carried out on the Silver Line route.

6 Operational Improvements to the Silver Line

Some key findings about the Silver Line were established in **Chapters 2, 3** and **4**:

- The Silver Line is one of the key transit services to Logan Airport, for both employees and air passengers
- Travel speeds decrease significantly when the Silver Line travels on surface streets and between terminals at Logan Airport
- The Silver Line is at a travel time disadvantage compared to the Blue Line for reaching destinations in downtown Boston and on the Green and Orange Lines

As a result, it is worthwhile to assess the existing operation of the Silver Line and determine if there are opportunities to reduce travel time and wait time. The purpose of this chapter is to assess potential operational improvements to the Silver Line and indicate whether they should be recommended or are worthy of more detailed consideration. The most successful operational improvements are combined into service improvement alternatives and evaluated in **Chapter 7**.

The purpose of the proposed operational improvements is to improve the service quality of the Silver Line by achieving:

- Travel time reductions
- Wait time reductions
- Reliability improvements

As discussed in **Chapter 3**, the segments of the trip with the greatest potential for travel time reductions are the surface portion between World Trade Center station and the Ted Williams Tunnel, and the segment through Logan Airport. Elements of the trips that result in delays on the surface portion are illustrated in **Figure 6-1**.

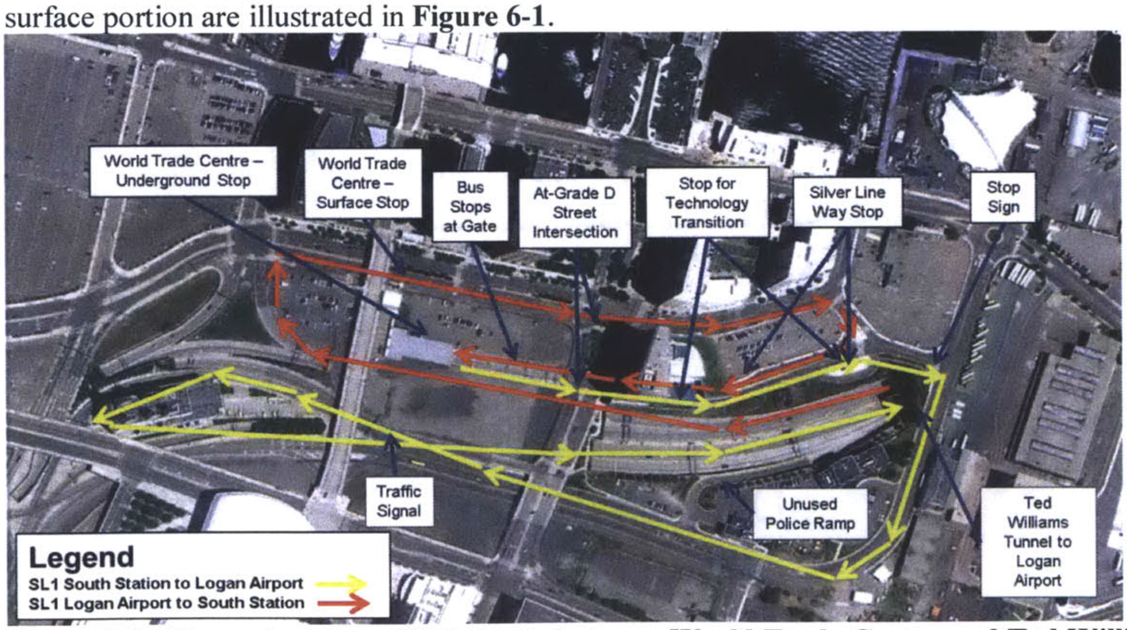


Figure 6-1: Characteristics of SL1 Route between World Trade Center and Ted Williams Tunnel

The primary causes of lower travel speeds on the surface segment of the route are:

- Transitway intersection with D Street: buses must wait for a green signal before crossing D Street
- Technology transition: buses must stop to transition between electric and diesel power
- Silver Line Way stop: buses must stop at Silver Line Way stop to allow passengers to board and alight
- Circuitous routing: the circuitous route increases travel time
- World Trade Center surface stop: the trip from Logan Airport to South Station has a surface stop on Congress Street outside World Trade Center station.
- D Street and Congress Street intersection: SL1 buses returning to South Station from Logan Airport must also wait at the intersection of Congress Street and D Street
- Gate before tunnel portal: buses must wait for a gate to open before proceeding into the portal before World Trade Center station

The primary causes of slower travel speeds through Logan Airport are:

- Dwell times at each terminal required for passengers to board and alight
- Travel through congested airport roadways

The primary causes of SL1 wait time are:

- Scheduled headway of 10 minutes or more during most time periods
- Headway variability

The primary causes of variability in running times and headways are:

- Inconsistent delays at D Street / Transitway intersection: some buses proceed directly through the intersection while other buses must wait more than one minute
- Wait time at signals: D Street and Congress Street, I-90 off-ramp to Congress Street, Haul Road and I-90 on-ramp
- Variable dwell times at stops, depending on number of boarding / alighting passengers and the level of crowding on the bus
- Congestion on the I-90, Ted Williams Tunnel and airport roadways
- Delays due to technical malfunction during the technology transition
- Variable dwell times at South Station

12 potential operational improvements have been identified to address the causes of travel time delays and variability. They are summarized in **Table 6-1.**

Table 6-1: 12 Potential Operational Improvements for the SL1

	Operational Improvement	Intended Purpose
1.	Grade separation of Silver Line Transitway at D Street	▪ Eliminate vehicle wait time at intersection ▪ Reduce travel time and its variability
2.	Implement Transit Signal Priority at D Street and the Silver Line Transitway	▪ Reduce wait time at intersection ▪ Reduce travel time variability
3.	Eliminate the Silver Line Way stop for SL1	▪ Reduce running time for SL1
4.	Switch to new vehicle technology that does not require technology transition when transferring from the tunnel to surface streets	▪ Reduce travel time ▪ Reduce risk of technical malfunction and delay
5.	Allow the trip from South Station to Logan Airport to use the State Police ramp to access the Ted Williams Tunnel	▪ Reduce travel distance and travel time ▪ Reduce travel time variability by avoiding Haul Road signal and congestion on I-90
6.	Increased frequency	▪ Reduce passenger wait time
7.	Free boardings of Silver Line at Logan Airport	▪ Reduce dwell time at the terminal stops ▪ Attract new ridership to the service by reducing cost
8.	Introducing branch SL1 routes that service specific terminals: ▪ SL1-A: Terminals A and B ▪ SL1-B: Terminals C and E	▪ Reduce travel time at Logan Airport
9.	Add a stop at Airport Station to the SL1route	▪ Simplify transit connections by having one bus connect to both the Blue Line and the Red Line ▪ Provide a BRT connection between the Blue Line and the Red Line
10.	Reduce travel time on airport roadways by reducing private vehicle volumes	▪ Reduce travel time on Logan Airport roadways
11.	Express service from South Station to Logan Airport	▪ Reduce travel time
12.	Remote Check-In at South Station	▪ Increase user comfort by checking bags before boarding bus on trip to Logan Airport

The following sections of this chapter define and assess each proposal.

6.1 Grade Separation at D Street

The South Boston Transitway transitions from underground tunnel to surface streets between World Trade Center station and D Street. Buses on routes SL1, SL2 and the South Station-Silver Line Way shuttle must travel through a signalized intersection with D Street. The transitway is used exclusively by Silver Line buses, while D Street is used by private vehicles, pedestrians, cyclists and a small number of MBTA buses (such as Route 171). The modal conflicts at this intersection are conceptually illustrated in **Figure 6-2**.

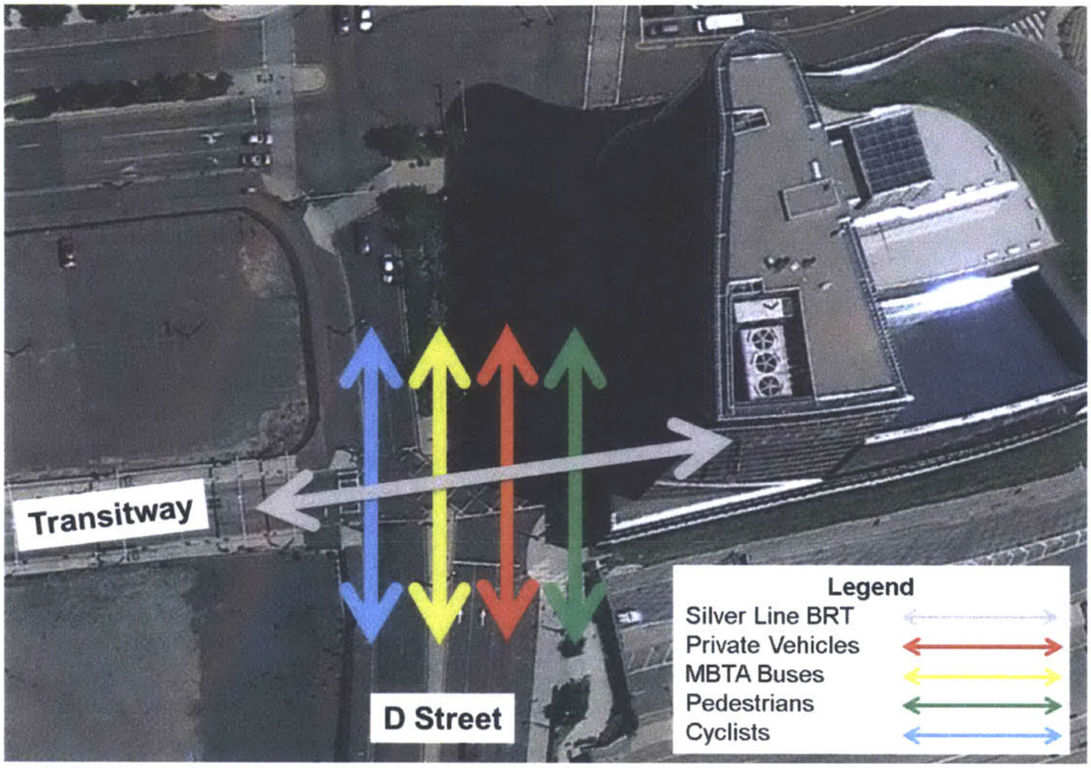


Figure 6-2: Modal Conflicts at D Street and Silver Line Transitway

Intersection operations were observed on a field visit during the PM Peak on Tuesday, October 9th, 2012:

- The signal was observed to change to green for the transitway only in response to a waiting bus; thus, SL buses proceed directly through a green light without delay **only** when the signal changes to green because of the presence of a bus in front of it, or on the opposite side of the intersection
- Queues of as many as 3 SL buses waiting for the signal to turn green were observed on the transitway
- Vehicle queues on D Street were observed to extend to the nearest signalized intersection (Congress Street) which is approximately 150 feet away
- Pedestrians were observed to wait on D Street to cross the Transitway

Photo 6-1, **Photo 6-2**, **Photo 6-3** and **Photo 6-4** illustrate operations at this intersection.

Photo 6-1: Bus bunching at the D Street intersection D Street

Photo 6-2: Vehicles wait while Silver Line buses cross D Street

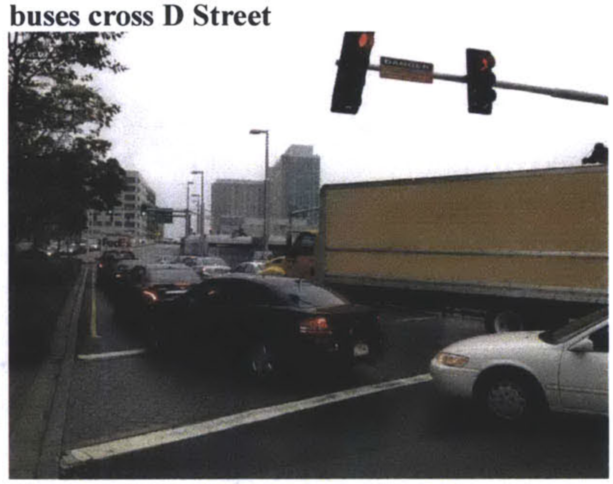


Photo 6-3: Silver Line bus waiting at the signalized intersection

Photo 6-4: Vehicles approaching the Transitway on D Street during PM Peak

Field data was collected to quantify the delays incurred by Silver Line buses while waiting to cross D Street. Data was collected during the mid-day period (12:30 to 2:00 PM) and the PM peak period (3:30-5:00 PM) on Friday, January 11, 2013. The results are shown in **Table 6-2**.

Table 6-2: Delay to Silver Line Buses at D Street

Mid-Day				
South Station to Silver Line Way (Inbound to Logan Airport)				
	SL1	**SL2**	**Shuttle**	**All Buses**
Minimum	0:10	0:00		0:00
Mean	0:47	0:36		0:41
Median	0:47	0:36		**0:46**
95th Percentile	1:18	1:06		1:14
Maximum	1:21	1:11		1:21
Standard Deviation	0:25	0:24		0:25
Number of Observations	9	10		19
Silver Line Way to South Station (Outbound from Logan Airport)				
	SL1	**SL2**	**Shuttle**	**All Buses**
Minimum	0:00	0:00		0:00
Mean	0:54	0:26		0:40
Median	0:56	0:17		**0:44**
95th Percentile	1:21	1:03		1:18
Maximum	1:23	1:09		1:23
Standard Deviation	0:25	0:23		0:27
Number of Observations	9	9		18
PM Peak				
South Station to Silver Line Way (Inbound to Logan Airport)				
	SL1	**SL2**	**Shuttle**	**All Buses**
Minimum	0:00	0:00	0:00	0:00
Mean	0:17	0:44	0:26	0:31
Median	0:00	0:57	0:13	**0:33**
95th Percentile	0:44	1:07	1:05	1:07
Maximum	0:45	1:12	1:13	1:13
Standard Deviation	0:21	0:25	0:26	0:26
Number of Observations	7	13	13	33
Silver Line Way to South Station (Outbound from Logan Airport)				
	SL1	**SL2**	**Shuttle**	**All Buses**
Minimum	0:21	0:00	0:04	0:00
Mean	0:57	0:48	0:52	0:51
Median	0:58	0:50	1:01	**0:55**
95th Percentile	1:42	1:49	1:14	1:45
Maximum	2:00	2:02	1:28	2:02
Standard Deviation	0:29	0:37	0:21	0:30
Number of Observations	9	16	15	40

These results were validated against a separate set of data that was collected from 3:30-4:15 PM on Tuesday, October 9th, 2012. The mean delays for this data set were 27 seconds and 50 seconds for the inbound and outbound directions, respectively. Longer delays in the direction from Silver Line Way to South Station were characteristic of both data sets. The delays during the PM Peak were plotted as histograms, shown in **Figure 6-3** and **Figure 6-4**.

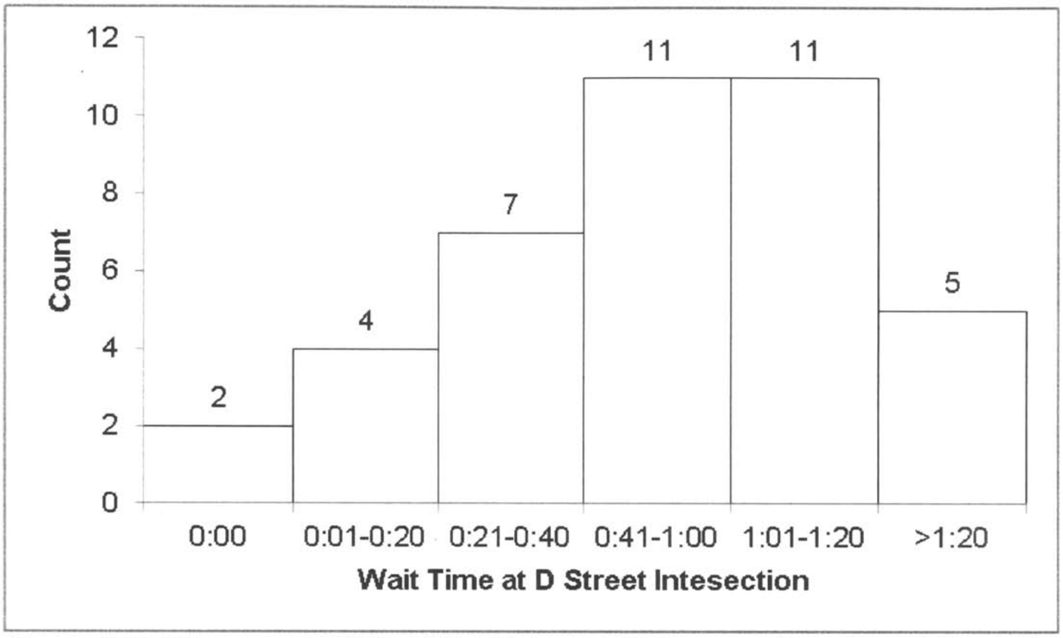


Figure 6-3: Histogram of Silver Line Delays at D Street – Silver Line Way to South Station, Outbound from Logan Airport

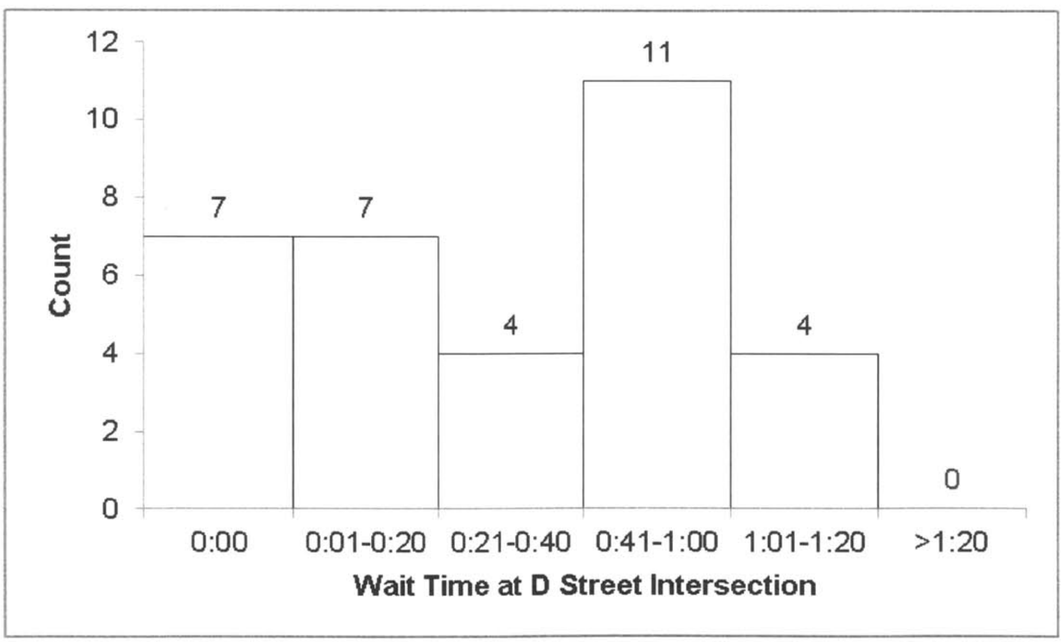


Figure 6-4: Histogram of Silver Line Delays at D Street – South Station to Silver Line Way, Inbound to Logan Airport

These results show that the signal at D Street results in delays to the majority of Silver Line buses that pass through the intersection. Summing the median inbound and outbound delays indicates that the median D Street delay for a round-trip to Logan Airport is 1:30 during the midday and 1:28 during the PM Peak. In addition to the time spent waiting at the intersection, the signal also requires buses to slow to a stop and then accelerate from a stop. The deceleration and acceleration further increase running time and are less comfortable for passengers.

The signalized intersection at D Street also introduces increased variability into the trip time. The standard deviation of the delay ranges from 25 seconds to 30 seconds, with a range of 0 seconds to more than 2 minutes in the maximum observed case. This delay is independent of time period, so modifying the bus schedule by time of day is unable to account for the variability. This element of variability in the running time requires increased recovery time at South Station to allow the buses to adhere to the scheduled departure times, or to ensure consistent headways between buses. Reducing the variability in running times will reduce the requirement for recovery time at the end of the route, which can enable more frequent service with no additional operational cost. More significantly, it reduces passenger anxiety on the trip to Logan Airport.

Furthermore, planned growth and development in the South Boston Waterfront area and increases to Silver Line ridership will further exacerbate the operational conditions at the intersection. Increased volumes of buses, vehicles, pedestrians and cyclists traveling through the intersection will result in more significant delays. Finally, increased frequency of buses will increase the extent of bus queuing on the transitway.

Based on the preliminary review in this section, grade separation is recommended for further consideration. A more detailed assessment of the benefits and costs associated with grade separation and a final recommendation are provided in **Chapter 7**.

6.2 Transit Signal Priority

Changing the signal timing at D Street and the South Boston Transitway could potentially reduce the travel time experienced by transit riders on the Silver Line. While it may reduce travel times less than grade separation, it is also far less expensive. Giving signal priority to the transit phase may, however, result in additional delay to vehicles on D Street and could result in queuing that affects upstream intersections.

To test the impacts of modifying the signal timing at D Street and the Transitway, a model of the D Street corridor has been constructed in TransModeler[62]. The modeled study area, which is illustrated in **Figure 6-5**, includes the following intersections:

- Summer Street and D Street
- D Street and Haul Road Onramp
- D Street and South Boston Transitway
- D Street and Congress Street
- D Street and Northern Avenue

The most recently available traffic counts from the City of Boston were from Tuesday, December 2, 2008. Based on a review of these counts, it appears that the PM Peak from 5:00 PM to 6:00 PM is the peak hour at each study area intersection. As a result, the model was constructed for the PM Peak Hour. The critical movements during the peak hour, defined as movements with more than 300 vehicles between 5:00 and 6:00 PM, are illustrated in **Figure 6-5**. Notably, there is a large number of conflicting traffic movements at D Street and Congress Street. Further, one of the primary movements is the right-turn from Congress Street to D Street and then from D Street to the I-90 onramp.

Six scenarios have been assessed, testing varying levels of demand against existing signal timings and Transit Signal Priority (TSP):

- Scenario 1.1 – Existing Conditions
- Scenario 1.2 – Existing Travel Demand with TSP
- Scenario 2.1 – Medium Growth in Travel with Existing Signal Timings
- Scenario 2.2 – Medium Growth in Travel with TSP
- Scenario 3.1 – High Growth in Travel with Existing Signal Timings
- Scenario 3.2 – High Growth in Travel with TSP

[62] TransModeler traffic simulation software by Caliper Corporation

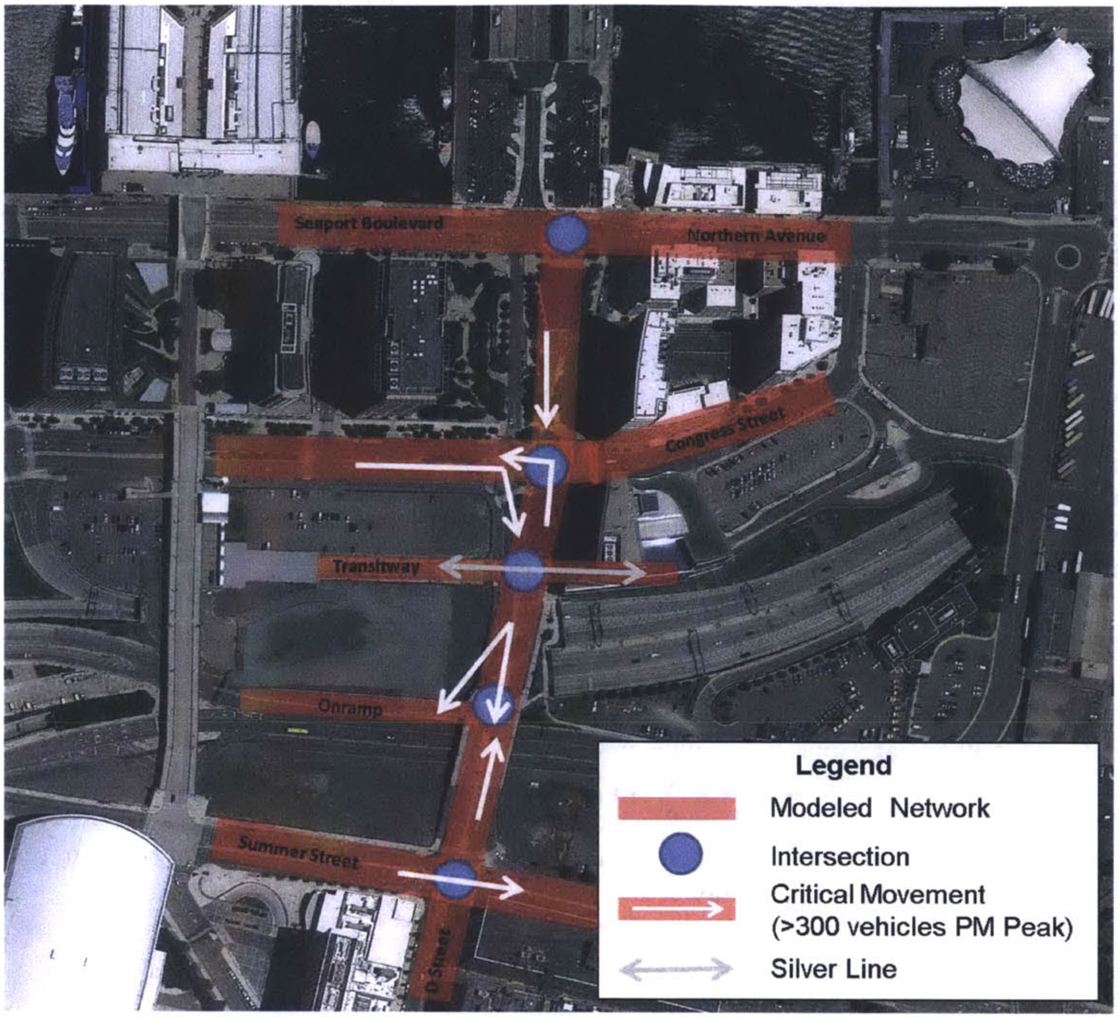


Figure 6-5: Study Area for TransModeler Model of D Street Corridor

The key model outputs that will be used to assess the impacts of each scenario to the system are presented in **Table 6-3**.

Table 6-3: Transit Signal Priority Performance Measures

Performance Measure	Meaning
Overall Trip Statistics	
Average Speed (mph)	This provides an indication of the average speed at which vehicles move throughout the network
Delay (hours)	This provides a measure of total delay in the network
Stopped Time (hours)	This provides a measure of the total stop time in the network
Intersection Delay and Stop Time	
Average Stop Time on Transitway at D Street (average EB and WB)	This measure shows the reduction in wait times for Silver Line buses at D Street (and thus the benefit to transit users)
Intersection Delay at D Street and Seaport Boulevard / Northern Avenue	These measures indicate how delay at neighboring intersections changes once TSP is implemented
Intersection Delay at D Street and Congress Street - All Approaches (sec/veh)	
Intersection Delay at D Street and the Transitway - All Approaches (sec/veh)	
Intersection Delay at D Street and Summer Street – All Approaches (sec/veh)	
Average Delay - EBRT from Congress to D Street (sec/veh)	These measures indicate the delay on critical movements that will be affected by the Transitway interaction
Average Delay – EBRT from Seaport Boulevard to D Street (sec/veh)	
Average Delay - SB through on D at Congress (sec/veh)	
Travel Times	
Change in Northbound Travel Time from Summer Street to Seaport Boulevard / Northern Avenue (min)	These measures provide an indication of how vehicle travel times along the D Street corridor will change
Change in Southbound Travel Time from Seaport Boulevard / Northern Avenue to Summer Street (min)	
Queuing	
Average and Maximum Queue Eastbound on Congress Street at D Street	The right-turn movement from Congress Street to D Street is one of the most critical movements in the study area. Further, its queues are expected to be directly impacted by changes to the timings at D Street and the Transitway
Average and Maximum Queue Eastbound on Seaport Boulevard at D Street	Under normal operations, there is little queuing on Seaport Boulevard for the right-turn movement onto D Street. However, as congestion increases, queues fill the southbound leg of D Street north of Congress Street and spill back onto Seaport Boulevard
Average and Maximum Queue Southbound on D Street at Congress Street	While queuing on the short section between the Transitway and D Street occurs under the existing condition, this captures queues on D Street that would extend beyond Congress Street

Model Development and Calibration

The existing conditions model was constructed using existing network geometry, existing signal timings provided by the City of Boston and a network O/D matrix constructed based upon traffic counts from December 2008 provided by the City of Boston. As the traffic counts are 5 years old, a manual traffic count was conducted by the project team between 4:30 and 5:30 PM on Tuesday, April 16th, 2013, the results of which are presented in **Table 6-4**. Traffic may have been lighter on this day as it was during spring school vacation.

Table 6-4: Traffic Count Results at D Street and the South Boston Transitway

	Northbound	Southbound	Inbound SL Buses	Outbound SL Buses
4:30-4:45	99	152	7	8
4:45-5:00	106	160	8	6
5:00-5:15	139	221	4	8
5:15-5:30	113	252	8	4
Total	**457**	**785**	**27**	**26**
Total 5:00-5:30	252	473	12	12
Expanded to 5:00-6:00 hour	504	946	24	24
5:00-6:00 2008 Traffic Counts	**431**	**975**	**33**	**29**

These results suggest that there has not been a significant increase in traffic between 2008 and 2013. However, to account for the possibility that traffic volumes were lower on the survey day, a case has been run within the existing conditions scenario with a scale factor of 1.15 applied to the O/D matrix. The O/D matrix was updated both to account for shifts in the traffic patterns. Factors were applied to the matrix to achieve 504 northbound and 946 southbound vehicles along D Street at the Transitway. 15 trips were also shifted from the southbound-through to the eastbound-right movement at D Street and Congress Street. These modifications increased the consistency between the modeled and measured values used for calibration, and also helped the simulation better replicate observed conditions at the intersection.

To calibrate the existing conditions model, 3 key model outputs were compared with observed data, summarized in **Table 6-5**.

Table 6-5: Calibration of D Street Model

	Model Output	Observed Data	Data Collection Date
Silver Line Average Stopped Time at D Street Intersection	Model: 48 seconds	Median stop time: 47 seconds	PM Peak data collected in January 2013
Northbound Vehicle Travel Time from Summer Street to Northern Avenue	Model: 1.4 minutes	Median time 1.6 minutes	Based upon 8 travel time runs between 4:30 and 5:30 PM on Friday, April 12, 2013
Southbound Vehicle Travel Time from Northern Avenue to Summer Street	Model: 1.9 minutes	Median time 1.6 minutes	Based upon 8 travel time runs between 4:30 and 5:30 PM on Friday, April 12, 2013

Thus, the model reasonably replicates the existing traffic pattern. The future scenarios will be assessed with respect to the modeled values in the existing condition scenario: therefore, percentage increase / percentage decrease values with respect to the existing conditions results will provide insight into the extent that conditions would change under each scenario.

Transit Signal Priority was introduced by modifying the existing signal timing as follows:

- Basic structure of the signal design retained: D Street is the main phase, and activation of the sensor by a Silver Line bus puts in a call for a green light on the Transitway
- D Street maximum green time reduced from 41 seconds to 20 seconds: now, when a call is placed, the D Street phase will switch to the Silver Line once it has reached 20 seconds. If 20 seconds have already elapsed on the D Street phase, the signal will switch to the Transitway phase immediately
- The second phase, which provides a green light for the southbound direction only, has been eliminated
- The sensor locations were moved so that they can sense the approach of a Silver Line bus before it reaches the intersection: as a result, the signal turns green by the time the Silver Line arrives at the intersection and the bus can proceed through without stopping. In reality, drivers would need to be trained to maintain a consistent speed between the sensor location and the intersection to be able to proceed through. Further, the gate on the Transitway west of D Street should be removed or reconfigured: presently, buses must stop at the gate and wait for it to open, resulting in delays to both inbound and outbound buses
- Based on field observations, it is sometimes challenging for multiple Silver Line buses to clear the intersection on one cycle: as a result, the vehicle extension (the extra green time allocated if another vehicle needs to cross the intersection) has been increased from 3 seconds to 5 seconds.
- Signal co-ordination with other signals on D Street has been eliminated: this co-ordination restricted when the signal could provide the Transitway with a green phase, and increased delay to Silver Line phases

6.2.1 Case 1: Existing Conditions

Four distinct cases were tested using the existing conditions model:

- Case 1.1: Existing Traffic with No Silver Line
- Case 1.2: Existing Traffic with Existing Silver Line Volumes
- Case 1.3: Existing Traffic with Existing Silver Line Volumes and TSP
- Case 1.4: Existing Traffic with 1.15 scale factor applied; Existing Silver Line volumes and TSP

By comparing the results of these scenarios, the influence of both the Silver Line crossing itself and transit signal priority can be quantified. The purpose of Scenario 1.4 is to test the resiliency of the network. By applying a scale factor of 1.15 to the vehicle demand matrix (exclusive of Silver Line vehicles), a more critical case with heightened vehicle demand is assessed. This serves to capture variability in travel demand or potential under-measurement in the existing traffic counts.

The results of the model simulations for the four scenarios are included in **Table 6-6**. For each case, 30 simulations were run. The main conclusions are as follows:

- Total delay and total stopped time increase as the Silver Line intersection is introduced to the network (Case 1.2), as signal priority is introduced (Case 1.3) and when the growth factor is applied (Case 1.4).
- This TSP configuration provides great benefit to transit users: average stopped time at D Street on the Silver Line decreases dramatically from 48 seconds to 6 – 10 seconds in Cases 1.3 and 1.4. Although overall network delay and stop time increase, the impacts to cross-traffic are relatively minor.
- Total delay and total stop time increase by 60% and 74% respectively after the scale factor of 1.15 is applied in Case 1.4. This disproportionate increase reveals the non-linear impact of congestion once the critical capacity threshold has been surpassed.
- Examining particular movements within the network, the greatest impact is on the eastbound right-turn and southbound through movement at D Street and Congress Street. Notably, the maximum eastbound queues (935 feet) extend past the existing I-90 offramp to the west of World Trade Center Station. This indicates that these are the critical movements in the network, which are nearing capacity under existing conditions

As expected, the implementation of Transit Signal Priority results in travel time savings to Silver Line buses and overall increases in delay, stopped time and travel time within the network. A screenshot of the simulation for Case 1.3 (**Figure 6-6**) illustrates the queues for eastbound and southbound traffic at Congress Street and D Street. This scenario has included the implementation of a particular form of Transit Signal Priority; however, other approaches which provide less benefit to Silver Line buses but also less impact to cross-traffic could also be considered. As demand increases, delay increases disproportionately within the network; the influence of the Silver Line on these increases will be assessed in **Section 6.2.2** and **Section 6.2.3**

Table 6-6: Existing Demand – Simulation Results

Performance Measure	1.1 - Existing Conditions without Silver Line	1.2 - Existing Conditions with Silver Line	1.3 - Existing Conditions with Silver Line and TSP	1.4 - Existing Traffic with 1.15 scale factor applied; TSP applied
Overall Trip Statistics				
Average Speed (mph)	12.4	12.1	11.9	9
Delay (hours)	62.8	64.5	66	105.8
Stopped Time (hours)	40.4	41.6	43.1	75
Intersection Delay and Stop Time				
Average Stop Time on Transitway at D Street (average EB and WB)	N/A	48.4	5.65	8.6
Intersection Delay at D Street and Seaport Boulevard / Northern Avenue	26	26	27	39
Intersection Delay at D Street and Congress Street - All Approaches (sec/veh)	49.2	50	53.5	94
Intersection Delay at D Street and the Transitway - All Approaches (sec/veh)	N/A	7.6	5.7	6.8
Intersection Delay at D Street and Summer Street – All Approaches (sec/veh)	27.4	26.9	26.8	29.6
Average Delay - EBRT from Congress to D Street	49.8	65.4	60.6	195
Average Delay – EBRT from Seaport Boulevard to D Street	24	24	25	55
Average Delay - SB through on D at Congress	62.5	62.1	69.6	102.5
Travel Times				
Northbound Travel Time from Summer Street to Seaport Boulevard / Northern Avenue (min)	1.2	1.4	1.6	1.7
Southbound Travel Time from Seaport Boulevard / Northern Avenue to Summer Street (min)	1.2	1.9	2.1	2.6
Queuing				
Maximum Queue Eastbound on Congress Street at D Street (feet)	268	379	337	935
Average Queue Eastbound on Congress Street at D Street (feet)	92	121	112	363
Maximum Queue Eastbound on Seaport Boulevard at D Street (feet)	200	184	188	375
Average Queue Eastbound on Seaport Boulevard at D Street (feet)	59	57	59	124
Maximum Queue Southbound on D Street at Congress Street (feet)	300	315	325	372
Average Queue Southbound on D Street at Congress Street (feet)	123	124	133	201

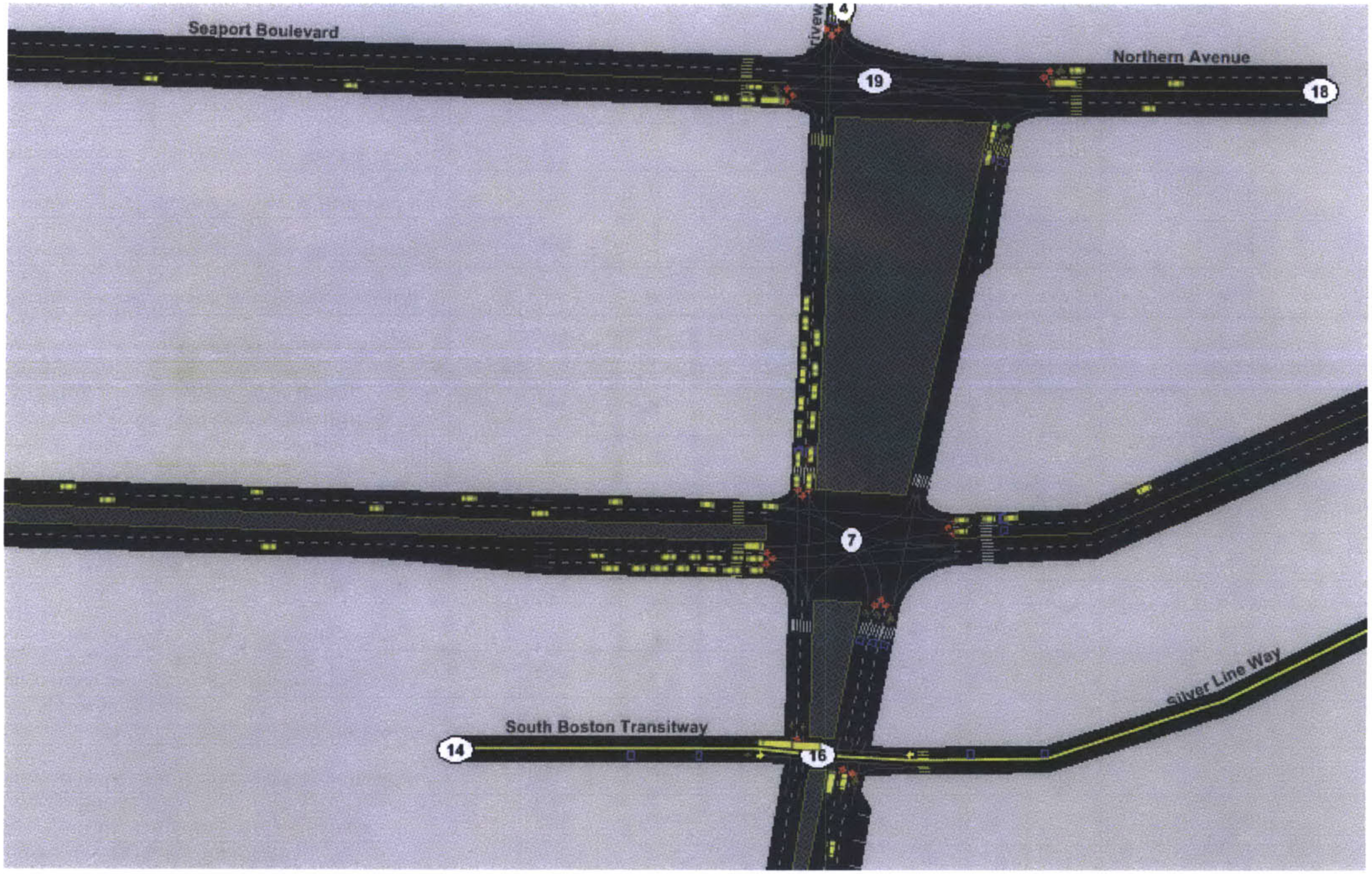


Figure 6-6: Existing Conditions with Transit Signal Priority Introduced

6.2.2 Case 2: Moderate Travel Growth

The purpose of Case 2 is to assess the operations of the network under moderate vehicular travel growth and with additional Silver Line buses. Moderate travel growth has been simulated by:

- Applying a scale factor of 1.1 to the vehicle travel matrix
- Increasing the scheduled number of Silver Line buses to 36 buses per hour per direction to account for either increased Silver Line frequency with 60 foot buses, or 40-foot buses in place of the existing 60-foot buses (although the use of 40-foot buses for the Silver Line has not been recommended by this study). This value was determined as follows:
    - Using a headway of 6 minutes for the SL1 (see **Section 6.6.5**) results in 10 buses per direction per hour
    - Under existing conditions, SL2 and the shuttle are scheduled at 5 minute headways, corresponding to 12 buses per hour. Based on field data collected on Thursday, January 31st, 2013 at Silver Line Way, the most crowded SL2 had 60 passengers and the most crowded shuttle had 33 passengers. These buses continue to pick-up passengers at World Trade Center and Courthouse on the trip to South Station. To be conservative, an additional bus for each route during the peak hour may be needed, resulting in 13 SL2 buses per direction per hour and 13 shuttle buses per direction per hour
    - 10 SL1 buses, 13 SL2 buses and 13 shuttle buses result in a total of **36** buses per direction per hour

  A standard deviation of 90 seconds has been used.

This moderate travel growth scenario may be achieved within the short-term, as a 10% increase in travel volumes could represent fluctuation of the existing demand, and an increase in peak hour Silver Line frequencies on existing routes would be required if 40 foot buses are used.

Three distinct cases were tested using the existing conditions model:

- Case 2.1: Moderate Travel Growth with No Silver Line
- Case 2.2: Moderate Travel Growth with Silver Line and no TSP
- Case 2.3: Moderate Travel Growth with Silver Line and TSP

The purpose of including Case 2.1 is to observe how network operations deteriorate with increased travel, independent of any influence from the intersection of D Street and the Transitway. The simulation results are presented in **Table 6-7**, along with the replicated results of Case 1.1 – Existing Conditions without Silver Line.

The following conclusions can be drawn from the results:

- The application of the scaling factor to the matrix (Case 2.1), the inclusion of the Silver Line Transitway (Case 2.2) and the implementation of Transit Signal Priority (Case 2.3) all result in a deterioration of network level of service (as shown by total delay, total stop time and average speed). Travel times also increase consistently
- Once the Silver Line is included there are long delays (approximately 3 minutes) for the eastbound right-turn movement from Congress Street to D Street)

- Even under heightened demand, TSP is able to significantly reduce Silver Line wait times at D Street. There is an increase in average delay at the intersection of Congress Street and D Street from 80 seconds to 89 seconds.
- A significant increase in delay and stop time results from the application of the scaling factor to the travel matrix (Case 2.1) as compared to the base case (Case 1.1). This demonstrates the sensitivity of the network – and the intersection of Congress Street and D Street in particular – to increased vehicle travel
- In Case 2.1, 2.2 and 2.3, the maximum southbound queues on D Street at Congress Street extend through the full length of the lane to Northern Avenue (approximately 350 feet). The average queues on the eastbound leg of Seaport Boulevard also increase, suggesting a spillback effect.
- Lengthy eastbound and southbound queues at Congress Street and D Street could be addressed by improving the signal timing to better balance delay between the intersection movements

Table 6-7: Moderate Travel Growth – Simulation Results

Performance Measure	1.1 - Existing Conditions without Silver Line	2.1 – Moderate Growth without Silver Line	2.2 – Moderate Growth with Silver Line	2.3 – Moderate Growth with TSP
Overall Trip Statistics				
Average Speed (mph)	12.4	11.1	9.9	9.4
Delay (hours)	62.8	79.2	89.4	96.3
Stopped Time (hours)	40.4	52.8	61.9	67.9
Intersection Delay and Stop Time				
Average Stop Time on Transitway at D Street (average EB and WB)	N/A	N/A	46.9	7.35
Intersection Delay at D Street and Seaport Boulevard – All Approaches (sec/veh)	26	31	32	34
Intersection Delay at D Street and Congress Street - All Approaches (sec/veh)	49.2	63.8	80	89.2
Intersection Delay at D Street and the Transitway - All Approaches (sec/veh)	N/A	N/A	9.5	8.3
Intersection Delay on D Street at Summer Street - All Approaches (sec/veh)	27.4	27.5	27.6	27.4
Average Delay - EBRT from Congress to D Street	49.8	96.8	180	171.2
Average Delay – EBRT from Seaport Boulevard to D Street	24	34	36	44
Average Delay - SB through on D at Congress	62.5	74.2	74	106
Travel Times				
Northbound Travel Time from Summer Street to Seaport Boulevard / Northern Avenue (min)	1.2	1.6	1.5	1.7
Southbound Travel Time from Seaport Boulevard / Northern Avenue to Summer Street (min)	1.2	2.1	2.1	2.6
Queuing				
Maximum Queue Eastbound on Congress Street at D Street (feet)	268	582	869	828
Average Queue Eastbound on Congress Street at D Street (feet)	92	199	323	317
Maximum Queue Eastbound on Seaport Boulevard at D Street (feet)	200	279	284	340
Average Queue Eastbound on Seaport Boulevard at D Street (feet)	59	83	89	107
Maximum Queue Southbound on D Street at Congress Street (feet)	300	352	353	375
Average Queue Southbound on D Street at Congress Street (feet)	123	153	153	205

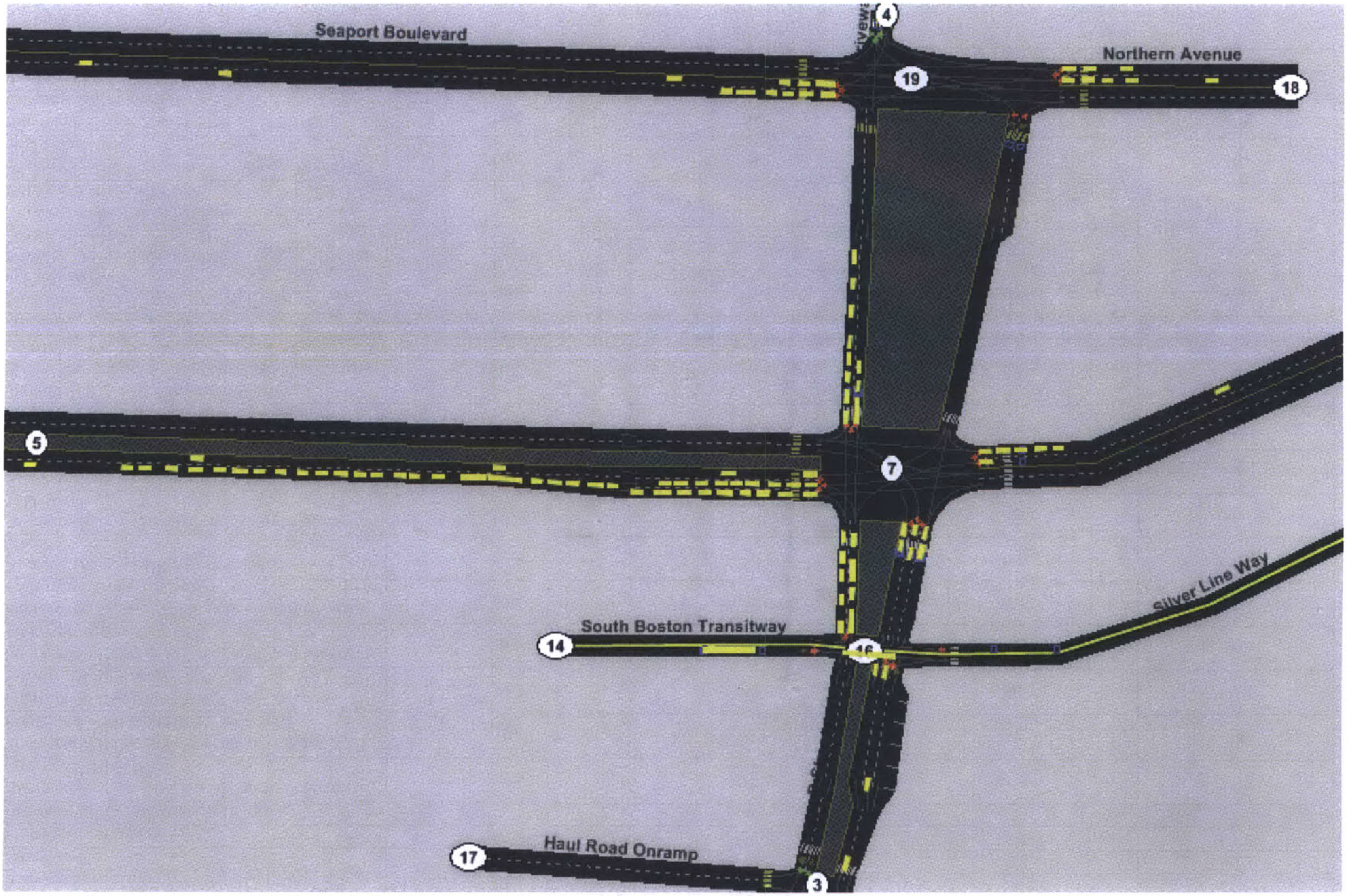


Figure 6-7: Moderate Travel Growth with Transit Signal Priority Introduced

6.2.3 Case 3: High Travel Growth

The purpose of Case 3 is to assess the operations of the network under high travel growth. High travel growth has been simulated by:

- Applying a scale factor of 1.2 to the vehicle travel matrix
- Increasing the scheduled number of Silver Line buses to 48 buses per hour per direction. This could represent 5 minute headways for each of the Silver Line 1, Silver Line 2, Silver Line short-turn shuttle and potential new Silver Line 6. A standard deviation of 90 seconds has been used.
- An additional case was completed with 60 scheduled Silver Line buses per direction per hour. This would result in 4 minute headways for each of the SL1, SL2, Shuttle and SL6, which could potentially be required if 40 foot buses are used on the route. A standard deviation of 60 seconds has been used

This high travel growth scenario may be achieved within the medium-term if frequencies are increased and if additional buses are procured.

Four distinct cases were tested using the existing conditions model:

- Case 3.1: High Travel Growth with no Silver Line
- Case 3.2: High Travel Growth with 48 Silver Line buses per direction per hour and no TSP
- Case 3.3: High Travel Growth with 48 Silver Line buses per direction per hour and TSP
- Case 3.4: High Travel Growth with 60 Silver Line buses per direction per hour

The purpose of including Case 3.1 is to observe how network operations deteriorate with increased travel, independent of any influence from the intersection of D Street and the Transitway. The simulation results are presented in **Table 6-8** along with the replicated results of Case 1.1 – Existing Conditions without Silver Line.

The following conclusions can be drawn based upon the results:

- The increase in traffic volume alone results in sizable increases to delay, stopped time and queuing in the network as seen by comparing Case 1.1 to Case 3.1
- Transit signal priority is still able to substantially reduce waiting time at D Street for Silver Line buses
- The introduction of the Silver Line in Case 3.2 has a substantial impact on the eastbound right-turn movement from Congress Street to D Street: average delay for this movement increases from 193 seconds (Case 3.1) to 271 seconds (approximately 4.5 minutes). The co-ordinated signal timing results in much more of the additional delay occurring on the eastbound right-turn movement instead of the southbound through movement
- The introduction of TSP in Case 3.3 results in increases to overall network delay and stopped time. As a result of the un-coordinated signal timing, the additional delay is now shared between the eastbound right-turn and southbound through movement at D Street and Congress Street. As the southbound through movement on D Street is filled to capacity, queues spill back onto Seaport Boulevard: the average delay for the eastbound right-turn from Seaport Boulevard to D Street nearly doubles from 78 seconds to 153 seconds. Queues also increase substantially.

- In Case 3.4, where there are 60 scheduled Silver Line buses per direction per hour, the network conditions continue to deteriorate. Further, TSP becomes slightly less effective at reducing the transit wait times, as buses are more likely to arrive immediately after a cycle has finished for the leading bus.

Table 6-8: High Travel Growth – Simulation Results

Performance Measure	1.1 - Existing Conditions without Silver Line	3.1 – High Growth without Silver Line	3.2 – High Growth with Silver Line	3.3 – High Growth with TSP	3.4 – TSP and Additional SL Buses
Overall Trip Statistics					
Average Speed (mph)	12.4	8.7	8.8	8.2	8.1
Delay (hours)	62.8	113.8	123	136	137
Stopped Time (hours)	40.4	79.1	88	100	101
Intersection Delay and Stop Time					
Average Stop Time on Transitway at D Street (average EB and WB)	N/A	N/A	43.6	8.25	9.5
Intersection Delay at D Street and Seaport Boulevard – All Approaches (sec/veh)	26	46	47.4	70	68
Intersection Delay on D Street at Congress Street - All Approaches (sec/veh)	49.2	90	102	114	115
Intersection Delay on D Street at the Transitway - All Approaches (sec/veh)	N/A	N/A	11	11	12.1
Intersection Delay on D Street at Summer Street - All Approaches (sec/veh)	27.4	32.7	34	32	33
Average Delay - EBRT from Congress to D Street	49.8	192.7	270.4	250	258
Average Delay – EBRT from Seaport Boulevard to D Street	24	74	78	153	145
Average Delay - SB through on D at Congress	62.5	94	92	138	132
Travel Times					
Northbound Travel Time from Summer Street to Seaport Boulevard / Northern Avenue	1.2	1.6	1.6	1.8	1.9
Southbound Travel Time from Seaport Boulevard / Northern Avenue to Summer Street	1.2	2.4	2.3	3.1	3.1
Queuing					
Maximum Queue Eastbound on Congress Street at D Street (feet)	268	926	1028	1038	1056
Average Queue Eastbound on Congress Street at D Street (feet)	92	361	392	388	390
Maximum Queue Eastbound on Seaport Boulevard at D Street	200	440	533	819	377
Average Queue Eastbound on Seaport Boulevard at D Street	59	175	181	323	242
Maximum Queue Southbound on D Street at Congress Street (feet)	300	370	375	379	779
Average Queue Southbound on D Street at Congress Street (feet)	123	197	190	258	321

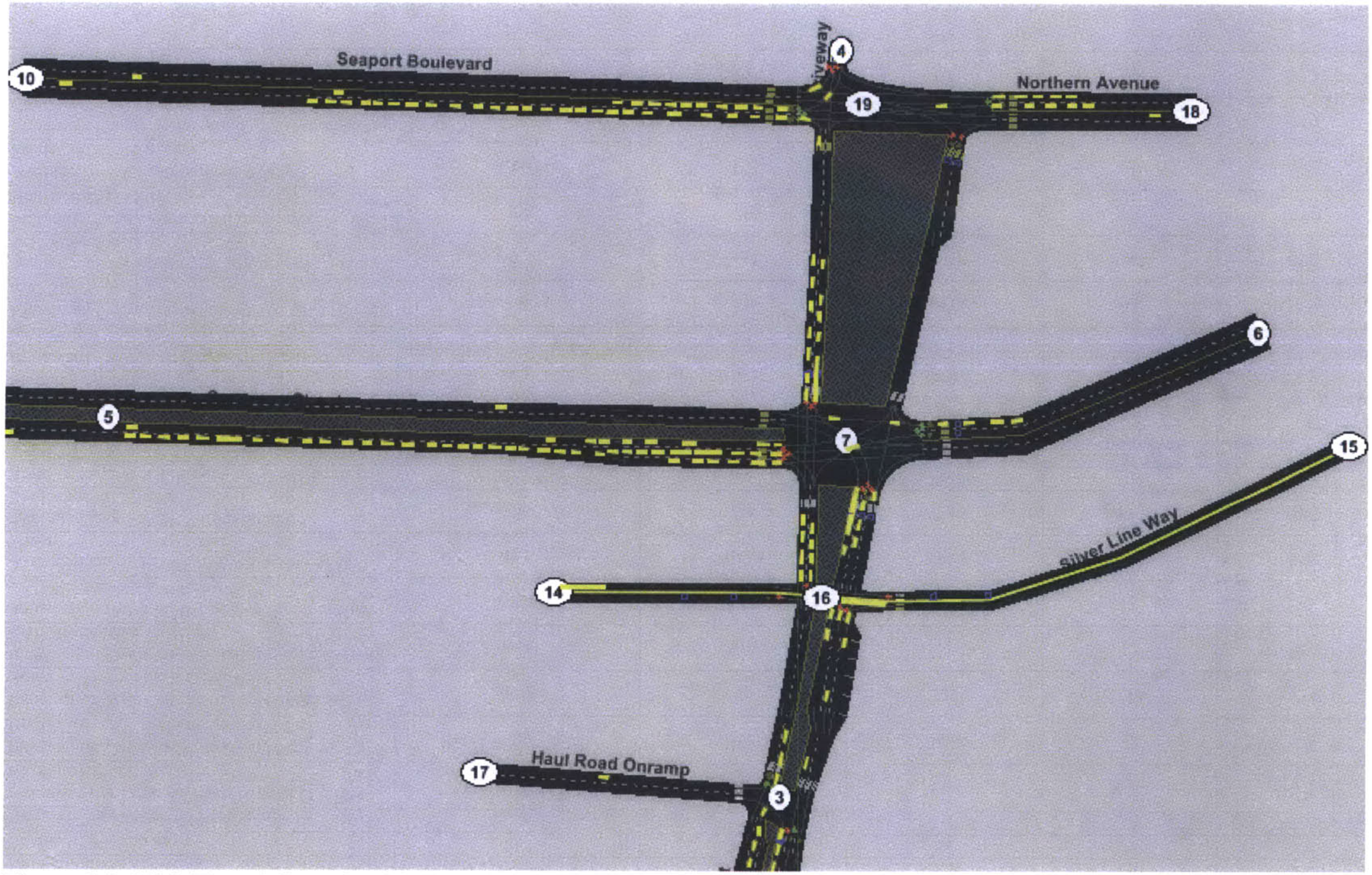


Figure 6-8: High Travel Growth with Transit Signal Priority Introduced

6.2.4 Conclusions and Recommendations

Based upon this assessment, the following conclusions and recommendations are provided:

- Under existing conditions, Transit Signal Priority does have the ability to provide travel time savings for Silver Line buses.
- Signal priority could be provided at very low cost by simply modifying the timings of the existing signal; therefore, experimentation with alternate signal timings at D Street and the Transitway is **recommended for immediate study and implementation**. If alternate timings result in excessive disruption to cross-traffic during the AM and PM Peak, then Transit Signal Priority could still be provided during the mid-day and evening periods
- Some major design and operational considerations include:
    - Moving the sensor locations to detect Silver Line buses earlier
    - Eliminating or reconfiguring the gate on the Transitway to allow more efficient flow of Silver Line buses in and out of the portal
    - Providing additional vehicle extension time for each Silver Line bus
    - Reducing the maximum green time for the D Street phase
    - Eliminating the phase for southbound-only on D Street
- Transit Signal Priority will not be viable as volumes of vehicles and Silver Line buses increase. Roadway operations deteriorate significantly with increased Silver Line frequencies, increased vehicular volume and TSP: the average delay for an eastbound right turn from Congress Street to D Street exceeds four minutes, and similar delays occur for vehicles turning right from Seaport Boulevard to D Street. Furthermore, as the Silver Line must travel along D-Street on its return trip from Logan Airport, additional delay on Congress Street resulting from TSP could even **increase the running time for the Silver Line return trip**. Alternate TSP strategies can be implemented to mitigate impacts to cross-traffic; however, these will result in less wait time savings for the Silver Line at D Street and less overall benefit. Therefore, transit signal priority is **not recommended** as a long-term solution at D Street and the Transitway.
- There are opportunities to optimize the signal timing at D Street and Congress Street to better balance queues and reduce overall network delays
- In the future case without transit signal priority, the presence of the Silver Line under regular signal timings will result in increased delay to cross-traffic, and continued delays for transit users. This suggests the need for alternatives to the existing at-grade crossing of the Transitway at D Street; see **Chapter 7** for further analysis.

6.3 Elimination of Silver Line Way Stop for SL1

The Silver Line Way stop is located east of D Street, past where the Silver Line buses emerge from the transitway tunnel.

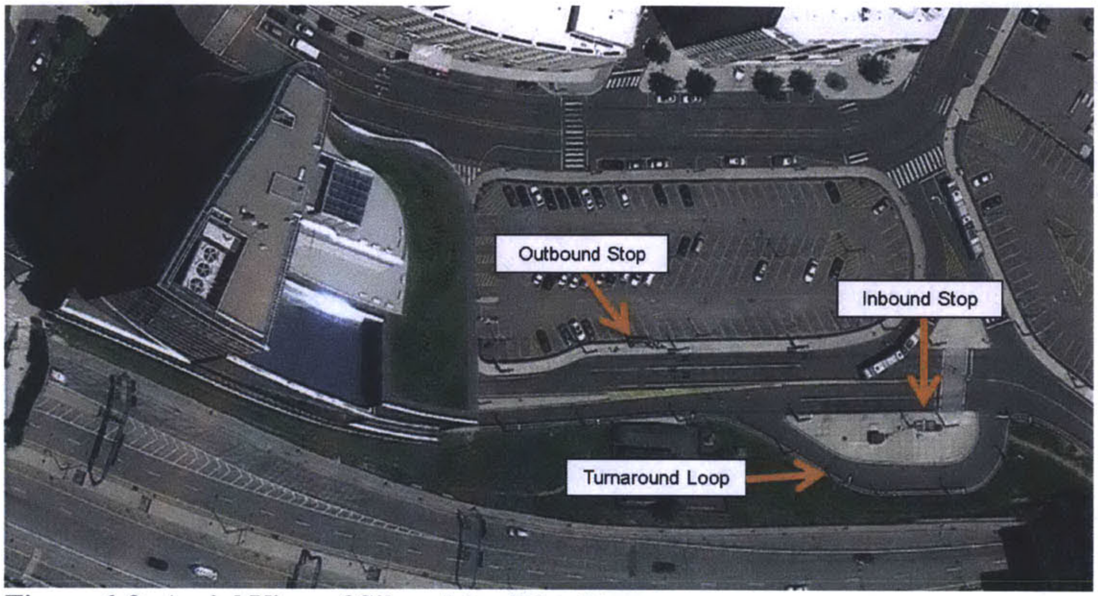


Figure 6-9: Aerial View of Silver Line Way Stop

The inbound and outbound stops are located on opposite sides of the street. Silver Line Way stop is served by three branches of the Silver Line:

- Silver Line 1 from South Station to Logan Airport
- Silver Line 2 from South Station to Design Center
- Silver Line shuttle, from South Station to Silver Line Way; the shuttle runs during the AM and PM peaks to serve heightened demand between South Station and Silver Line Way

This section investigates whether travel time savings can be achieved by eliminating Silver Line Way stop for the Silver Line 1 to Logan Airport. Travelers on the SL1 who do not board or alight at Silver Line Way would benefit from decreased running time. The estimated travel time savings for SL1 passengers is shown in **Table 6-9**.

Table 6-9: Estimated Travel Time Savings

	Average Number of Daily Passengers	Reduction in Dwell Time at Silver Line Way (seconds)	Total Travel Time Decrease, passenger-minutes per day
South Station to Logan Airport	2297	84	3,215
Logan Airport to South Station	2779	91	4,215

The travel time savings are estimated by multiplying the average daily number of passengers in each direction by the average amount of dwell time spent at Silver Line Way stop. The ridership numbers are based on 2012 point checks and the dwell times were determined from MBTA

Silver Line AVL data. It is important to note that the dwell time at Silver Line Way also includes time required for the technology transition (see **Section 6.4**).

Although through trips experience a reduction in travel time, there are four types of trips for which travel times would increase. They are outlined in **Table 6-10.**

Table 6-10: Types of SL1 Boardings and Alightings at Silver Line Way

Trip Origin	Trip Destination	New Travel Path	Approximate Number of Average Daily Trips*
Silver Line Way	World Trade Center, Courthouse or South Station	Use the SL2 or SL shuttle to make the trip. Average wait time will increase because the SL1 no longer stops at Silver Line Way	204
South Station	Silver Line Way	Use the SL2 or SL shuttle to make the trip. Average wait time at South Station will increase because the SL1 no longer stops at Silver Line Way	168
Logan Airport terminals	Silver Line Way	Alight at World Trade Center and walk to destination. Walk time will increase	52
Silver Line Way	Logan Airport terminals	Board at World Trade Center. Walk time will increase	100

*Boarding and alighting numbers for SL1 from Logan Airport to South Station based on team data collection on January 31st, 2013; boarding and alighting numbers for SL1 from South Station to Logan Airport based on MBTA 2010 Blue Book

The expected increase in walk time was determined by assuming transit users will have to walk the distance from Silver Line Way stop to World Trade Center, a distance of approximately 460 meters. Although several users likely originate from buildings between the two stops, this longer distance has been used as a conservative assumption. Walk speed was taken as 1.4 m/s. The expected increase in walk time is shown in **Table 6-11.**

Table 6-11: Expected Increase in Walk Time

	Daily Number of Passengers	Increased Walk Distance	Increased Walk Time per Passenger (minutes)	Total Increased Walk Time (passenger-minutes)
Silver Line Way to Logan Airport	100	460	5.48	548
Logan Airport to Silver Line Way	52	460	5.48	283

The expected increase in wait time was determined by assessing the change in expected wait time. Using field data collected on Friday, January 11th, 2013, the expected wait time for any bus – either SL1, SL2 or the shuttle – was calculated for the PM peak period when the shuttle runs and the mid-day period when the shuttle does not run. Then, the expected wait time for only SL2 buses and shuttle buses was determined using the same set of data. If the SL1 does not serve Silver Line Way, transit users who presently use SL1 to travel between South Station and Silver Line Way will now need to wait for either an SL2 bus or a shuttle. The estimated change in wait time is shown in **Table 6-12.**

Based on the field data collected on January 31st, 2013, half of the passenger trips have been allocated to the peak periods, and half of the trips have been assigned to the mid-day period. During the peak periods, the wait time changes slightly because the combination of the shuttles and SL2 buses still provide frequent service. Wait times increase more significantly during the mid-day period when the shuttle does not run. A comparison of the total change in travel time is provided in **Table 6-13**.

Table 6-12: Change in Expected Wait Time

	Time Period	Number of Passengers	Average Headway - All Buses	Average Wait Time - All Buses	Average Headway – SL2 and Shuttle	Average Wait Time – SL2 and Shuttle	Change in Average Wait Time per User	Total Change in Wait Time
South Station to Logan Airport	Peak Period - with Shuttle	84	0:02:51	0:02:08	0:03:40	0:02:52	0:00:44	1:01:57
	Mid-day Period	84	0:04:47	0:02:58	0:09:33	0:05:06	0:02:09	3:00:07
							Total	**4:02:04**
Logan Airport to South Station	Peak Period - with Shuttle	102	0:02:11	0:02:09	0:02:58	0:02:29	0:00:20	0:33:13
	Mid-day Period	102	0:04:53	0:02:59	0:10:00	0:05:13	0:02:13	3:46:16
							Total	**4:19:29**

Table 6-13: Overall Travel Time Impact of Removing Silver Line Way Stop from SL1

Travel Time Decrease				
	Number of Daily Passengers	**Reduction in Dwell Time at Silver Line Way (seconds)**	**Total Travel Time Decrease (passenger-minutes)**	
South Station to Logan Airport	2297	84	3215	
Logan Airport to South Station	2779	91	4215	
Travel Time Increase				**Ratio**
	Increase in Access Time (passenger-minutes)	**Increase in Wait Time (passenger-minutes)**	**Total Travel Time Increase (passenger-minutes)**	
South Station to Logan Airport	548	242	790	4.07
Logan Airport to South Station	283	259	542	7.77

Recommendation: Removing Silver Line Way stop from the SL1 route results in net travel time savings for both the inbound and the outbound direction. However, part of the dwell time at Silver Line Way is required for the vehicle technology transition, so if buses continue stopping at Silver Line Way for the technology transition they should continue allowing passengers to board and alight. Passengers will feel frustrated if the bus stops without allowing boarding or alighting. The removal of Silver Line Way stop should thus be considered in conjunction with elimination of the technology transition, which is discussed in **Section 6.4**.

6.4 Elimination of the Technology Transition

Presently, the buses must transition from electrical overhead power within the transitway to diesel power on surface streets. Drivers must pull over and stop to allow the bus to attach (detach) from the catenary overhead wires, depending on the direction (see **Photo 6-5** and **Photo 6-6**). Drivers also exit the bus and check the wiring at the back. On the trip from South Station to Logan Airport, drivers have been observed to stop for the transition either below the Manulife building or at Silver Line Way stop; however, even when they stop under the Manulife building, they exit the bus at Silver Line Way stop to check the wiring. On the trip from Logan Airport to South Station, the drivers stop at the Silver Line Way stop.

Photo 6-5: Driver Checking Bus following Technology Transition

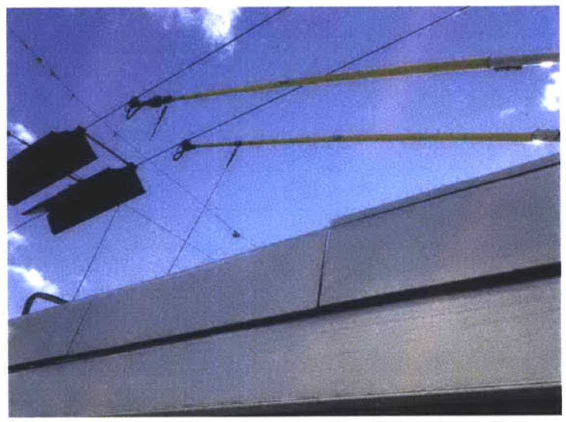


Photo 6-6: Attaching to the Overhead Catenary

The technology transition increases the running time for the trip from South Station to Logan Airport. Field data was collected during the mid-day and PM Peak periods on Friday, January 11th to assess the amount of time spent for the technology transition, as shown in **Table 6-14**. These data are the measurements of the time required for the bus to stop beneath the Manulife Building. The time required for the driver to check the wiring at the back at Silver Line Way stop is incorporated into the total dwell times at Silver Line Way, discussed in **Section 6.3**.

Table 6-14: Stop Time for Technology Transition – South Station to Logan Airport

Time Period	Time	Bus ID	Duration of Technology Transition
Mid-day	2:09 PM	1128	0:23
	2:19 PM	1129	0**
	2:29 PM	1127	0:19
	2:40 PM	1121	0:24
	2:46 PM	1125	0:18
	2:58 PM	1128	0:16
		Average	**0:16**
PM Peak	4:30 PM	1125	0:18
	4:37 PM	1128	0:39
	4:47 PM	1129	0:10
	4:58 PM	1124	0:16
	5:17 PM	1127	1:39
		Average	**0:36**
Average of All Measurements			**0:25**

In this case, the technology transition took place at Silver Line Way stop; dwells at Silver Line Way are addressed in **Section 6.3.

These data show that the technology transition results in average stop time of 25 seconds. Some other disadvantages associated with the technology transition are:

- The bus must decelerate to a stop, and then accelerate from a stop; this increases travel time and decreases the smoothness of the ride for passengers
- Users perceive stop time in a vehicle more negatively than travel time. Users expect buses to stop at signalized intersections when travelling on surface streets; however, stopping for the technology transition is not common for transit
- The lights in the bus turn off for a moment during the technology transition, which may give riders the impression that the bus has broken down. As the SL1 route carries a number of unfamiliar riders to and from Logan Airport, this may be confusing or stressful for riders concerned about arriving at the airport on time. An announcement plays on the bus to reassure users that the stop is part of normal operations.
- The technology transition introduces the potential for malfunction and delay into the service
- The requirement for the technology transition constrains route flexibility (for example, buses are unable to turn right at D Street to bypass the signalized intersection)

Recommendation: Eliminating the technology transition requires the procurement of a new vehicle technology. Considering that the original manufacturer of the buses is no longer in business and there are opportunities to implement a new vehicle technology such as a battery-electric bus to replace the existing Silver Line buses at the end of their service life (see **Section 5.8**), the introduction of a technology that can more efficiently transition from the transitway to the surface streets would be advantageous from the perspective of both travel time and user perception of the service.

Until a new vehicle technology is available, drivers should be instructed to stop only once at Silver Line Way (instead of once under the John Hancock Building and then again at Silver Line Way) to reduce the total number of stops for passengers.

6.5 Use of South Boston Emergency Access Ramp

The use of the South Boston Emergency Access Ramp would result in a reduction in trip distance and travel time for the SL1 trip by providing more direct access to I-90 and the Ted Williams Tunnel. The existing route and proposed route using the ramp are shown in **Figure 6-10**.

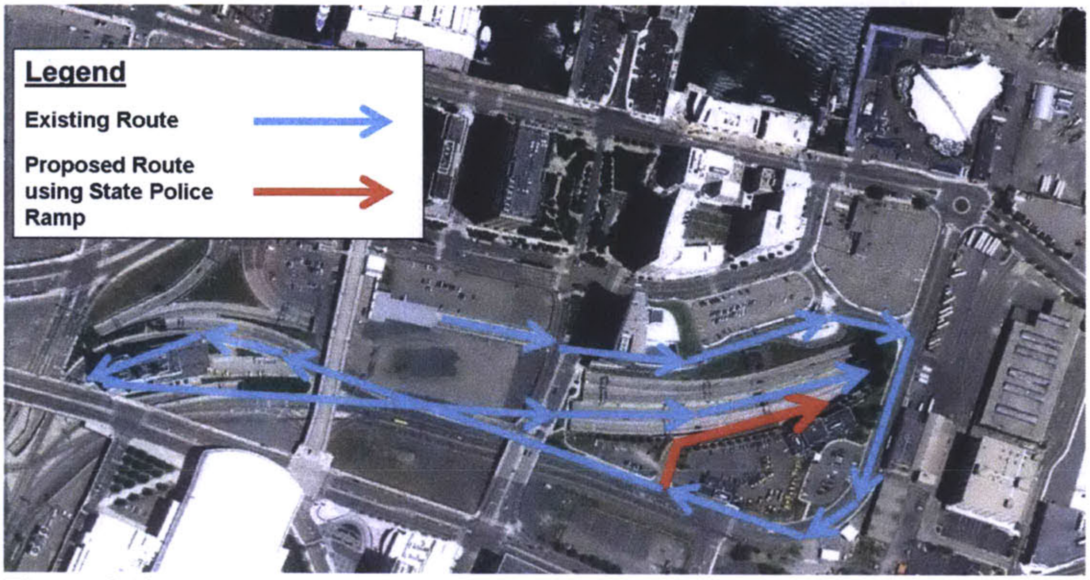


Figure 6-10: Proposed Route using South Boston Emergency Access Ramp

This ramp is presently used by the State Police, but is directly accessible from Haul Road by using the driveway to the police station, as shown in **Figure 6-11**, **Photo 6-7**, **Photo 6-8** and **Photo 6-9**.

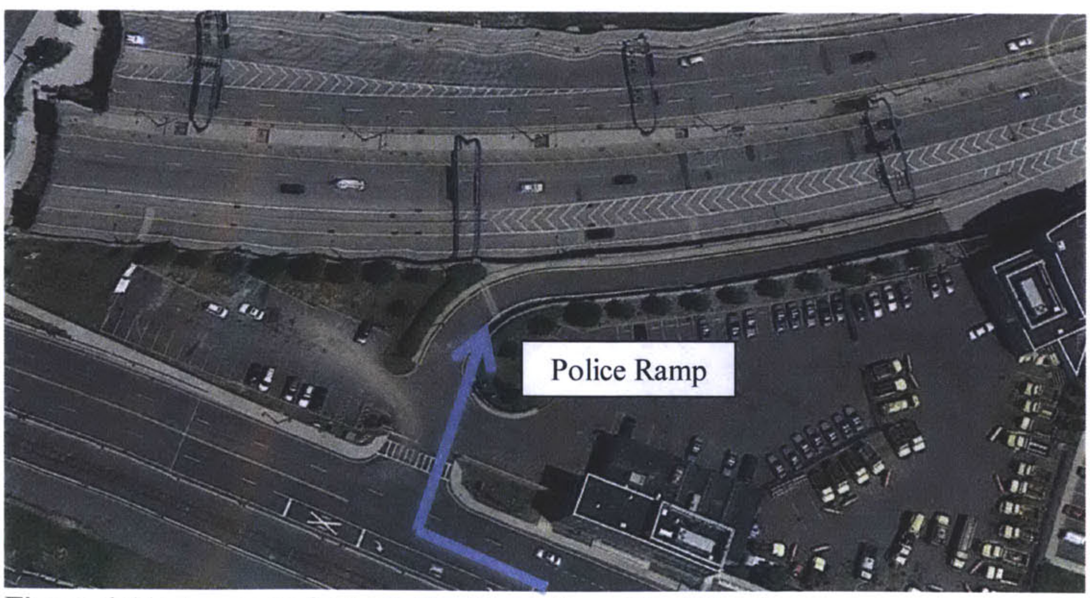


Figure 6-11: Access to State Police Ramp from Haul Road

Photo 6-7: Ramp viewed from Silver Line Way stop

Photo 6-8: Ramp viewed from Haul Road

Photo 6-9: Ramp connection to Haul Road

The original Silver Line Environmental Impact Statement (EIS) from 1996 called for use of the ramp. Further, Vanasse & Associates completed a study for Massport in 2010 about use of the ramp by the Silver Line. The study included an assessment of the technical feasibility of using the ramp and reported the following key findings[63]:

- The ramp is accessible from Haul Road with minimal impact to the operations of the existing intersection
- The ramp geometry meets design standards for low speed vehicle travel; speed at the top of the ramp should be limited to <15 mph as a result of the alignment and sight restrictions
- Adequate distance exists for acceleration and merging into the traffic stream at the HOV lane and I-90 eastbound

[63] Vanasse and Associates, Inc., Technical Memorandum: Silver Line Access Study, November 2010, p. 1

Use of the ramp would reduce the trip distance by 0.65 miles, reducing fuel costs for the MBTA. The project team conducted a field visit on Friday, January 11, 2013 to assess the travel time savings. The time saving was calculated as the difference in time between when the bus passed the following two points:

- Time when the bus passed the top of the police ramp on Haul Road
- Time when the bus passed the top of the police ramp on I-90

The results are shown in **Table 6-15**.

Table 6-15: Travel Time Savings by using South Boston Emergency Access Ramp

Time Period	Time	Bus ID	Time Savings
Mid-day	2:09 PM	1128	1:25
	2:19 PM	1129	1:48
	2:29 PM	1127	1:33
	2:40 PM	1121	1:45
	2:46 PM	1125	1:42
	2:58 PM	1128	1:32
		Average	**1:37**
PM Peak	4:30 PM	1125	1:27
	4:37 PM	1128	1:50
	4:47 PM	1129	1:48
	4:58 PM	1124	1:28
	5:17 PM	1127	2:48
		Average	**1:52**

The field tests indicated an average travel time savings of 1:37 during the mid-day period and 1:52 during the PM Peak period. These findings are corroborated by field measurements that were undertaken by Massport on Wednesday, August 19th, 2009 between 3:00 and 7:00 PM, which estimate the travel time savings of using the emergency access ramp to be approximately 2 minutes[64]. Using the ramp also allows the Silver Line to bypass the signals at the Haul Road / I-90 onramp and congestion on I-90. As these elements of the trip contribute to the variability in the running time, bypassing them is expected to improve service reliability.

The memo by Vanasse and Associates estimates the cost of retro-fitting the ramp for usage by the Silver Line to be $156,000, although this estimate is from 2010 and would need to be reviewed and updated. The bulk of the cost is for a vehicle detection system that would use an actuated signal / signing system to detect and alert ramp users of the following two situations[65]:

- Presence of SL1 bus on the ramp traveling from Haul Road toward the I-90 / Ted Williams Tunnel
- Contra-flow use of the ramp by Massachusetts State Police or other emergency vehicles

[64] Vanasse and Associates, Inc., Technical Memorandum: Silver Line Access Study, November 2010, p. 24
[65] Vanasse and Associates, Inc., Technical Memorandum: Silver Line Access Study, November 2010, p. 11

Some additional modifications to the police ramp may be required to ensure that there is sufficient sight distance for drivers. Additionally, some reconfiguration of the lanes on the I-90 may be required to provide safe merging distance for the buses.

Recommendation: This option results in substantial travel time savings for a relatively low cost. Although this ramp is used by the police, a vehicle detection system could be implemented to alert Silver Line buses when the ramp is in use by emergency vehicles. The Silver Line could revert to its existing route when the ramp is unavailable. As the main concerns about using the ramp can be mitigated, this alternative is **recommended for further consideration**.

6.6 Increased SL1 Frequency

This section explores opportunities to increase the frequency of the SL1 in order to reduce passenger wait times and thus total transit travel times to Logan Airport. This section is structured as follows:

- **Sections 6.6.1** and **6.6.2** assess the existing demand and desired functionality of the SL1, and recommend the **necessary headways** with both 60 foot and 40 foot buses (although the use of 40-foot buses for the Silver Line has not been recommended by this study).
- **Sections 6.6.3** and **6.6.4** review the existing cycle time and operational practices at South Station, and recommend a proposed **cycle time** by time of day
- **Section 6.6.5** assesses the headways and cycle times to recommended the required **fleet size**

6.6.1 Existing Conditions

Existing posted headways for the SL1 to Logan Airport are shown in **Table 6-16**. Headways are generally 10-12 minutes, with increased service on Sunday afternoons between noon and midnight.

Table 6-16: SL1 Headways

Weekday	5:50 AM to 6:50 AM	15 minutes
	6:50 AM to 8:00 PM	10 minutes
	8:00 PM to 12:30 AM	12 minutes
Saturday	6:00 AM to 12:30 AM	12 minutes
Sunday	6:12 AM to Noon	12 minutes
	Noon to Midnight	8 minutes
	Midnight to 12:30 AM	10 minutes

The Silver Line is classified as Bus Rapid Transit, and is a part of the MBTA's "rapid transit" system. For the purpose of benchmarking, headways for other North American rapid transit services are summarized in **Table 6-17**.

Table 6-17: Weekday Headways for North American Rapid Transit Services

Transit Agency	Rapid Transit Line	Type of Service	Peak Period Headway	Mid-Day Headway
Heavy Rail				
MBTA – Boston	Orange Line	Heavy Rail	5 minutes	8 minutes
	Blue Line	Heavy Rail	5 minutes	9 minutes
CTA - Chicago	Red Line	Heavy Rail	3-6 minutes	7-8 minutes
TTC – Toronto	Yonge-University-Spadina Line	Heavy Rail	2-3 minutes	4-5 minutes
	Bloor-Danforth Line	Heavy Rail	2-3 minutes	4-5 minutes
Bus Rapid Transit				
MBTA – Boston	Silver Line – SL1	Bus Rapid Transit	10 minutes	10 minutes
	Silver Line – SL2	Bus Rapid Transit	5 minutes	10 minutes
	Silver Line – waterfront shuttle	Bus Rapid Transit	5 minutes	Does not run – peak period service only
	Cumulative SL Transitway Headways	**Bus Rapid Transit**	**2 minutes**	**5 minutes**
TTC - Toronto	York University Busway	Bus in dedicated corridor	2 minutes	2 minutes
OC Transpo – Ottawa	Transitway	Bus Rapid Transit	1-2 minutes on central portions of the Transitway (served by different routes)	Varies
Translink – Vancouver	B-Line	Bus Rapid Transit	2 minutes in AM Peak direction to UBC	4.5 minute base
Metro – Los Angeles	Metro Orange Line Transitway	Bus Rapid Transit	4-5 minutes	10 minutes

This comparison yields two significant findings with respect to the Silver Line:

- Based on the schedule, SL buses run every 2 minutes through the South Boston Transitway during the peak period. This implies a high level of service, comparable to that of other North American BRTs, for the trunk portion between South Station and Silver Line Way.
- A 10 minute peak period headway for SL1 is longer than the headways for other peak period rapid transit services (both bus and heavy rail).

Field data has been collected to measure SL1 headways and total bus service levels at the South Boston Transitway. Silver Line bus arrival times were measured at Silver Line Way (outbound from Logan Airport to South Station) and D Street in January 2013. The resulting SL1 headway statistics are shown in **Table 6-18**.

Table 6-18: SL1 Headways at Silver Line Way and at D Street

Location	Silver Line Way	D Street			
Direction	Outbound (Logan-SS)	Inbound (SS-Logan)	Outbound (Logan-SS)	Inbound (SS-Logan)	Outbound (Logan-SS)
Date	January 31, 2013	January 11, 2013			
Time Period	7:00 AM to 8:00 PM	Midday: 12:30 – 2:00 PM		PM Peak: 3:30 – 5:00 PM	
Number of Observations	77	8	8	6	7
Average Headway	0:10:09	10:00	09:37	12:00	10:43
Standard Deviation	0:04:25	01:04	04:00	05:01	02:34
Expected Wait Time	0:06:02	05:03	05:39	07:03	05:40

For the full-day count which has the greatest number of observations, the average headway is close to the scheduled headway of 10 minutes, although the standard deviation is 4:25. Based on this data, the expected wait time for SL1 passengers is 6:08. The smaller samples during the Midday and PM Peak also indicate some variability in travel times. The variability in headways results in the average passenger waiting for 5 to 7 minutes, with an expected wait time of 6 minutes based on the full-day data set.

These data sets were also used to estimate the total number of buses running in the South Boston Transitway (on all routes) during the AM and PM Peak period when the SL1, SL2 and Short-Turn shuttle are running. The results, shown in **Table 6-19**, indicate that the measured number of buses per hour approaches the scheduled number of peak period buses of 30.

Table 6-19: Number of Silver Line Peak Period Buses at Silver Line Way and D Street

Measurement Location	Silver Line Way		D Street	
Direction	Outbound (Logan to SS)		Inbound (SS-Logan)	Outbound (Logan-SS)
Date	January 31, 2013		January 11, 2013	
Time Period	7:15 AM to 9:15 AM	4:15 to 5:45 PM	4:00-5:00 PM	4:00-5:00 PM
Total Number of Buses	54	36	23	30
Measured Number of Buses per Hour	27	24	23	30
Scheduled Number of Buses per Hour	30	30	30	30

Section 6.2 addresses operational impacts of increasing the number of peak period buses at D Street.

In addition to service levels and Transitway capacity, ridership demand is another key determinant of the required service level. Ridership counts conducted by the Central Transportation Planning Staff (CTPS) in November 2012 were used in addition to a count by the project team in January 2013. Inbound volumes to Logan Airport by time of day are shown in **Figure 6-12** and outbound volumes from Logan Airport by time of day are shown in **Figure 6-13**.

Some trends with respect to inbound Silver Line volumes from South Station to Logan Airport are visible:

- Highest volumes generally on Friday, followed by Sunday and then Tuesday
- Friday and Sunday PM Peak between 3:00 PM and 6:00 PM; relatively consistent demand on Tuesdays from 6:00 AM to 6:00 PM
- Uniformly lower volumes after 8:00 PM compared to the remainder of the day

Some trends with respect to outbound Silver Line volumes from Logan Airport to South Station are visible:

- Demand relatively consistent throughout the day
- Ridership after 8:00 PM are greater for the outbound direction than for the inbound direction
- Greatest ridership on Friday

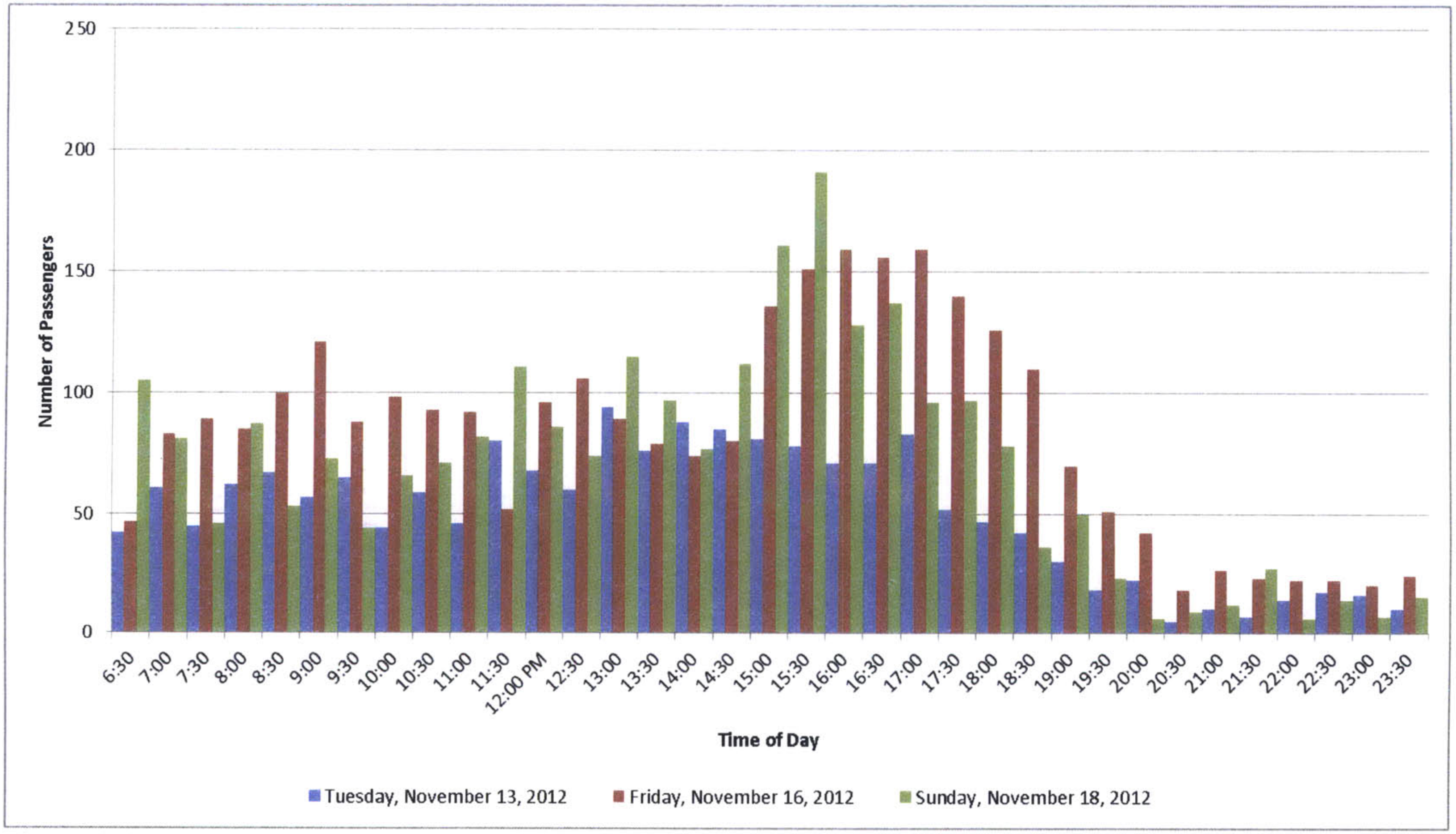
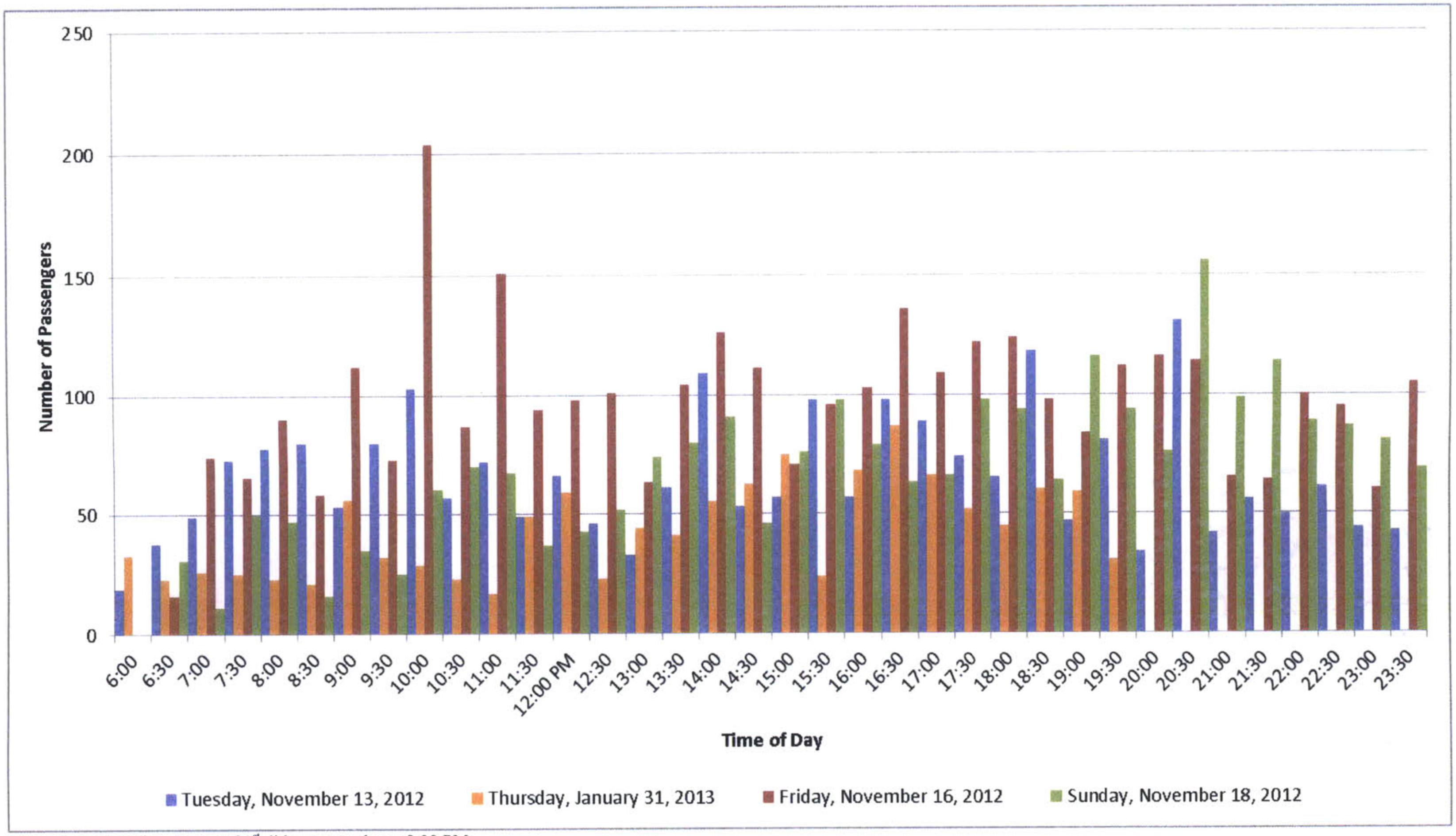


Figure 6-12: Inbound Silver Line Volumes from South Station to Logan Airport, by Half Hour



*Counts on Thursday, January 31[st] did not extend past 8:00 PM

Figure 6-13: Outbound Silver Line Volumes from Logan Airport to South Station

This time of day data is supplemented by data presenting Silver Line ridership by day of week, shown in **Table 6-20**. These counts are based on SL1 fare payment taps, and include boardings at Logan Airport and Silver Line Way. They are based on the average boardings from May to December 2011. These data show that boardings are relatively consistent throughout the week; the variation between days is not significant enough to warrant different timetables and headways for different days of the week.

Table 6-20: Silver Line Logan Airport Boardings by Day of the Week

Day	Average Ridership
Sunday	2,521
Monday	2,966
Tuesday	2,658
Wednesday	2,501
Thursday	2,599
Friday	2,793
Saturday	2,038

The Friday and Sunday daily profiles were used to determine the headways required for the service. The following equation, adapted from Vuchic[66], was used to calculate the required headways based on the maximum demand:

$$h = \frac{60 \alpha n C_v}{P_d}$$

The variables and assumptions used for this analysis are defined in **Table 6-21**, and the results are presented in **Table 6-22**.

[66] Vuchic, "Urban Transit Operations, Planning and Economics", 2005, page 51

Table 6-21: SL1 Headway Calculation Parameters

Variable	Explanation	Assumptions
h	Headway – number of minutes between buses; inverse of frequency	The headway is the output of this calculation
n	Number of vehicles per transit unit	The SL bus is the complete transit unit: therefore, n=1 for all cases
C_v	Capacity of the vehicle	For this analysis, the seating capacity of the SL buses (38) was used as C_n
α	Load factor on Maximum Load Section; ratio of number of people to number of seats on the transit vehicle; can be adjusted to reflect the desired level of crowding	For 60-foot buses: Set to **1.25** and multiplied by the number of seats on the SL1 (**38**). The resulting total of **47.5** is less than the MBTA planning capacity of 65, but is intended to reflect additional crowding on the SL1 as a result of passengers travelling with luggage. Although luggage racks are provided, luggage still generally occupies seats and aisle space, reducing the space available for passengers For 40-foot buses: Set to **0.9** and multiplied by the number of seats on a standard 40 foot bus (**39**), resulting in **35**. Some seats would need to be removed to make space for luggage racks so some riders would be required to stand.
P_d	Design volume, in people per hours. Vuchic defines this parameter as 4 times the peak 15 minute transit ridership volume	For this analysis, the full-day Friday and Sunday counts were divided into 15 minute increments. The design volume was taken as 4 times the 95th percentile 15 minute volume. This was done to avoid providing excessive capacity throughout the day.

Table 6-22: Required Headways based upon Demand

		Friday - Inbound to Logan	**Friday - Outbound from Logan**	**Sunday - Inbound to Logan**	**Sunday - Outbound from Logan**
Existing Conditions - 60 ft Buses	Design Demand (Pd)	350	356	326	276
	Planned Capacity	47.5	47.5	47.5	47.5
	Headway	8.1	8.0	8.7	10.3
	Frequency	7.4	7.5	6.9	5.8
Existing Conditions - 40 ft Buses	Max Demand	350	356	326	276
	Planned Capacity	35.1	35.1	35.1	35.1
	Headway	6.0	5.9	6.5	7.6
	Frequency	10.0	10.1	9.3	7.9

60 Foot Buses

The headway analysis shows that headways of 8 minutes are required to achieve the desired comfort levels on the SL1 on both Fridays and Sundays using 60 foot buses. While the SL1 runs at 8 minute headways on Sunday afternoons, the scheduled headway on weekdays is 10 minutes. It is recommended that weekday headways be decreased from 10 minutes to 8 minutes to reduce both crowding and passenger wait time. Silver Line crowding has been observed at both Logan Airport and South Station:

- Passengers were unable to board an SL1 bus departing Terminal E at 10:00 PM on President's Day, Monday February 18th 2013, because it was at crush capacity

- Passengers were unable to board SL1 buses departing South Station during the PM Peak period on Friday, March 1, 2013 because they were at crush capacity

Crush loading to the point where passengers are unable to board the bus is undesirable for several reasons:

- Dwell times increase significantly as passengers try to squeeze into the bus; this increases travel time for all passengers
- Crowding significantly decrease the comfort level on the bus. Luggage further complicates boarding and alighting, and decreases comfort
- Passengers unable to board the bus and left on the curb or platform feel frustrated and may perceive that the transit system is operating poorly

<u>40 Foot Buses</u>
Using 40 foot buses, headways of 6 minutes – corresponding to a frequency of 10 buses per hour – would be required during the peak period on weekdays and weekends. Dwell time may increase as there are now two sets of doors instead of three sets of door.

In conclusion, the expected wait time for the SL1 to Logan Airport exceeds 6 minutes and there are instances of overcrowding during the peak periods. An immediate shift to 8 minute headways would decrease both passenger wait time and crowding; if 40 foot buses were to be used, a headway of 6 minutes would be required during the peak.

6.6.2 Increased Frequency to Attract New Ridership

Section 6.6.1 recommended decreasing the weekday headway from 10 minutes to 8 minutes at existing demand levels. This section recommends allocating additional resources to the SL1 to further decrease headways to **5 minutes** in order to improve the passenger experience and attract new riders. These improved headways will enable the SL1 to serve an increased proportion of existing trips to and from Logan Airport and also serve the projected future growth in demand for travel to and from the airport. This recommendation is independent of whether the buses are 60 feet or 40 feet long: the primary factor driving this recommendation is the desired level of service and passenger wait time.

Running the SL1 at 5 minute headways would result in a significant reduction in total transit travel time for trips to and from Logan Airport. A headway of 5 minutes, with a target standard deviation of 1 minute, would result in an expected wait time of 2:36. This would result in a time saving of **3:26** compared to the existing expected wait time of 6:01.

Wait time has a significant impact on a passenger's perception of transit service. Ameen and Kamga[67] have summarized the modal utility coefficient estimates from various airport ground access models in "Forecast of Airport Ground Access Mode Choice Using the Incremental Logit Model: A Case Study of the AirTrain at JFK International Airport (building upon work contained in ACRP Synthesis 5 "Airport Ground Access Mode Choice Models"). The models for Atlanta International Airport, Miami International Airport and Oakland International Airport all model user perception of wait time. The coefficient for wait time is larger than the coefficient for in-

[67] Ameen, N. and Kamga, C., "Forecast Of Airport Ground Access Mode Choice Using The Incremental Logit Model: A Case Study Of The Airtrain At JFK International Airport", 2013

vehicle time for each model, at ratios ranging from 1.08 to 2.5 depending on the airport and the market segment (i.e. resident-business, resident non-business, etc.). Further, the coefficients used in the Atlanta and Oakland models indicate that business travelers are more sensitive to wait time than are non-business travelers. This suggests that a decrease in the wait time of 3:26 will improve user perception of the service more than will an equivalent decrease in the in-vehicle travel time. These results also suggest that reducing the wait time could be an effective technique to capture more business travellers.

This valuable service improvement comes at the cost of running additional buses. The following implementation strategy is recommended:

- **Massport investment in HOV**: As part of its strategy to increase the HOV mode share to the airport and address a looming parking shortage, Massport can fund additional SL1 buses as a strategy to improve the quality of the service and attract more riders
- **Pilot Project with Staged Implementation**: The project could be introduced as a pilot project for a trial period. If ridership does not increase or if there are operational challenges, the program can be discontinued at the end of the trial period. Implementation should also be staged, with 5 minute headways initially being introduced during the SL1's peak day peak periods (i.e. afternoons on Sundays, Mondays and Fridays). The program can then be expanded to additional days and time periods in a staged approach
- **Marketing:** An aggressive and multi-faceted marketing campaign should accompany service improvements so that as many passengers as possible can take advantage of the improved service quality. Most air passengers travel to the airport infrequently; thus, if a passenger uses the SL1 and has a positive experience, it may be months before he or she uses the service again, regardless of his or her level of satisfaction with the service. Massport and the MBTA should publicize service improvements so that trip-makers are aware of the reduced wait time when planning their trip to the airport. Massport can supplement its existing radio advertisements about the Silver Line with a promotional campaign such as "Five-Minute Fridays and Mondays on the Silver Line, with a bus every 5 minutes during the afternoon".
- **Monitoring and Adjustment:** Several factors suggest that demand for the Silver Line will increase in the coming years. SL1 boardings at Logan Airport grew by 40% between 2006 and 2011 while overall passenger volumes at the airport increased by only 4%, implying that the Silver Line has been attracting passengers from other modes. Further, the recent shift to free boardings has also resulted in increased ridership (see **Section 6.7** for additional details) in response to the lower cost. Finally, future growth in airport travel, Massport's targeted increase of the HOV mode share and growth in the South Boston waterfront will also result in heightened demand for the SL1. Demand should be monitored carefully, and additional buses should be provided on the route to further reduce headways and increase capacity as warranted.
- **Use Government Center Closure as a Catalyst for Improved Headways**: The proposed closure of Government Center (see **Section 4.2**) is expected to result in an additional number of SL1 trips to and from Logan Airport, and consequently, the need for shorter SL1 headways. Massport and the MBTA should work together to provide better SL1 service during the Government Center closure and to market this improved service aggressively. Rider awareness of improved SL1 service during the Government

Center closure may attract new riders, and once Government Center re-opens sufficient demand may have materialized to justify maintaining shorter headways on the SL1.

6.6.3 SL1 Scheduling and Timetable Adjustments

This section reviews the cycle time required for SL1 buses. The existing MBTA timetable for the SL1 includes 10 to 20 minutes of recovery time at South Station, and opportunities to shorten this recovery time to reduce passenger wait time are also explored. AVL data was reviewed in terms of the full cycle time (including dwell and turnaround at South Station), the running time (not including South Station time) and the dwell and turnaround time at South Station. The results are shown in **Table 6-23**.

Table 6-23: SL1 Cycle Times based upon AVL Data

	Full Cycle	Running Time	South Station Dwell
Minimum	27:27	22:36	1:49
5th Percentile	39:31	32:47	4:19
10th Percentile	42:21	33:45	5:08
Mean	49:10	38:36	11:08
Median	49:03	38:03	11:03
90th Percentile	56:23	44:24	16:33
95th Percentile	59:29	46:07	18:53
Maximum	1:07:39	59:37	30:52
Standard Deviation	5:48	4:11	4:35
Count	1180	1180	1120

Initially, the cycle times, running times and South Station dwell time were all assessed for the full day. Distributions of the trip times have been plotted as histograms in **Figure 6-14** to **Figure 6-16**.

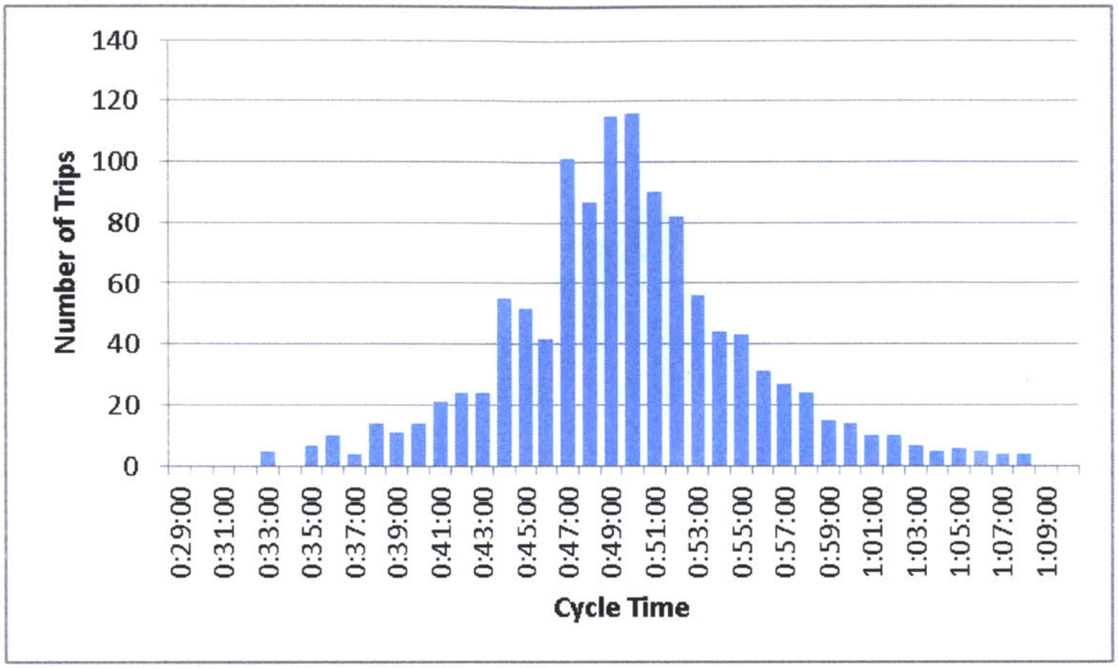


Figure 6-14: Distribution of SL1 Cycle Times

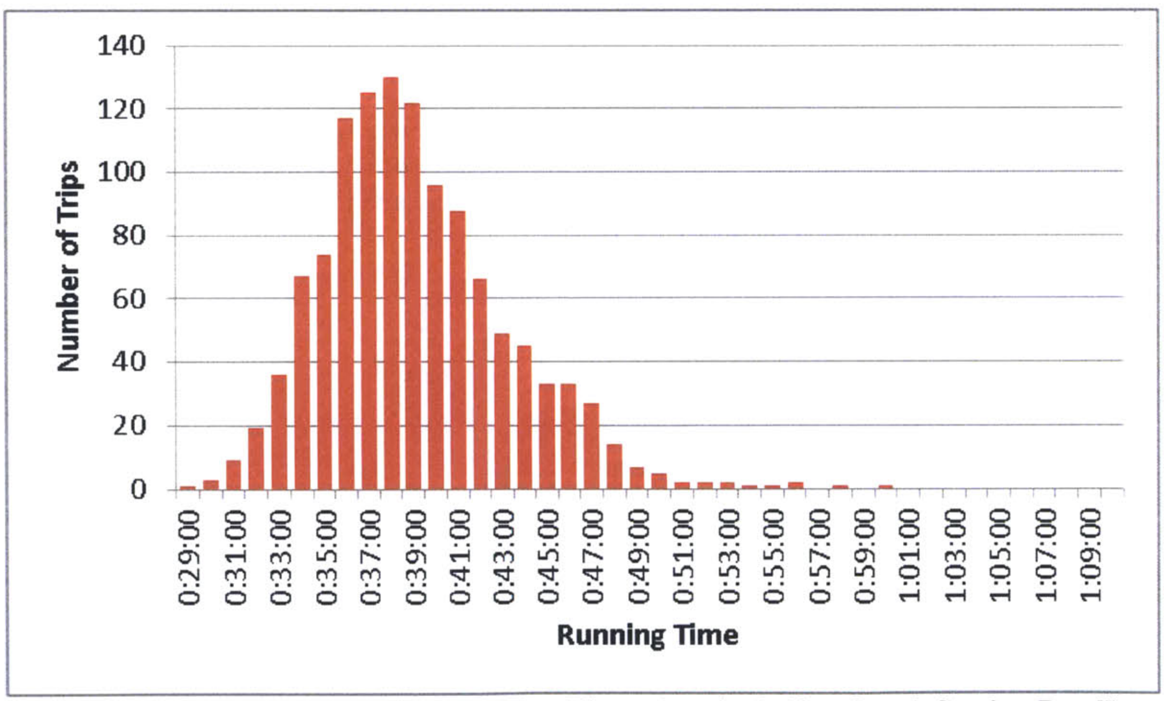


Figure 6-15: Distribution of SL1 Running Times (not including South Station Dwell)

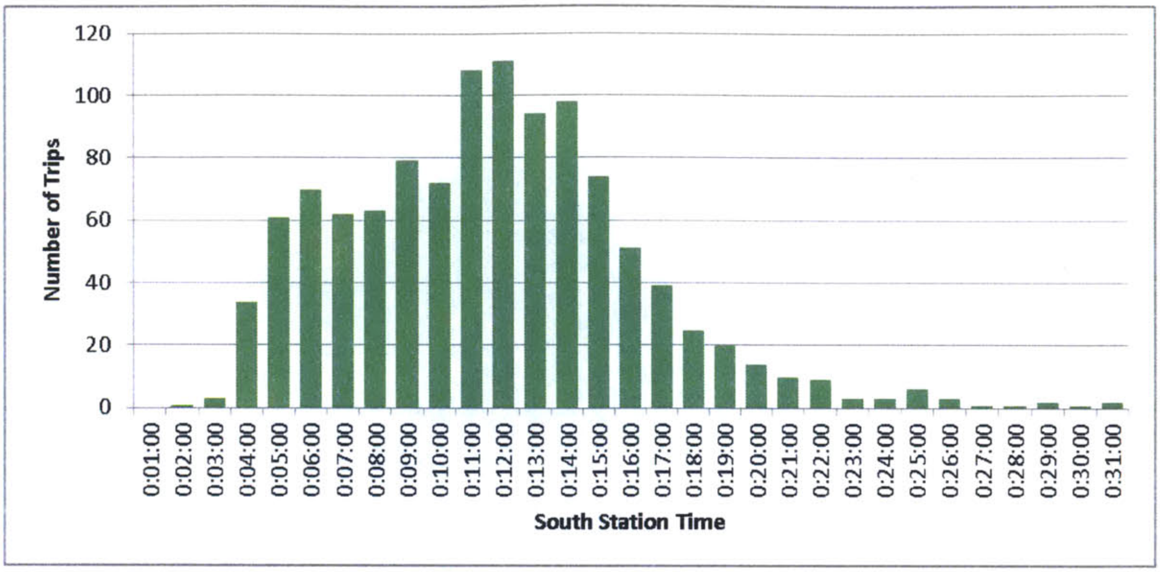


Figure 6-16: Distribution of South Station Time (Dwell and Turnaround)

The distribution of cycle times is shifted to the right of the distribution of running times, as the cycle times are simply the sum of the South Station time and the running time. The plots of running times and cycle times both approximate normal distributions, while the distribution of South Station time has uneven tails. This is the result of the fixed minimum South Station dwell required for unloading, turning around and loading.

The running times were plotted by time of day to review how running times vary by time period in **Figure 6-17**. Although it is difficult to discern a clear pattern from this plot, there is a mild parabolic shape implying longer running times during the midday and PM Peak. A small cluster of longer travel times occur during the PM Peak period.

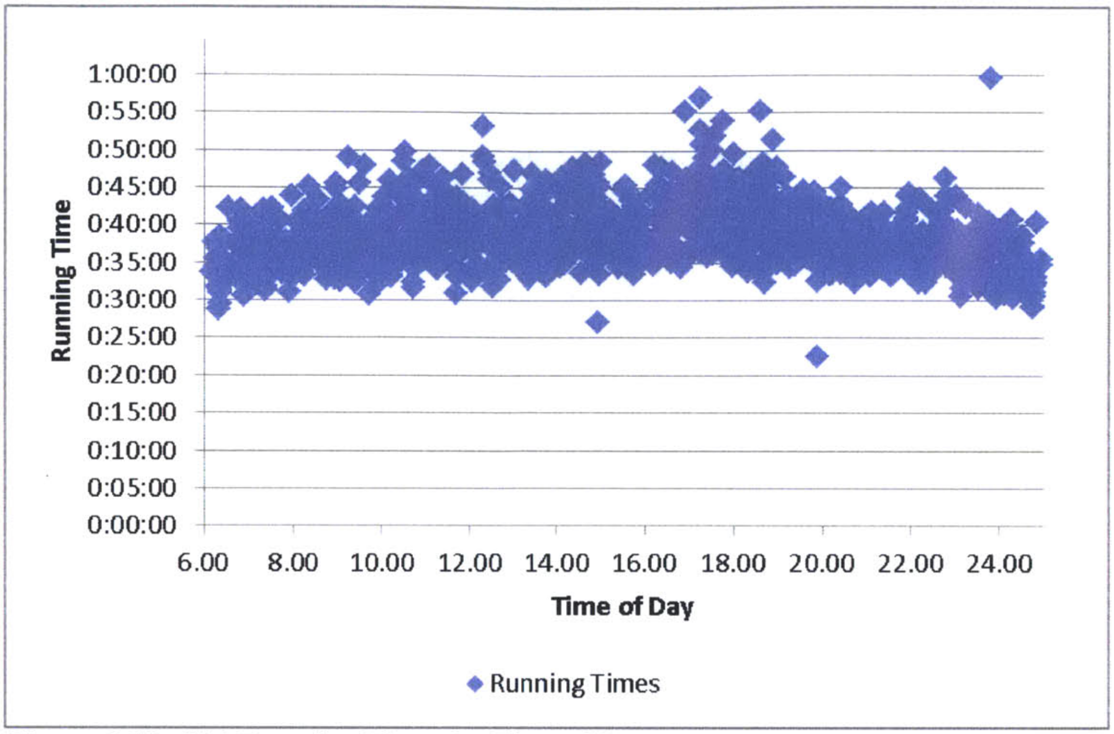


Figure 6-17: SL1 Running Times by Time of Day

The quantitative review in **Table 6-24** provides more insight into the variation of running times by time of day. Median running times are highest during the PM Peak and midday, followed by the evening and AM Peak.

Table 6-24: Running Times by Time Period

Running Times	AM Peak - 6:30 to 9:30 AM	Midday - 9:30 AM to 4:00 PM	PM Peak - 4:00 PM to 7:00 PM	Evening - 7:00 PM to Midnight
Minimum	0:30:38	0:27:06	0:32:24	0:22:36
5th Percentile	0:32:37	0:33:47	0:35:06	0:32:40
10th Percentile	0:33:06	0:34:55	0:36:16	0:33:42
Mean	0:37:05	0:39:13	0:42:05	0:37:22
Median	0:36:37	0:38:45	0:41:59	0:37:07
90th Percentile	0:41:36	0:44:39	0:47:25	0:41:41
95th Percentile	0:42:23	0:46:09	0:49:45	0:42:49
Maximum	0:49:03	0:53:14	0:57:07	0:59:37
Standard Deviation	0:03:16	0:03:46	0:04:35	0:03:22
Count	168	425	195	321

Another finding from this analysis is that the dwell and turn-around time at South Station is quite long, with a median of 11 minutes. While this AVL data for the SL1 includes timepoints corresponding to when the bus enters and exits South Station, it does not however distinguish between the four distinct activities that occur at South Station:

- SL1 passenger unloading
- Turnaround time in the tunnel (approximately 1,400 feet in length)
- Recovery time / driver break time in the staff-only area within the tunnel
- SL1 passenger loading

A field visit was conducted between 2:00 PM and 5:00 PM on Friday, March 1st, 2013 to observe the proportion of time spent on each activity while the bus is at South Station. The time required for the bus to travel through the turn-around tunnel was estimated by dividing the tunnel's length (1,400 feet) by the tunnel speed limit of 10 mph, resulting in an estimated time of 1.6 minutes. The results are summarized in **Table 6-25** and **Table 6-26**.

Table 6-25: Statistical Summary of SL1 South Station Time in Minutes

	Inbound Dwell	Recovery	Outbound Dwell	Total South Station Time
Min	0.4	0.1	1.1	5.7
Median	0.6	7.2	2.1	11.6
Mean	0.7	7.4	2.4	12.0
Standard Deviation	0.26	3.38	1.06	3.28
Max	1.3	14.5	5.3	18.8

Table 6-26: Proportion of SL1 South Station Time by Activity

	Cumulative Minutes	Percentage
Dwell for Passenger Alighting	11.9	6%
Recovery / Break	133.1	61%
Turnaround Time	28.6	13%
Dwell for Passenger Boarding	43.2	20%
Total Minutes	216.8	100%

These results show that a large proportion of the time the SL1 spends at South Station is recovery. Often, several passengers were waiting on the SL1 platform to Logan Airport while a bus was waiting inside the tunnel. On each cycle, the bus spends time waiting in the station while passengers are waiting on the platform.

Based on these data and observations, a recommended minimum time at South Station has been generated as follows:

	Peak	Off-Peak	Rationale
Inbound Dwell	1.3	1	To be conservative, the maximum observed inbound dwell time was used, to account for cases where the bus is full and passengers take time to gather their luggage and alight. One minute is used for the off-peak period when there are fewer alightings
Turnaround Time	1.6	1.6	The estimated 1.6 minutes to travel 1,400 feet at 10 mph has been used for the turnaround time during both time periods
Recovery Time	5	5	The difference between the 90th percentile and median travel time varies from 4:34 to 5:54, depending on the time period. The scheduled recovery time has been set somewhat aggressively at 5 minutes.
Outbound Dwell	2	1	The maximum outbound observed dwell time was **not** used, because the drivers waited at the second stop for longer than was actually required to pick-up all the passengers. Based on the field observation, 2 minutes is used as a reasonable maximum to allow all passengers to board if the SL1 stops only once and there is no additional wait time on the platform. One minute is used for the off-peak period when there are fewer boardings
Total Minutes	**9.9**	**8.6**	The observations are felt to be conservative for scheduling purposes, as they were recorded during the high-volume Friday afternoon period when dwell times are expected to be longest.

If this configuration does not fulfill driver break requirements, the MBTA and Massport should implement **dropback scheduling**. With **dropback scheduling**, the driver will exit the bus and take a break upon arriving at South Station and completing the cycle. However, the bus will not dwell while the driver takes a break; rather, the driver of the previous bus will finish his or her break and board the bus to start the next trip. In this way, each driver gets a break equivalent to the headway of the bus, but the buses continue moving through the system.

The data described so far in this section outline the required running times and the time required for activities at South Station. Based upon this information, cycle times to use for scheduling purposes for each time period are recommended in **Table 6-27**.

Table 6-27: Recommended SL1 Cycle Times

	AM Peak - 6:30 to 9:30 AM	Midday - 9:30 AM to 4:00 PM	PM Peak - 4:00 PM to 7:00 PM	Evening - 7:00 PM to Midnight
Existing Conditions				
Median Running Time	36:37	38:45	41:59	37:07
South Station Time	8:36	8:36	9:54	8:36
Recommended Cycle Time	45:13	47:21	51:53	45:43
Existing Scheduled Cycle Time	50:00	50:00	60:00	50:00

These results show that more aggressive cycle times than those currently scheduled could be used. The cycle times are rounded to integer values in the final stage of the calculation where fleet size requirements are determined.

6.6.4 South Station Platform Management

To help achieve reductions in the required dwell time at South Station, operational improvements to the SL1 are also possible at the platform level. Presently, the SL1 stops twice before leaving the platform and heading for Logan Airport, as shown in **Figure 6-18**.

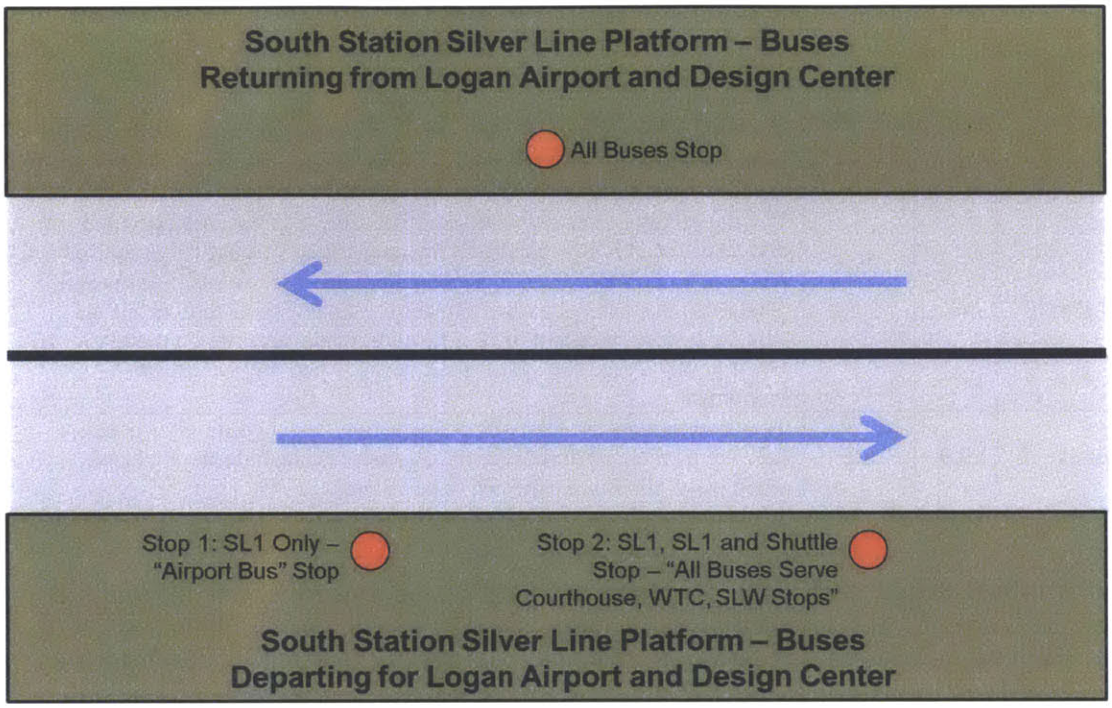


Figure 6-18: South Station Silver Line Platform Stop Locations

The first stop is signed as the "Airport Stop" (see **Photo 6-10**), and there is a well-sized waiting area on the platform. The second stop has a sign (see **Photo 6-11**) that indicates that all buses at this stop serve Courthouse, World Trade Center and Silver Line Way, the trunk portion of the Silver Line.

Photo 6-10: Sign at Silver Line Outbound Platform Stop 1

Photo 6-11: Sign at Silver Line Outbound Platform Stop 2

The primary advantage of this stop and signage system is that it clarifies a somewhat complex piece of information for users: while the buses here have different final destinations, they serve shared stations on the trunk portion of the line. An unfamiliar user who wants to travel to a station on the trunk portion may not realize that they can board the SL1.

This system also has with some disadvantages:

- Requiring the SL1 to stop twice increases its total dwell time on the outbound platform. The bus must decelerate, open doors, close doors and accelerate twice.
- Having the SL1 stop at two different locations is confusing to airport users. All of the signage on the platform points users to Stop 1; however, in reality users can actually board the SL1 at either stop. This inconsistency undermines the signage system
- In some instances, buses were observed to dwell at the second stop for longer than required to pick-up the passengers there
- The second stop allows the Silver Line to pick-up "just-in-time" riders who rush up the stairs from the Red Line platforms after a train has arrived. While this is an advantage in the sense that it reduces the wait time for these passengers, it also increases the dwell time for passengers already on the bus and was observed to lead to crush crowding conditions. Shorter and more consistent headways would reduce wait times for all passengers and increase the comfort level

This system is clear for users who want to access the trunk stations, but somewhat confusing for passengers traveling to the airport. However, passengers traveling to the trunk portion are more likely to be familiar with the system while passengers traveling to the airport are more likely to be unfamiliar with the system.

To improve both operations and clarity for users, the following measures are recommended:

- Have SL1 stop at Stop 1 **only**
- Have SL2 and the shuttle stop at Stop 2 **only**
- Clearly sign the SL1 and SL2 stops on the platform
- On the signage, indicate that both the SL1 and SL2 serve trunk stations
- Where possible, have the SL1 and SL2 depart at the same time (platooning) so that everyone waiting on the platform is able to board a bus

Buses can also depart in platoons to allow simultaneous boarding of the SL1 and SL2.

6.6.5 Fleet Size Requirements

In this section, fleet size requirements are determined based upon the recommended headways and cycle times. To determine the number of buses that would be required, the following formula from Vuchic[68] was used:

$N_{TU} = \frac{T}{h}$	N_{TU}	Number of transit units required to run the service
	T	Final cycle time – including all running time and recovery time
	h	Headway

The required fleet size is calculated for 5 minute headways, 6 minute headways and 8 minute headways with the existing cycle time. The results are shown in **Table 6-28**.

Table 6-28: Fleet Size Requirements – Existing Cycle Time

	AM Peak	Midday	PM Peak	Evening
8 Minute Headways – 60 Foot Buses				
Cycle Time	45:13	47:21	51:53	45:43
Headway	8	8	8	8
Number of Transit Units	5.65	5.92	6.49	5.71
Rounded Number of Transit Units	6.00	6.00	7.00	6.00
Adjusted Cycle Time	48	48	56	48
Adjusted Total South Station Time	11.38	9.25	14.02	10.88
6 Minute Headways – 40 Foot Buses				
Cycle Time	45:13	47:21	51:53	45:43
Headway	6	6	6	6
Number of Transit Units	7.54	7.89	8.65	7.62
Rounded Number of Transit Units	8.00	8.00	9.00	8.00
Adjusted Cycle Time	48	48	54	48
Adjusted Total South Station Time	11.38	9.25	12.02	10.88
5 Minute Headways				
Cycle Time	45:13	47:21	51:53	45:43
Headway	5	5	5	5
Number of Transit Units	9.04	9.47	10.38	9.14
Rounded Number of Transit Units	9	10.00	11.00	9.00
Adjusted Cycle Time	45	50	55	45
Adjusted Total South Station Time	8.38	11.25	13.02	7.88

At present there are only 32 dual-mode technology buses which can be used in the South Boston Transitway. Eight of them are owned by Massport and are dedicated to the SL1 route. The number of buses scheduled for use during the peaks is summarized in **Table 6-29**.

[68] Vuchic, "Urban Transit Operations, Planning and Economics", 2005, page 52

Table 6-29: Silver Line Buses during the Peak Periods

	AM Peak	PM Peak
SL1	5	6
SL2	6	7
Short Turn Shuttle	4	4
Total	**15**	**17**

Bus totals based on headway reports provided by the MBTA

Seven buses are required to operate 8 minute headways and eleven buses are required to operate 5 minute headways. Considering that Massport already owns 8 SL1 buses and that only 17 of the 32 buses are currently in use during the peak, the existing fleet size may be sufficient (depending upon how many spares are required and whether any buses are out of order). Additionally, buses can be re-allocated from the SL2 and short-turn shuttle to the SL1 if there are any additional fleet size constraints. However, any additional buses must be retrofit with luggage racks before deployment on the SL1 route. From the data collected by the project team at Silver Line Way on January 31, 2013, the average load of both the shuttle and the SL2 was 8 people (although much higher loads were observed during the PM Peak when more SL1 buses would be required).

6.6.6 Recommendation

Recommendation: Increasing the frequency of the SL1 is **recommended** as a measure to improve transit access to Logan Airport. It has several advantages:

- Increased frequency will result in a perceptible decrease in expected wait time, to which travelers are particularly sensitive
- A service adjustment by the MBTA is very easy to implement: this solution requires no new design work, consultant studies, construction, public consultation, inter-agency approvals outside of Massport and the MBTA, etc.
- The frequency can be reduced easily if anticipated benefits are not realized
- The message is simple and resonant; it is easy to advertise and explain to passengers
- The upcoming Government Center closure provides a natural opportunity to experiment with increased service levels on the SL1

6.7 Free Boardings at Logan Airport

A significant change to SL1 operations was implemented on June 6, 2012, when the fare for boarding the Silver Line at all airport stops was eliminated in a pilot project. There are several benefits to eliminating fare payment at the airport:

- Less user confusion on the curb with respect to buying tickets
- Increased convenience for transit users
- Faster boarding as passengers can board at all doors
- Reduced curb occupancy by Silver Line buses
- Better service for residents, tourists and business travelers alike

These benefits all improve the quality of the Silver Line service. This section reviews the impacts of the change and recommends whether it is worth implementing permanently.

6.7.1 Impact on Silver Line Ridership

A comparison of the change in ridership for sample days following the introduction of free boardings at Logan Airport is provided in **Table 6-30**.

The 2011 ridership numbers show ridership before the introduction of the free fare. This data, provided by Massport, was based upon MBTA Automated Fare Collection (AFC) data on boardings of the Silver Line. The original data did not distinguish between boardings at Logan Airport and boardings at the Silver Line Way stop. The counts were slightly reduced to obtain a more accurate estimate of boardings at Logan Airport only:

- Weekday counts were reduced by 200 boardings
- Sunday trips were reduced by 100 boardings

Field data collected on Thursday, January 31st, 2013 between 5:50 AM and 8:00 PM indicated that 173 people boarded the SL1 at Silver Line Way stop as it returned from Logan Airport. The weekday estimate of SL1 boardings at Silver Line Way was increased to 200 boardings to account for boardings after 8:00 PM. The weekend estimate was reduced to 100 boardings as many of the trips were observed to be work commute trips which would not occur on Sundays.

After the introduction of free boardings at Logan Airport in June 2012, AFC data was no longer available to track boardings. As a result, manual counts have been undertaken by the Central Transportation Planning Staff (CTPS) and the MIT project team to assess ridership on the SL1 after the introduction of free boardings:

- The ridership counts from June 2012 to September 2012 were based on CTPS field data counts on sample days at Logan Airport between 6:00 AM and 8:00 PM. Expansion factors were used to convert these counts into estimates of full-day ridership
- The ridership counts from October 2012 to December 2012 were based on full-day CTPS field data counts at Logan Airport.
- The ridership count from January 2013 was based on the MIT project team's data collection at Silver Line Way stop from 5:50 AM to 8:00 PM. An expansion factor was used to convert this count into an estimate of full-day ridership

Table 6-30: Change in Silver Line 1 Ridership after Introduction of Free Boardings at Logan Airport

	Sunday		Monday		Tuesday		Thursday		Friday	
	Number	**% Change**	**Number**	**% Change**	**Number**	**% Change**	**Number**	**% Change**	**Number**	**% Change**
May 2011	2,445		2,858		2,649		2,331		2,542	
May 2012*	2,571	5.2%	2,868	0.3%	2,471	-6.7%	2,380	2.1%	2,541	0.0%
June 2011	2,524				2,338				2,721	
June 2012	2,913	15.4%			2,824	20.8%			2,922	7.4%
July 2011	2,480		2,611		2,786				2,688	
July 2012	2,931	18.2%	3,272	25.3%	2,708	-2.8%			3,004	11.7%
Aug 2011	1,847		2,927		2,749				2,833	
Aug 2012	3,211	73.8%	3,345	14.3%	3,210	16.8%			3,382	19.4%
Sept 2011	2,435		2,729		2,292				2,557	
Sept 2012	3,038	24.7%	2,961	8.5%	2,168	-5.4%			3,293	28.8%
Oct 2011	2,432								2,960	
Oct 2012	2,953	21.4%							2,758	-6.8%
Nov 2011	3,346				2,401				2,545	
Nov 2012	2,454	-26.7%			2,364	-1.5%			3,401	33.6%
Dec 2011	1,871				1,973				1,909	
Dec 2012	2,094	11.9%			2,300	16.6%			2,320	21.5%
Jan 2012							2,119			
Jan 2013							1,553	-36%		

*May 2011 to May 2012 as a baseline control comparison before introduction of free Silver Line boardings in June 2012

The counts from May 2011 and 2012 were included to show the change in ridership independent of the change in the fare. These counts show that boardings increased on Sundays, were stable on Mondays and Fridays, and decreased on Tuesdays. The percentage change month-by-month after the introduction of free boardings at Logan Airport is illustrated in **Figure 6-19** through **Figure 6-22**. The change from May 2011 to May 2012 is shown in yellow, to clearly illustrate the change in the following months as compared to the baseline change.

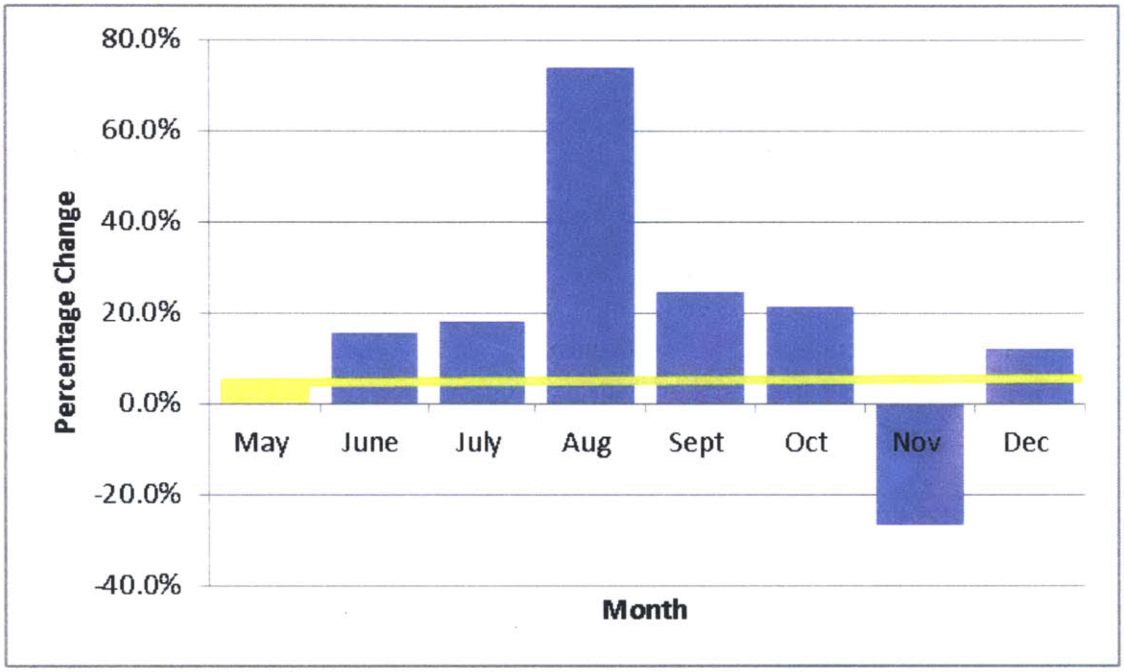


Figure 6-19: Percent Change in Logan Airport Silver Line Boardings on Sundays, 2011 to 2012

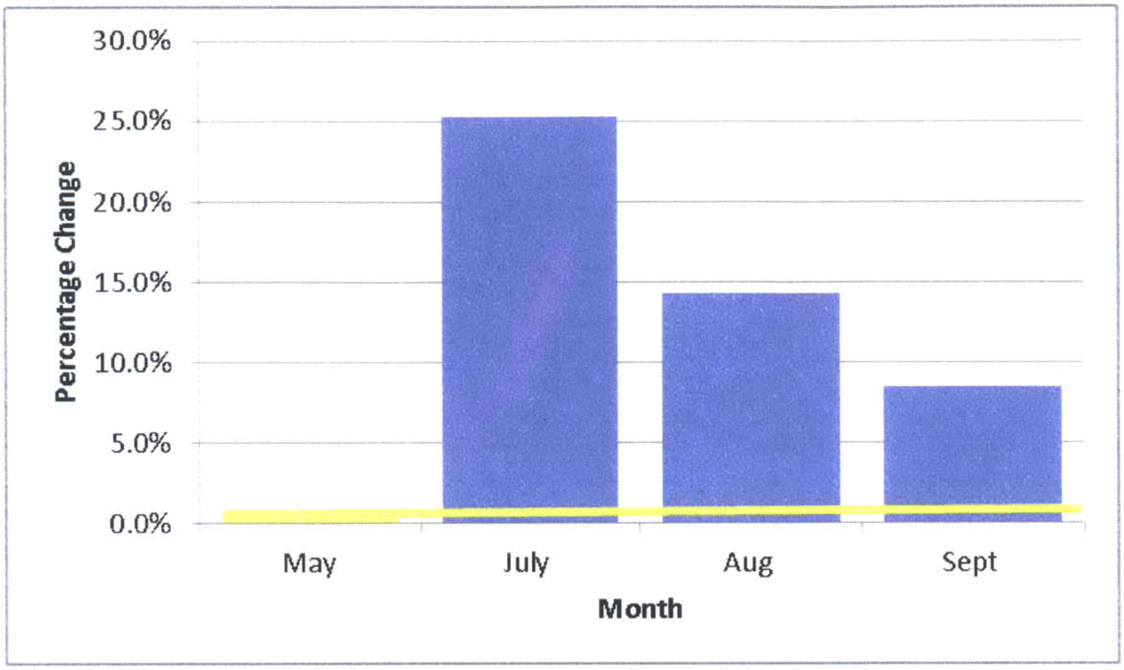


Figure 6-20: Percent Change in Logan Airport Silver Line Boardings on Mondays, 2011 to 2012

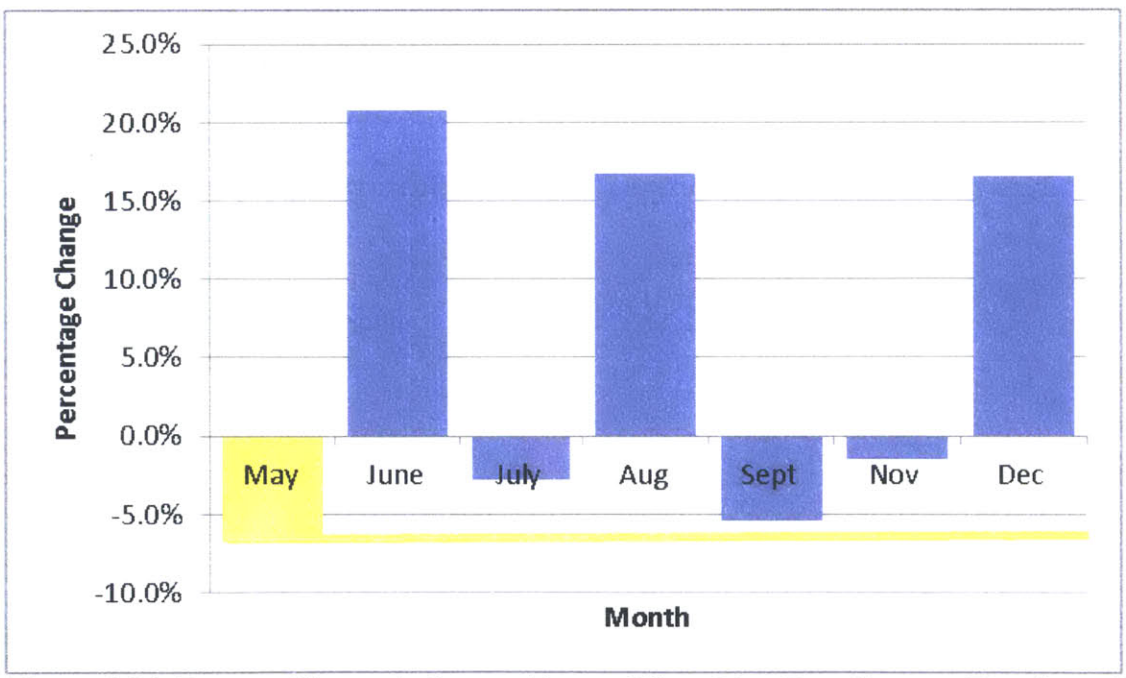


Figure 6-21: Percent Change in Logan Airport Silver Line Boardings on Tuesdays, 2011 to 2012

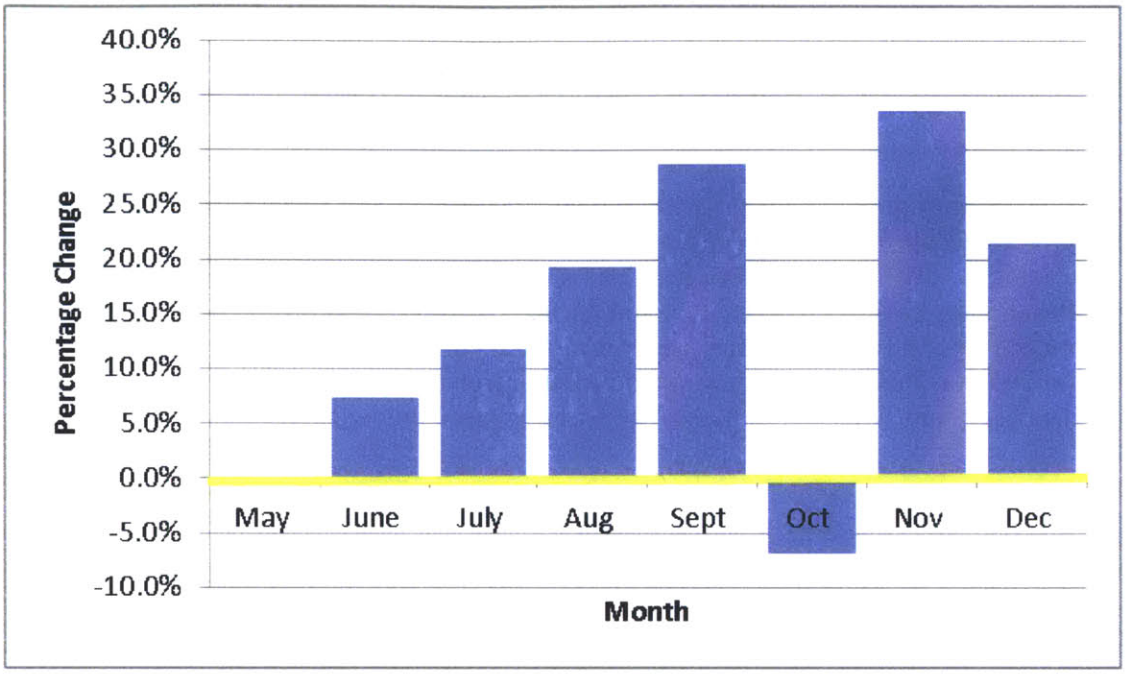


Figure 6-22: Percent Change in Logan Airport Silver Line Boardings on Fridays, 2011 to 2012

On most of the sample days when data was collected, SL1 ridership had increased after the introduction of the free fare. Ridership increased by more than the May 2011-May 2012 baseline change in ridership for all counts aside from the following:

- Friday count in October
- Sunday count in November
- Thursday count in January

The counts from Tuesdays in July, September and November 2012 all decreased compared to 2011, but they decreased less than the baseline decrease of -6.7% between May 2011 and May 2012. These findings point to both the variability in transit travel patterns to Logan Airport and the need for comprehensive data collection in order to assess changes since the introduction of the free fare. On any given sample day, several factors may have a significant impact on the number of Silver Line trips:

- Weather: travelers less likely to use transit in inclement weather conditions
- Overall volume of passengers arriving at Logan Airport: fewer air passenger trips results in fewer ground access trips
- Randomness: inherent variability in traveler demand and mode choice

To assess the level of variability for Silver Line boardings, AFC data for SL1 boardings in April and May 2012 (before the introduction of the free fare) was analyzed to determine the standard deviation by day of the week by month, as shown in **Table 6-31**.

Table 6-31: Standard Deviation of SL1 Daily Boardings by Day of Week, by Month

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
April 2012	669	196	181	103	361	422	265
May 2012	222	181	652	357	163	166	187

The standard deviations are relatively large for Sundays, Thursdays and Fridays in April, and for Tuesdays and Wednesdays in May. The difference in the standard deviations by day of the week points to the variability that can take place in Silver Line boardings. The percent increases shown in the preceding figures have been derived by comparing a one-day count from 2012 to the monthly average from 2011. As individual counts are much more susceptible to influence by extenuating factors, it is important to focus on the broader trends in lieu of specific data points. A majority of the data points collected indicate that ridership has increased since the introduction of the free fare.

6.7.2 Impact on Entrances at Airport Station

Passengers arriving at the airport who intend to use transit can now choose between a free service and a service for which a fare is required:

- Silver Line: free boarding with free transfer to the Red Line and South Station
- Blue Line: take Massport shuttle to Airport Station on the Blue Line, where a fare is required

Entrances at Airport Station on the Blue Line have been reviewed to determine whether there has been a shift from the Blue Line to the Silver Line as a result in the difference in fare. The results are shown in **Table 6-32**.

As the free Silver Line pilot project was introduced on June 6, 2012, the Airport Station entrances after this date are shown in red. This data is based on fare array measurements and includes all entrances at Airport Station (i.e. those from the airport, the community and courtesy shuttles – data sub-divided by the community side and airport side are presented in the next part of this chapter). Entrances by month are illustrated in **Figure 6-23**. Notably, the 2012 values are consistently lower than the 2011 values from September 2012 onward.

Airport Station entrances as a percentage of total Blue Line boardings (exclusive of boardings at Government Center) are also provided in this table. As transit ridership fluctuates by month, this provides another perspective on boardings at Airport Station. The average percentage decreased slightly from 18.9% before the free boardings program to 18.6% after the free boardings program. The percentage is illustrated in **Figure 6-24**.

Table 6-32: Entrances at Airport Station Before and After Free Silver Line

	2011			2012			2013		
	Airport	Total Blue Line	Percentage	Airport	Total Blue Line	Percentage	Airport	Total Blue Line	Percentage
January	144,671	790333	18.3%	179138	960784	18.6%	177944	995953	17.9%
February	138,922	795623	17.5%	172626	965116	17.9%	149460	872514	17.1%
March	181,021	974424	18.6%	210533	1102983	19.1%			
April	194,868	1041564	18.7%	211068	1102770	19.1%			
May	211,756	1,094,130	19.4%	240386	1153982	20.8%			
June	212,996	1,142,118	18.6%	222218	1172071	19.0%			
July	223,285	1203582	18.6%	228410	1239199	18.4%			
August	216,610	1163276	18.6%	245868	1230633	20.0%			
September	214,077	1121379	19.1%	211154	1121311	18.8%			
October	217,564	1116217	19.5%	213358	1134407	18.8%			
November	204,376	1033615	19.8%	199304	1057865	18.8%			
December	185,864	994,438	18.7%	175915	969822	18.1%			

*Based on monthly ridership summary data provided by the MBTA

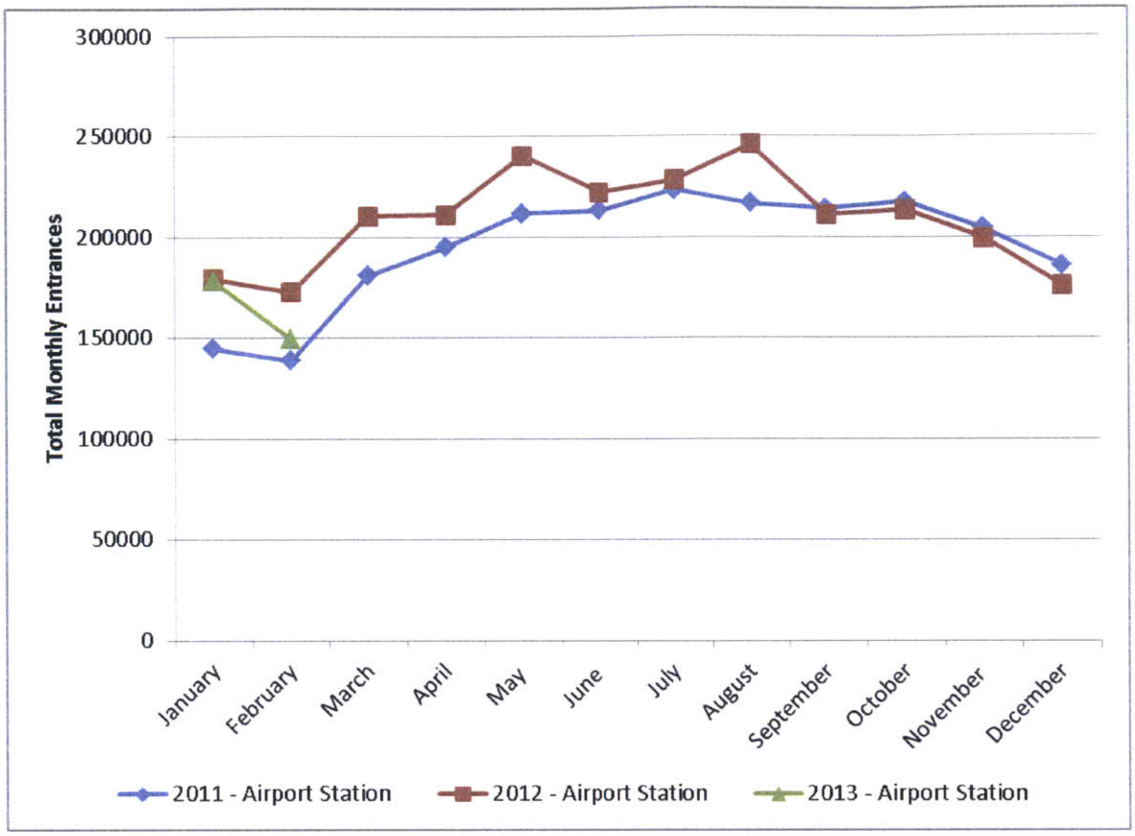


Figure 6-23: Airport Station Entrances, 2011, 2012 and 2013

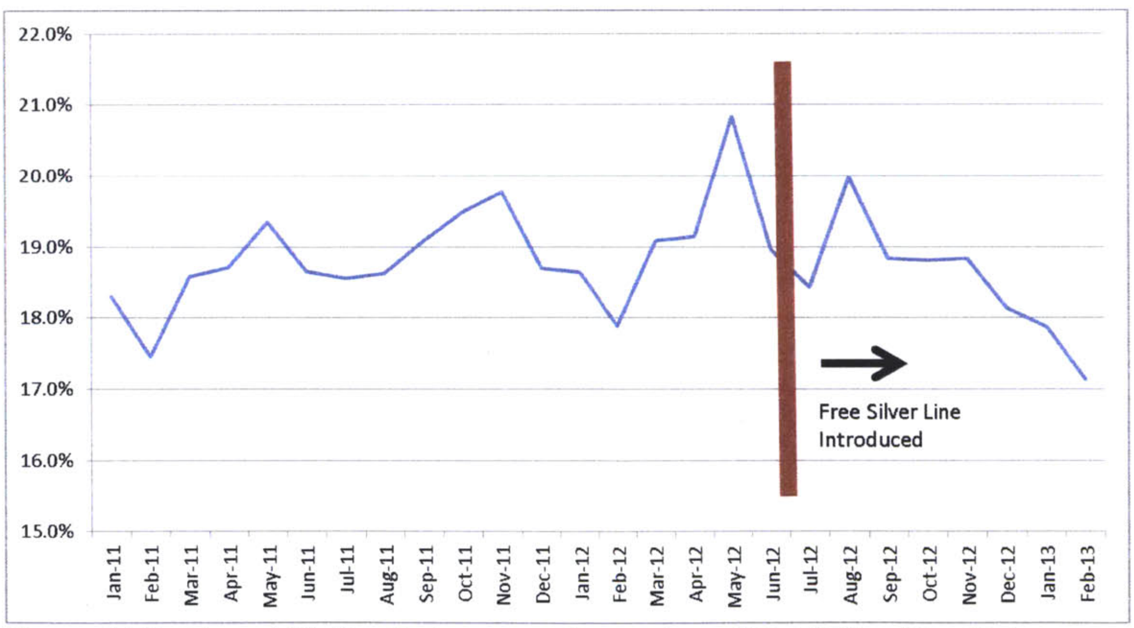


Figure 6-24: Airport Station Entrances as Percentage of Total Blue Line Entrances

This data also enables a comparison of the percent change in Airport Station entrances between 2011, 2012 and 2013, as shown in **Figure 6-25** and **Table 6-33**.

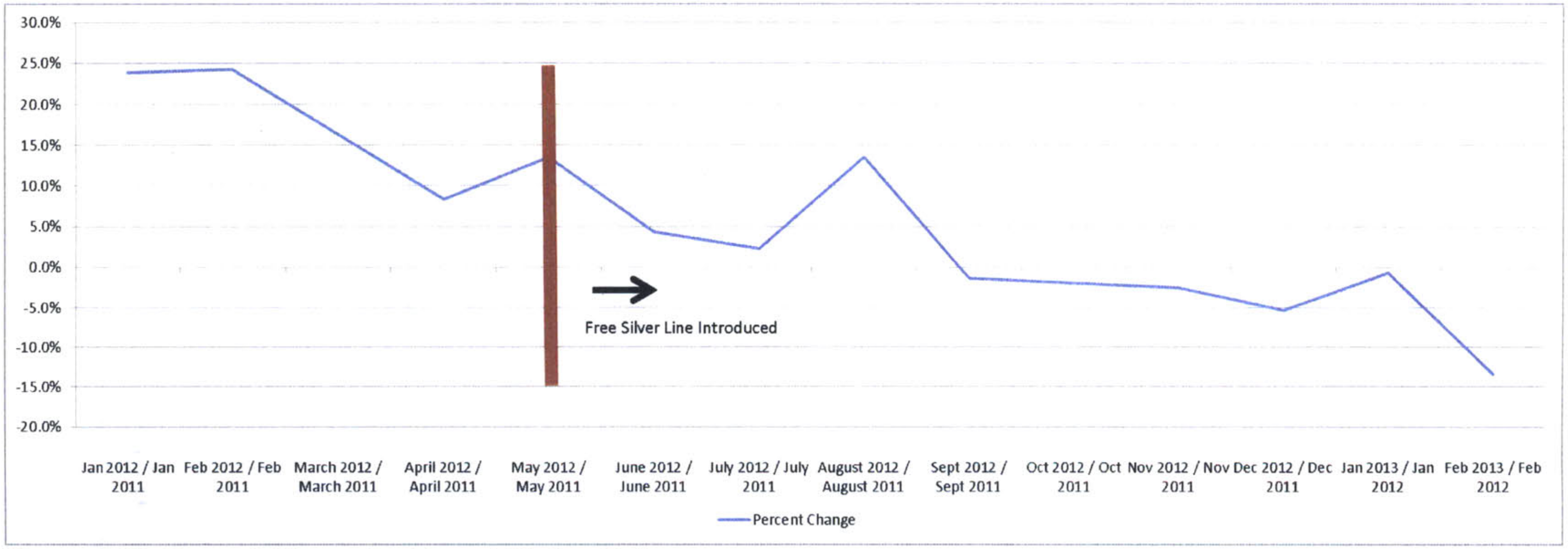


Figure 6-25: Percent Change in Airport Station Entrances

Table 6-33: Percent Change in Airport Station Entrances

Month	2011	2012	% Change 2011 to 2012	2013	% Change 2012 to 2013
January	144671	179138	23.8%	177944	-0.7%
February	138922	172626	24.3%	149460	-13.4%
March	181021	210533	16.3%		
April	194868	211068	8.3%		
May	211756	240386	13.5%		
June	212996	222218	4.3%		
July	223285	228410	2.3%		
August	216610	245868	13.5%		
September	214077	211154	-1.4%		
October	217564	213358	-1.9%		
November	204376	199304	-2.5%		
December	185864	175915	-5.4%		

The average growth rate has been calculated for three distinct periods:

- January to May 2012, before the free Silver Line: **17.2%**
- June to August 2012, as users started becoming familiar with the free Silver Line; MBTA fare increase implemented in July 2012: **6.7%**
- September 2012 to February 2013, after increased signage for free Silver Line introduce at Logan Airport: **-4.2%**

These results indicate that growth was slower during the summer months (June through August), and then became negative after September 2012. Further, Airport Station's share of total Blue Line boardings was also somewhat smaller after the introduction of free Silver Line fares. While transit ridership volumes do fluctuate for a variety of causes, the direct and consistent nature of the decrease in entrances at Airport Station after September 2012 suggest that some riders have switched from the Blue Line to the Silver Line. Entrances at Airport Station should continue to be monitored to determine whether the decrease persists.

Fare array data from April, May, June, July, August and November 2012 have been more closely analyzed to further investigate ridership trends at Airport Station before and after the introduction of free boardings of the Silver Line at Logan Airport. These are the only months for which detailed data is available at this point in time. Month-to-month comparisons within the same year are challenging, because they cannot account for seasonal variation. As discussed in **Chapter 3**, there is significant seasonal variation in Silver Line boardings at the airport, relating to both seasonal variation in airport activity and passenger aversion to using transit in inclement weather. To address this seasonal variation, an approximate "expected total" for each month in 2012 has been developed as follows:

- Total entrances at Airport Station by month were available for the years 2008 to 2011 from Massport
- January was used as the base month: the ratio of total boardings over the 4 years in each other month to total boardings over the 4 years in January was determined. For example, on average between 2008 and 2011, the number of boardings in February is 95% of the boardings in January.

- The ratio of each other month with respect to January was applied to the January 2012 entrances to determine the approximate "expected total" for each other month in 2012
- As a result of this methodology, the "expected total" is equal to the actual total for January 2012.

While there are additional causes of month to month variation, this approximation accounts for some of the variation. A comparison of the 2008-2011 average, actual 2012 ridership and "expected" 2012 ridership are shown in **Figure 6-26**

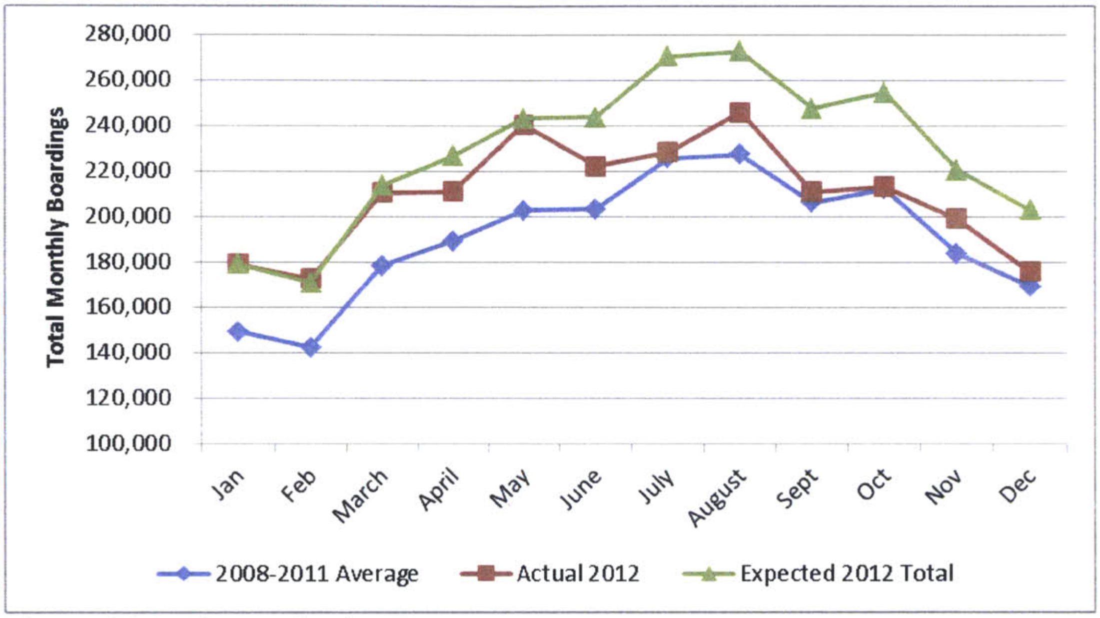


Figure 6-26: Airport Station Entrances

Some key results from this figure include:

- The totals for February, March and May all fit quite well, indicating that this approach predicts these values relatively well. In April 2012, the number of entrances was lower than expected based on the average ratio of January to April boardings from 2008 to 2011.
- From June 2012 to December 2012, after the introduction of the free Silver Line program, the number of entrances at Airport Station was less than the expected number of entrances, and is much closer to the average number of entrances between 2008 and 2011. It should be noted that the "expected" number of entrances for July and August are higher than any monthly entrances recorded between 2008 and 2011 – the particularly large number of entrances in the early months of 2012 result in the high predictions for the summer months. Regardless, the results indicate that the high pace of growth in the early months of the year slowed in the summer, after the introduction of the free Silver Line
- Notably, the MBTA increased fares on July 1, 2012. However, broader studies of MBTA ridership have shown that overall ridership did not decrease in response to the July 1 2012 fare increase, so it is not expected that the fare increase had a significant impact on Airport Station entrances. The fare increase may have slowed the rate of growth, however.

As reviewed in **Chapter 3** of the report, a sizable number of entrances at Airport Station are attributed to the community entrance and are not related to airport travel. Thus, entrances at Airport Station have been reviewed by fare array to detect any differences in the boarding pattern. The free Silver Line is expected to influence entrances on the airport side, but have no impact on the number of entrances on the community side. The data is shown in **Table 6-34**.

Table 6-34: Entrances at Airport Station

		Apr-12	May-12	Jun-12	Jul-12	Aug-12	Nov-12
Weekday	Airport Side	3727	3702	4258	4274	4290	3378
	Community Side	3587	3594	3739	3623	3698	3626
	Total	7314	7296	7997	7897	7988	7004
Saturday	Airport Side	3364	5650	3706	3787	5684	3371
	Community Side	2744	2912	2731	2825	2837	2734
	Total	6107	8563	6437	6612	8522	6105
Sunday	Airport Side	3202	4915	3961	3989	5389	3792
	Community Side	1936	2200	2244	2226	2277	2038
	Total	5137	7115	6204	6216	7665	5830

The number of Airport Station entrances is also illustrated in **Figure 6-27**.

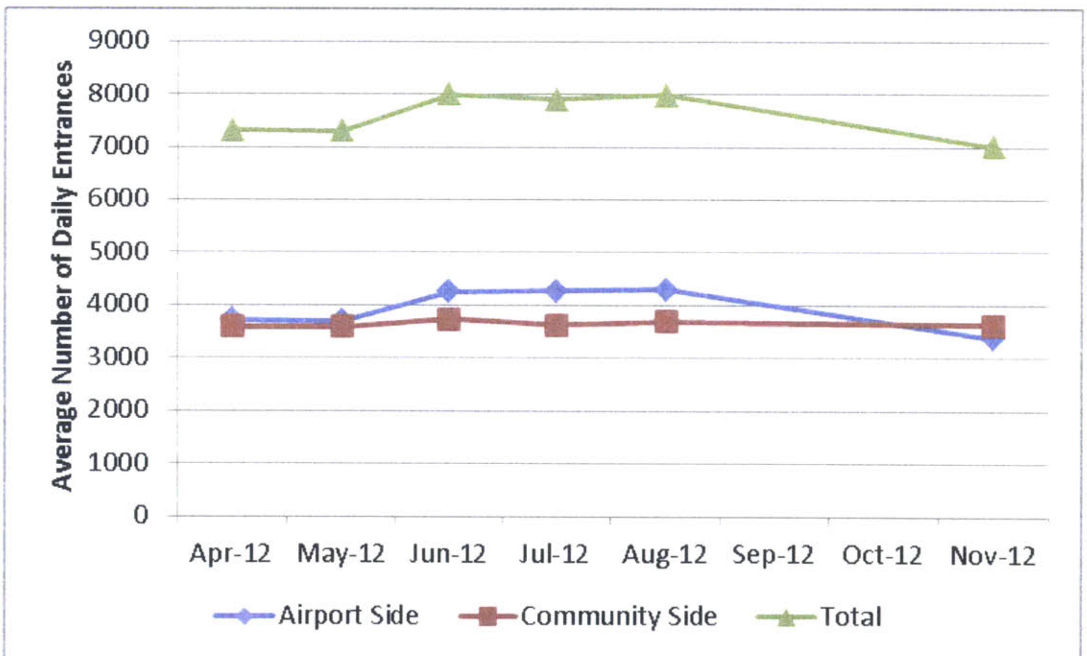


Figure 6-27: Weekday Entrances at Airport Station by Month, 2012

This figure shows that for the months for which data is available, there was no sizable decrease in the number of airport side boardings on week days after May 2012. However, the historical data shown in **Figure 6-26** shows more distinct peaks during the summer months at Airport Station. The summer peak during 2012 was less pronounced. Given the relative consistency of entrances on the community side (which is expected, as a result of the more predictable daily work trip pattern), it is hypothesized that the "missing trips" in the summer are the result of some passengers using the Silver Line instead of the Blue Line.

Based on the data reviewed to date, it is likely that the introduction of the free Silver Line has resulted in some passengers switching from the Blue Line. However, many passengers continue to use the Blue Line, and the free Silver Line has not resulted in significant decreases in airport-related entrances at Airport Station. Entrances at Airport Station should continue to be monitored:

- Entrances should be assessed by fare array to distinguish between community side entrances and airport side entrances
- The trend of negative growth starting in September 2012 suggests more sizable shifts of passengers may be occurring, and should be monitored carefully
- To avoid seasonal impacts, year-over-year comparisons should be made once this data is available. For example, the number of airport side entrances in November 2011 should be compared to the number of airport side entrances in November 2012, with overall growth in the MBTA system accounted for.
- Impacts may become more pronounced in 2013, once more travelers have become aware of the free Silver Line service

There are some potential reasons why the elimination of the Silver Line fare did not result in substantial and consistent ridership increases on the Silver Line and decreases at Airport Station during the initial months of the program:

- **Rider Awareness**. The initial signage at the airport (summer 2012) did not clearly alert riders to the free Silver Line service, although improved signs were introduced in the autumn of 2012. For new riders to use the service, they must be aware that it is free; for users unfamiliar with the system, it is also important to clarify that there is a free transfer to the subway system at South Station. Otherwise, potential users may think it is simply a free shuttle bus to the subway.
- **Ramp-Up Period**. A ramp-up period is generally required for new services or facilities, to allow users to become familiar with the service. The relatively minor impact to Airport Station entrances detected during the summer months may be a result of user unfamiliarity with free Silver Line program.
- **Transit Price Inelasticity**. The price to use the Silver Line may not be the most significant deterrent to potential users. Aside from walk/cycle trips, taking the MBTA is already the least expensive ground access mode, and the segment of the market concerned with the price of ground access is likely already using it. An improvement to other characteristics of the service – such as the travel speed, wait time and comfort of the waiting area – is more likely to attract users from competitive modes (such as taxis, pick-up/drop-off and single occupant vehicle).
- **Transit Travel Patterns**. The data have not provided conclusive evidence of a shift of users from the Blue Line to the Silver Line. This may be because the Blue Line provides a more direct connection to their destination, and the difference in travel time and transfer time is valued more than the difference in fare between the two options.

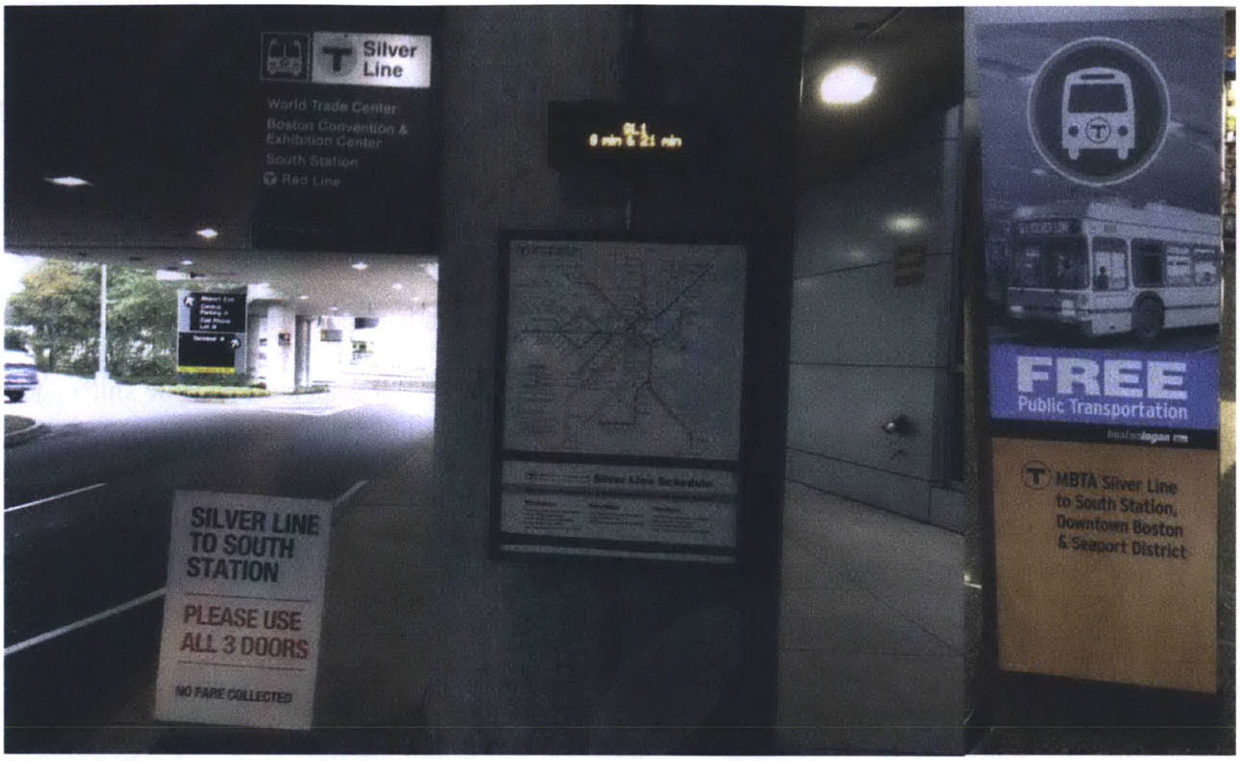


Photo 6-12: Signage and Real-Time Information at a Logan Airport Silver Line Stop

6.7.3 Impact on Operations

A comparison of the change in stop times at the stops at each airport terminal is shown in **Table 6-35**. This is based upon Automated Vehicle Location (AVL) data made available by the MBTA. The AVL technology records an "arrival" time once the bus is within a 250 foot radius of the stop and a "departure" time once the bus has travelled 250 feet (i.e. to the stop itself) plus 140 feet. "Stop Time" has been calculated as Departure Time minus Arrival Time, and incorporates some deceleration, dwell and acceleration. The change in stop time has been determined during the AM Peak, PM Peak and Off-Peak to assess how the elimination of the fare has affected stop times. Stop times exceeding 5 minutes were removed from the dataset, as these stop times are likely the result of measurement error or other unusual circumstances.

Table 6-35: Change in Stop Time at Logan Airport Stops

Stop	Stop Time – Fare Required[1]	Stop Time – No Fare Required[2]	Reduction in Stop Time
AM Peak – 6:30 AM to 9:30 AM			
Terminal A	01:33	01:28	00:05
Terminal B – Stop 1	01:05	00:59	00:06
Terminal B – Stop 2	00:54	00:46	00:08
Terminal C	01:35	01:09	00:26
Terminal E	01:05	00:55	00:10
Total	**06:12**	**05:17**	**00:55**
PM Peak – 4:00 PM to 7:00 PM			
Terminal A	02:05	01:43	00:22
Terminal B – Stop 1	01:24	01:08	00:16
Terminal B – Stop 2	01:08	00:55	00:13
Terminal C	01:31	01:10	00:21
Terminal E	01:44	01:24	00:20
Total	**7:52**	**6:20**	**1:32**
Evening Off-Peak – after 10:30 PM			
Terminal A	01:28	01:21	00:07
Terminal B – Stop 1	00:57	00:51	00:06
Terminal B – Stop 2	00:46	00:43	00:03
Terminal C	01:07	00:53	00:14
Terminal E	01:11	01:03	00:08
Total	**5:29**	**4:51**	**0:38**

[1]Based on data from October 21, 2011 to June 5th, 2012
[2]Based on data from June 6th, 2012 to October 15th, 2012, after free fare introduced at Logan Airport
*Full table is Monday through Sunday data

As expected, stop times decreased at all airport stops after the introduction of free fares. Passengers are now able to board at all doors and do not need to pay the driver; as a result, buses are able to load and depart more quickly. The statistical significance of the change in the mean stop time was tested using the following test:

$$z = \frac{\overline{x} - \overline{y} - \Delta}{\sqrt{\frac{\sigma_1^2}{m} + \frac{\sigma_2^2}{n}}}$$

Whereby:

$\overline{x}$	Mean stop time before free fare introduced
$\overline{y}$	Mean stop time after free fare introduced
Δ	Tested difference between the means; set to '0' for this analysis
σ_1^2	Variance of stop time before free fare introduced
σ_2^2	Variance of stop time after free fare introduced
m	Number of data points before free fare introduced
n	Number of data points after free fare introduced
z	Test statistic; magnitude of this test statistic compared to a t-statistic of 1.96 which corresponds to a confidence interval of 95%. In this case, the null hypothesis is that the change in mean stop time is not significant; therefore, if the z statistic exceeds the t statistic of 1.96, it indicates that the null hypothesis is false and the

The statistics for each of the stops and periods are shown in **Table 6-36**.

Table 6-36: Statistical Significance of Change in Stop Time

	Fare Required		No Fare Required		Z Statistic
	Mean	Standard Deviation	Mean	Standard Deviation	
AM Peak – 6:30 AM to 9:30 AM					
Terminal A	01:33	00:38	01:28	00:23	6.99
Terminal B – Stop 1	01:05	00:31	00:59	00:18	9.90
Terminal B – Stop 2	00:54	00:30	00:46	00:16	11.87
Terminal C	01:35	00:52	01:09	00:25	22.63
Terminal E	01:05	00:34	00:55	00:20	12.64
PM Peak – 4:00 PM to 7:00 PM					
Terminal A	02:05	00:51	01:43	00:32	19.59
Terminal B – Stop 1	01:24	00:45	01:08	00:23	18.20
Terminal B – Stop 2	01:08	00:41	00:55	00:22	14.98
Terminal C	01:31	00:48	01:10	00:28	20.97
Terminal E	01:44	00:54	01:24	00:32	17.04
Evening Off-Peak – after 10:30 PM					
Terminal A	01:28	00:34	01:21	00:25	9.85
Terminal B – Stop 1	00:57	00:29	00:51	00:19	10.45
Terminal B – Stop 2	00:46	00:27	00:43	00:18	5.58
Terminal C	01:07	00:38	00:53	00:22	19.79
Terminal E	01:11	00:39	01:03	00:29	8.79

These results show that the change in stop time is strongly statistically significant for all cases (the z statistic is greater than 2).

The most significant reduction in stop times was during the PM Peak period, when boardings and alightings are greatest. The reduction was least during the late evening period (after 10:30 PM) when there are fewer boardings and alightings. The changes in stop times are illustrated in **Figure 6-28** through **Figure 6-30**.

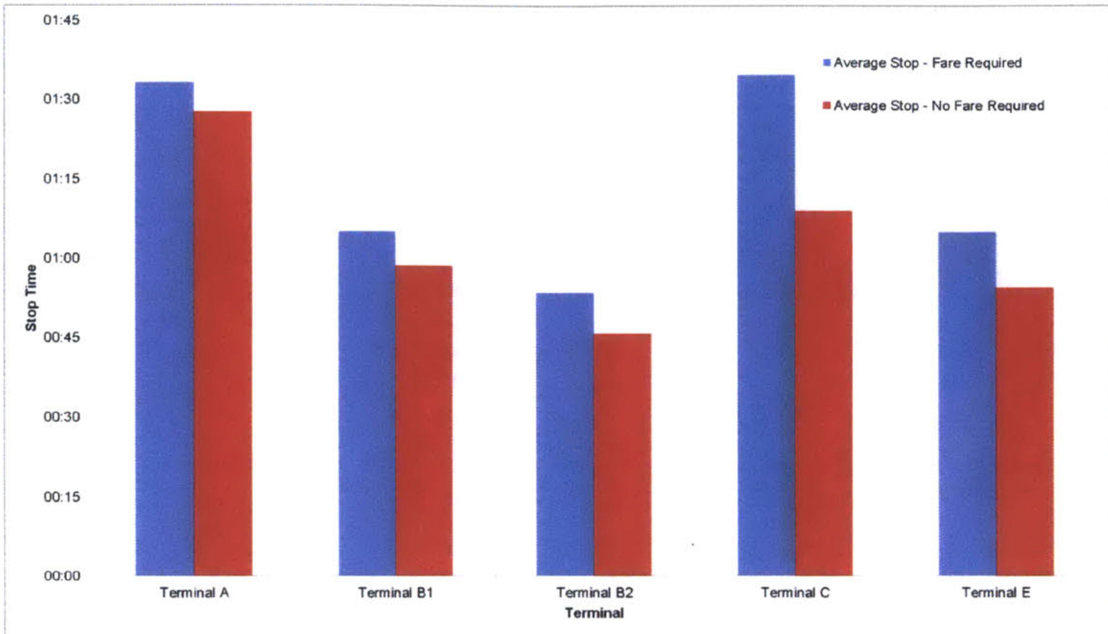


Figure 6-28: AM Peak Stop Time at Terminal Stops, Logan Airport

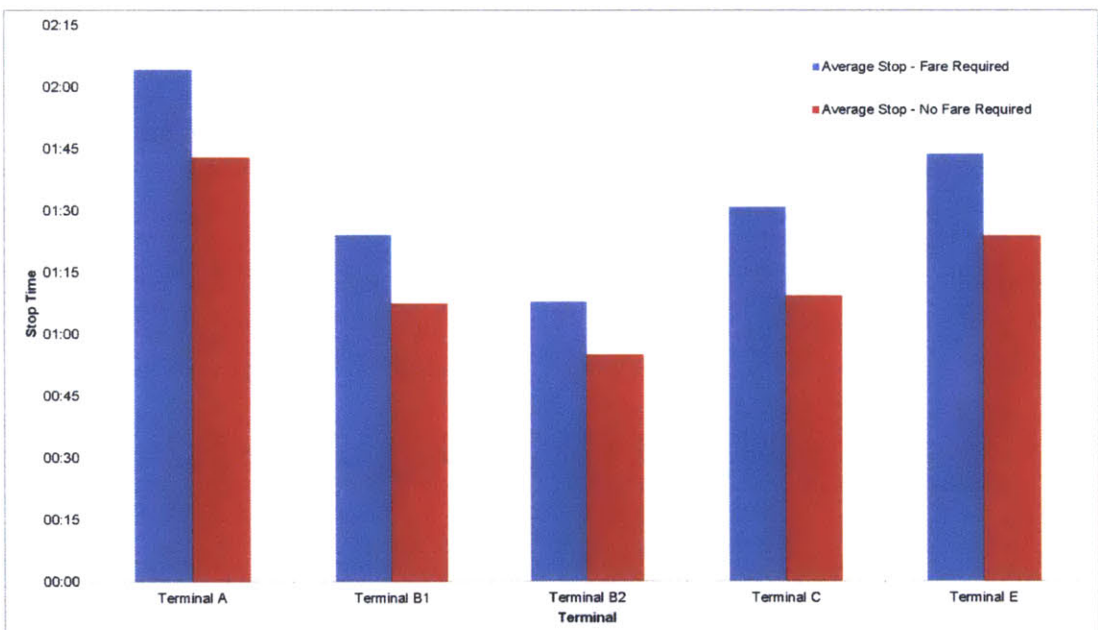


Figure 6-29: PM Peak Stop Time at Terminal Stops, Logan Airport

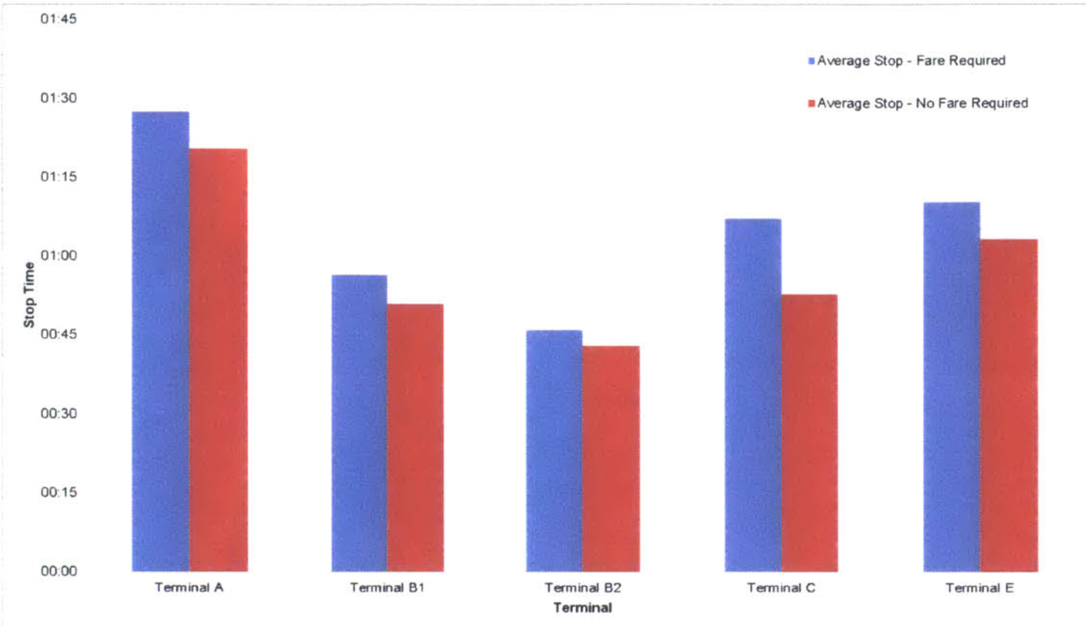


Figure 6-30: Evening Off-Peak Stop Time at Terminal Stops, Logan Airport

6.7.4 Recommendation

Based upon the increased ridership and decreased dwell time at each terminal, permanent implementation of the free Silver Line program is **recommended**. Ridership changes on the Silver Line and at Airport Station should continue to be monitored to ensure that the program is resulting in increased use of transit, and not a re-distribution of existing transit users.

6.8 Silver Line Branch Routes to Logan Airport

As reviewed in **Chapter 3**, on-airport travel time is one of the longest elements of the round-trip between South Station and Logan Airport. Under the existing operations, passengers heading to Terminal E must wait while the bus travels through Terminals A, B and C. Likewise, passengers boarding at Terminal A must wait while the bus travels through Terminals B, C and E before it begins its trip to South Station.

The Airport Shuttles run by Massport to connect Airport Station to the airport terminals operate branch services during the peak period to reduce in-vehicle travel times:

- Route 22: Serves Airport Station, Terminal A and Terminal B
- Route 33: Serves Airport Station, Terminal C and Terminal E

A similar concept could be introduced on the Silver Line:

- Silver Line 1-A: Serves South Station, Terminal A and Terminal B
- Silver Line 1-B: Serves South Station, Terminal C and Terminal E

On-Airport travel times based on AVL data are shown in **Table 6-37**; these data are based on the period from June 6 to October 15, 2012, after the free Silver Line boardings program was introduced. Estimated travel times for the potential SL1-A and SL1-B branch routes are also included in this table. These travel times were estimated by selecting common start and finish locations on the airport roadway system, located before Terminal A and after Terminal E, respectively. Travel times between the terminals and the common start / finish locations were estimated using the measured distances and an average speed of 25 mph to reflect the high-speed nature of these roads. The trip time for the branch routes was constructed by summing the travel times to the common start and finish locations with the terminal dwell and inter-terminal times determined from the AVL data.

Table 6-37: On-Airport Travel Times

Location	Average Time - Full Day	Average Time - AM Peak (6:30 AM to 9:30 AM)	Average Time - PM Peak (4:00 PM to 7:00 PM)	Average Time - Evening (after 10:30 PM)
Common Start to Terminal A	00:37	00:37	00:37	00:37
Common Start to Terminal B-2 Offramp*				
Terminal A	01:37	01:28	01:45	01:22
Terminal A to Terminal B1	00:50	00:47	00:56	00:49
Terminal B1	01:03	00:59	01:13	00:55
Terminal B1 to Terminal B2	00:36	00:34	00:40	00:37
Terminal B2	00:48	00:46	00:57	00:43
Terminal B2 to Terminal C	01:19	01:17	01:27	01:15
Terminal B2 to **Common Finish****	01:28	01:28	01:28	01:28
Terminal C	01:06	01:10	01:10	00:54
Terminal C to Terminal E	00:57	00:46	01:07	00:58
Terminal E	01:11	00:55	01:25	01:06
Terminal E to **Common Finish**	00:50	00:50	00:50	00:50
Existing Travel Time	**10:55**	**10:09**	**12:07**	**10:05**
Silver Line 1-A Travel Time	07:00	06:39	07:36	06:31
Silver Line 1-A Travel Time Savings	**03:55**	**03:30**	**04:31**	**03:34**
Silver Line 1-B Travel Time	06:12	05:47	06:48	05:51
Silver Line 1-B Travel Time Savings	**04:43**	**04:22**	**05:19**	**04:14**

*Used to calculate the travel time for Silver Line 1-B, which travels from the Common Start to Terminals C and E

**Used to calculate the travel time for Silver Line 1-A, which travels from Terminal B-2 to the Common Finish

However, the decrease in travel time is accompanied by an increase in wait time. If you are waiting for the SL1-A, you cannot take the SL1-B if it arrives first. **Table 6-38** shows a comparison of how the headway and expected wait time would change with the introduction of branch routes. It presents the impact on existing conditions (10 minute headway) and the proposed future headway (5 minutes; see **Section 6.6.2**). As the headway in the future case is halved, it has conservatively been assumed the expected wait time will also be half of the existing (although it would be less if travel time variability decreases in the future)

Table 6-38: Change in Headway and Wait Time with Branch Routes

		Existing Conditions	Proposed Future Frequency
No Branch Routes	Scheduled Headway	10:00	5:00
	Expected Wait Time	6:02	3:01
Branch Routes	Branch Route Headway	20:00	10:00
	Branch Route Expected Wait Time	12:04	6:02
	Change in Expected Wait Time	**6:02**	**3:01**

As shown, under existing conditions the introduction of branch routes would result in 20 minute headways and an increase in the expected wait time of 6:02. In the future case with 5 minute headways, the effective headway and wait time for a particular bus (i.e. SL1-A or SL1-B) become 10:00 and 6:02, respectively.

It is important to consider how the changes in travel time and wait time are distributed; consider the summary of impacts shown **Table 6-39**.

Table 6-39: Impact of Branch Route on Airport Origins and Destinations

	Change to Travel Time	Change to Wait Time
Travelers to Terminal A and B	No change in Travel Time	Wait Time increases
Travelers to Terminal C and E	Travel Time decreases	Wait Time increases
Travelers from A and B	Travel Time decreases	Wait Time increases
Travelers from C and E	No change in Travel Time	Wait Time increases

As shown in the table, for a round-trip to Logan Airport a traveler will experience an increase in the wait time on both the inbound and outbound trips, but a travel time reduction on **one** of the trips – either inbound **or** outbound. Thus, for the implementation of branch routes to make sense, the travel time decrease should be twice the increase in the wait time for one bus. Furthermore, this assumes that travelers perceive in-vehicle time as equivalent to wait time, when some researchers have suggested that wait time is perceived more negatively than in-vehicle travel time by a ratio ranging from 1.08 to 2.5 (see **Section 6.6**). Recognizing this, the decrease in travel time should <u>exceed</u> the increase in travel time to compensate for the passengers' aversion to wait time. A comparison of the impacts to travel times and wait times is shown in **Table 6-40**.

Table 6-40: Travel Time Impacts of Introducing Branch Routes

Headway Scenario	Route	Impact	AM Peak (6:30 AM to 9:30 AM)	PM Peak (4:00 PM to 7:00 PM)	Off-Peak (after 10:30 PM)
Existing – 10 Minute Headways	**SL1-A**	Travel Time Decrease	3:30	4:31	3:34
		Wait Time Increase	6:02	6:02	6:02
	SL1-B	Travel Time Decrease	4:22	5:19	4:14
		Wait Time Increase	6:02	6:02	6:02
Future Proposed – 5 Minute Headways	**SL1-A**	Travel Time Decrease	3:30	4:31	3:34
		Wait Time Increase	3:01	3:01	3:01
	SL1-B	Travel Time Decrease	4:22	5:19	4:14
		Wait Time Increase	3:01	3:01	3:01

As shown in the table, under the existing (10 minute) headway scenario, the travel time savings do not exceed the increase in wait time on one end of the trip. If the SL1 runs at 5 minute headways, then the travel time decrease exceeds the increase in the wait time for one trip; however, as a traveler will benefit from the travel time decrease on only one airport trip but experience longer wait times for both airport trips, the net impact is a travel time increase.

Further, the introduction of branch routes may result in increased user confusion, particularly as most travelers to the airport do not make the trip on a regular basis. Confusion has been observed on the Massport shuttles when the branch routes operate in the afternoon.

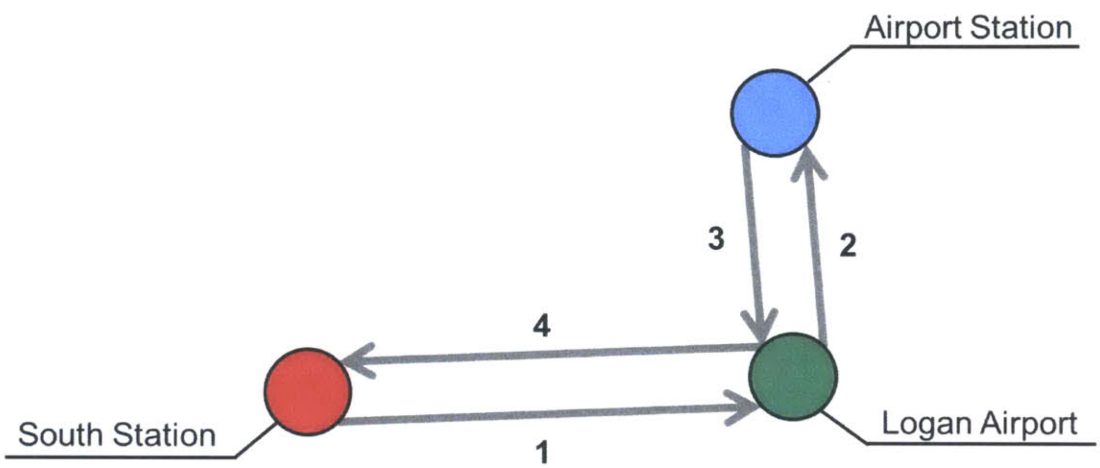
Recommendation: As a result of the increased wait time on both the inbound and outbound trip to Logan Airport, branch routes are **not recommended** under the existing 10 minute headways. Based on this assessment, branch routes also result in a total travel time increase under a 5 minute headway scenario. This analysis, however, is based on a conservative assumption of the expected wait time, and does not account for potential future increases in airport congestion which may further slow travel time. If the MBTA and Massport introduce 5 minute headways, expected wait time and on-airport travel time should be monitored. If on-airport travel times are increasing and headways are consistent, then the MBTA and Massport could consider implementing a pilot program during the PM Peak period.

6.9 Silver Line Connection to Airport Station

Another potential improvement to the Silver Line would be a connection of the Silver Line route to Airport Station. There are three primary advantages of extending the SL1 route to Airport Station:

- Silver Line service between Logan Airport and Airport Station could obviate the need for shuttle service. This would reduce shuttle operating costs; the cost savings could be allocated to improved Silver Line service
- One bus would serve both South Station and Airport Station – serving both major transit stations with one bus would be more straightforward for users to understand, and would lend itself to clear and unambiguous signage and wayfinding systems within the airport and at the curb
- The Silver Line could serve as a rapid transit connection between the Blue Line and the Red Line; this could provide improved accessibility for non-airport travelers within the MBTA system, and provide a more direct connection for Blue Line travelers to the South Boston waterfront

Three potential operating concepts are discussed below.

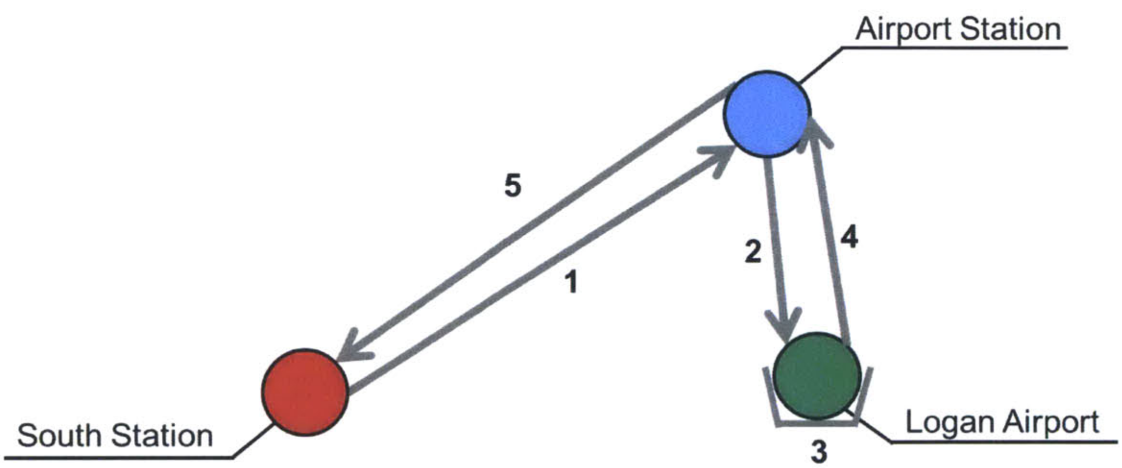
Operating Concept 1: Sequential Connections
Description: The Silver Line would serve South Station, Logan Airport and Airport Station, replacing the Massport shuttles. The order of stops would be as follows: 1. SL1 picks up passengers at South Station and travels to Logan Airport 2. SL1 drops off South Station passengers and picks up passengers from Logan Airport terminals, and then travels to Airport Station. 3. At Airport Station, SL1 drops-off passengers who boarded at Logan Airport, picks up passengers destined to Logan Airport and returns to Logan Airport terminals 4. After dropping off passengers who boarded at Airport Station and picking up any additional passengers at Logan Airport, SL1 returns to South Station.
Route Schematic 
Assessment of Route: -This route is highly circuitous, resulting in lengthy travel times for passengers boarding at Logan Airport -Inefficient connection between Red Line and Blue Line: Silver Line stops at Logan terminals between South Station and Airport Station in each direction
Recommendation: This service is **not recommended** as a result of the sizable travel time increases for passengers who board at Logan Airport on the first run of the bus. These passengers must travel through Logan Airport terminals twice. While branching routes might reduce the terminal travel time, it was demonstrated in **Section 6.8** that branch routes result in additional wait time.

Operating Concept 2: Separate Pick-Up Route and Drop-Off Routes

Description: In this concept, the SL1 would first complete a "drop-off" circulation at the Logan Airport terminals, followed by a "pick-up" circulation. The order of stops would be as follows:

1. SL1 picks up passengers at South Station and travels to Airport Station
2. SL1 picks up passengers at Airport Station and travels to Logan Airport
3. SL1 drops off passengers from both South Station and Airport Station on upper level deck of each Logan Airport terminal. The SL1 bus, now empty after dropping off all passengers, heads from the upper level of Terminal E to the lower level of Terminal A to start the "pick-up" circulation. The SL1 picks-up passengers at the lower level of each terminal. For SL1 buses to operate on the upper deck, new buses with a lower height would be required
4. The SL1 travels to Airport Station to drop passengers off. At Airport Station it can also pick up passengers heading to the South Boston Waterfront or the Red Line
5. The SL1 travels to South Station and drops off passengers

Route Schematic



Assessment of Route:

-These changes would increase the cycle time of the SL1 route, as it must now circulate through the Logan Airport terminals twice. However, the cost savings from replacing the Massport shuttles could be used to increase the number of buses on the SL1 and maintain the headways

-Every SL1 leaving South Station travels to Airport Station; every second bus leaving Airport Station travels to the Red Line. Thus, there are some direct connections between the Blue Line and Red Line

-Every SL1 bus that picks-up passengers at Logan Airport travels to both Airport Station and South Station; thus, it is a more straightforward transit connection for users

-Travel time for passengers boarding at Logan Airport increases, because the bus must now stop at Airport Station on the way to South Station. Based on the measured travel times for the airport shuttles during the PM Peak period, the increase in travel time to Airport Station would be approximately 3:40; passengers would also wait through additional dwell time at Airport Station (approximately 1:00), and additional travel time to the Ted Williams Tunnel on the service road from Airport Station. While this distance

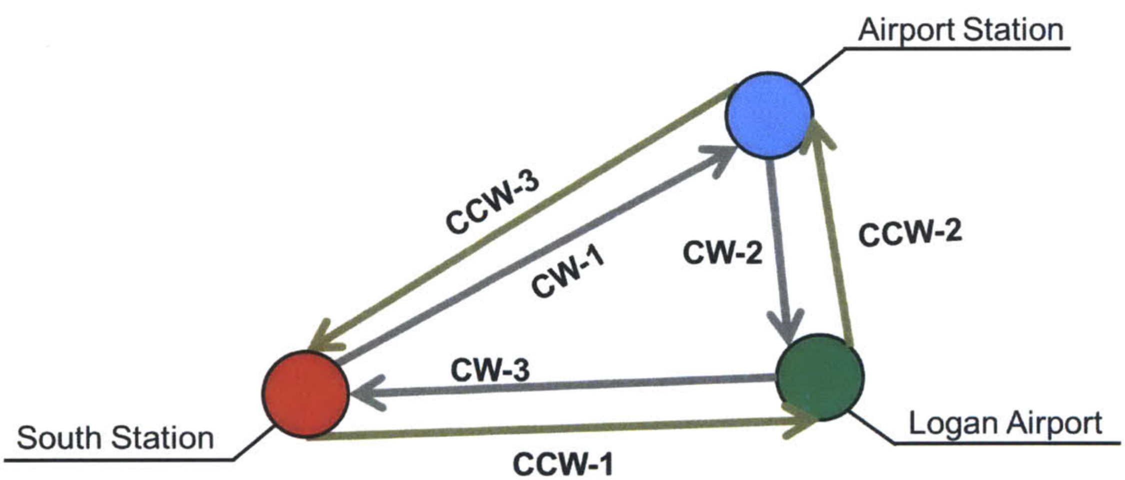
is comparable to the distance from Terminal E to the tunnel, speeds are lower on the service roadway -Travel time for passengers traveling from South Station to Logan Airport increases because the bus must now first travel to Airport Station, dwell at Airport Station and then travel to the Logan Airport terminals. Based on the Massport shuttle travel time measurements, the average travel time to the Logan Airport terminals is 3:10. Further, travel to Airport Station from the Ted Williams Tunnel requires travel on surface streets with signalized intersection, which are expected to increase delay on the trip. -Expected wait time for passengers at Airport Station could increase: while existing headways range from 3:47 to 7:25, existing Silver Line headways are 10 minutes, and an increased number of buses would be required to maintain 10 minutes as a result of the increased cycle time
Recommendation: This configuration is **not recommended**, as it results in increases in travel time for passengers traveling between South Station and Logan Airport, and increases in expected wait time for passengers traveling between Airport Station and Logan Airport

Operating Concept 3: Concurrent clockwise and counterclockwise service

Description: In this service, there are two concurrent services. Essentially, the clockwise service travels to Airport Station and then Logan Airport, while the counter-clockwise service travels to Logan Airport and then Airport Station.

Clockwise Service	Counter-Clockwise Service
1. SL1 picks up passengers at South Station and travels to Airport Station to pick-up passengers 2. SL1 travels through lower level of Logan Airport terminals to drop-off and pick-up passengers 3. SL1 returns to South Station with passengers from Logan Airport	1. SL1 picks up passengers at South Station and travels to lower level of Logan Airport terminals to drop-off and pick-up passengers 2. SL1 travels to Airport Station to drop-off passengers and pick-up passengers travelling to the Red Line 3. SL1 travels to South Station with passengers from Logan Airport and Airport Station

Route Schematic



Assessment of Route:

-The clockwise service provides a direct connection from the Red Line to the Blue Line (i.e. without stops at Logan Airport), while the counter-clockwise service provides a direction connection from the Blue Line to the Red Line

-Every second bus leaving Logan Airport travels directly to Airport Station, and every second bus leaving Airport Station travels directly to Logan Airport; this could be confusing for travelers

-As with operating concept 2, travel time increases for passengers traveling between South Station and Logan Airport and wait time increases for passengers traveling between Airport Station and Logan Airport

Recommendation: This configuration is **not recommended**, as a result of the increase in travel and wait time for airport passengers

Recommendation: As summarized in the table above, the different operating scenarios all have a negative impact on the travel times and wait times of airport passengers. Further, Massport has recently invested in new shuttles and an operations control center and it is not advisable to replace the shuttles so early into their operating life. Thus, any connection of the Silver Line 1 to Airport Station is **not recommended**. Any connectivity improvements between the Blue Line and the Red Line could take the form of a new Silver Line route that does not serve the Logan Airport terminals. Further, a potential Silver Line extension to Chelsea or Everett could include a connection to Airport Station, as discussed in **Chapter 10** of this report.

6.10 On-Airport Travel Time Savings

On-airport travel time is a substantial component of travel time for not only the Silver Line, but also the airport shuttles, Logan Express buses and other charter buses. The measures outlined in this section aim to reduce congestion on airport roadways and thereby improve the running time for these transit services. Several potential alternatives are discussed below, with a particular focus on alternatives that reduce the number of single-occupant vehicles on airport roadways.

6.10.1 Implement Tolls on Airport Roadways

Massport could toll private vehicles using airport roadways to accomplish the following objectives:

- Tolls could raise revenue to support sustainability goals, such as providing free service on the Silver Line, Blue Line and Logan Express. Public transit users place less strain on the airport roadway network, so their travel could be cross-subsidized by users of private vehicles (who cause greater emissions and consume more space on airport roadways)
- Tolls are also expected to reduce single occupant vehicle travel demand to the airport; however, it is unlikely that they will suppress trip-making. If air passengers are willing to spend hundreds of dollars on an airplane ticket, it is unlikely that airport roadway tolls will dissuade them from making a trip. Therefore, the tolls are expected to result in a shift of passengers from automobiles to public transportation, supporting Massport's sustainability targets
- Reduced vehicle volumes will reduce congestion on airport roadways and decrease the running time for the Silver Line, airport shuttles, Logan Express and other buses
- Demand-responsive tolls would increase the efficiency of use of Massport's airport roadway infrastructure: in response to high demand for a finite resource, prices should increase. For example, during low demand periods the tolls could remain low; however, during peak periods and peak times of the year, the tolls should be increased. In this way, the finite capacity of airport roadway can be effectively managed. Instead of facing congestion and over-capacity parking facilities, higher tolls would shift drivers to other, higher-occupancy modes.
- Increases in parking fees may motivate users to switch to PUDO on the curb for which there is no fee; this does not reflect the marginal cost that an additional driver imposes on all other users of the airport roadway. Thus, tolls on airport roadways could be implemented to balance the impact of increased parking fees.

Tolling may require political capital to implement, as several existing airport users are expected to object to tolls (particularly as there are already tolls to use the Ted Williams Tunnel when travelling from Logan Airport to Boston). Tolls should be introduced while – or potentially even after – improvements to the public transportation system are being implemented. This will ensure that users recognize that their tolls are being put to productive use, and also provide enhanced alternatives to driving to the airport. In consideration of equity, employees should be exempted from paying tolls.

The Commonwealth of Massachusetts is presently examining open road tolling with overhead gantries capable of automatic tolling. Massport could wait until the Commonwealth has implemented new tolling technology and learn from its experiences. Alternately, in conjunction with the Commonwealth's consideration of open road tolling, tolls on the highways leading to Logan Airport could be considered.

6.10.2 Increase Parking Fees

To discourage further increases in single-occupant vehicle travel to Logan Airport, parking fees could be increased. Considering the projected increases in demand and the fixed capacity of parking (as a result of the parking freeze), it is expected that Massport will be able to increase its total revenue by increasing parking fees. As it is desirable for Massport to maximize the revenue from its existing parking infrastructure, this may not result in a reduction in existing volumes, but should curb future increases in vehicle volumes. Further, placing higher fees for short-term parking and lower fees for long-term parking will discourage short-term parking and encourage long-term parking. This will result in a reduction of the total number of trips to and from the airport.

A summary of daily maximum parking rates at other North American airports is shown in **Table 6-41**.

Table 6-41: Daily Parking Rates at North American Airports

Airport	Maximum Daily Parking Rate
Chicago O'Hare Airport	$53 in hourly / short term and $33 in daily garage
Dorval Airport (Montreal)	$25 for one day
JFK Airport	$33 maximum for 24 hour period
Logan Airport	$27 for one day at Central Parking garage
Los Angeles Airport	$30 for one day in Central Lot; $12 in economy lot
Miami International Airport	$17 per day for self-parking / $30 per day for valet parking
Minneapolis St. Paul International Airport	$22/day at Terminal 1 lot; $16 per day at Terminal 2 lot
Newark Liberty International Airport	$33 daily maximum
Pearson International Airport (Toronto)	$28 for one day at the daily parking area
Sea-Tac Airport (Seattle)	$35 terminal direct / $28 general parking
Vancouver International Airport	$28 daily self-serve / $30 cashier

The parking rates at Logan Airport are comparable to those at other major North American airports. If the rates at Logan Airport were increased slightly, they would remain within the range of rates at other airports. Further, Massport should continue its approach of charging premium rates for short-term parking. When air passengers park for longer periods of time, there is less total VMT: therefore, a pricing structure that favors long-term parking and discourages short-term parking is expected to decrease airport related VMT.

It is possible, however, that an increase in parking fees will encourage more passengers to be picked-up or dropped-off at the terminal curb. This outcome would be detrimental for the following reasons:

- Pick-up / Drop-Off trips result in twice as many trips to the airport than does parking at the airport, increasing congestion and greenhouse gas emissions
- Increased vehicle volumes at the terminal curb will increase the running time for transit services

Thus, increases to parking fees must be co-ordinated carefully to ensure that the traffic volume is not redistributed to the curb; they could be implemented in conjunction with tolls on roads leading to the airport, or on airport roadways (as discussed in **Section 6.10.1**).

6.10.3 Re-Structure Airport Taxi Service

Within the existing regulatory environment, only Boston cabs are able to pick passengers up at the airport without a prior reservation. However, cabs deliver passengers to the airport from cities and towns all around the region. Thus, many cabs arriving at the airport are unable to pick-up passengers from the airport, and must return from Logan Airport empty. This imbalance between arriving and departing taxicabs also contributes to congestion and VMT on Logan Airport roadways. Further, some Boston cabs travel to the airport empty to pick-up passengers. Finally, because airport fares are lucrative many cabs queue and wait at the airport, which reduces the number of cabs available in the rest of the city and decreases productivity.

Re-structuring the system and allowing more cabs to pick-up passengers at Logan Airport would decrease the total VMT on airport roadways. One potential concept would be to allow taxis to travel directly to the pick-up area after dropping passengers off. These cabs could take priority over cabs already in the queue, which would result in a reduction of cab queues. This system could be introduced initially for Boston cabs without any changes to the existing legislation.

This topic is deserving of further study, but is mentioned in this report as it would also improve transit service by the marginal reduction in other vehicles on airport roadways.

6.10.4 Consolidate Shuttle Services

At present, there are several courtesy shuttles for hotels and rental car facilities that circulate on the airport roadways. Based on field observations, several of these buses carry very low passenger volumes. Shuttle services should be consolidated in order to reduce the volume of buses circulating on airport roadways and dwelling at the terminal curb. Massport is currently constructing a consolidated rental car facility, and is planning to run consolidated shuttles between the terminals and the facility[69]. This will reduce the number of private rental car buses operating on airport roadways. Consolidation of the hotel courtesy shuttles should also be considered.

6.10.5 Stricter Enforcement and Curbside Management

Private vehicles, shuttles and delivery vans sometimes stop or park illegally at the terminal curb. In some situations, private vehicles park or stop in the area reserved for buses: when buses arrive, they must stop in one of the travel lanes. This slows all traffic behind the bus, and also forces passengers to step off the curb and walk across a lane with their luggage.

Stricter enforcement of vehicle stopping and parking would help reduce congestion. Locating the priority transit services close to the main terminal doors (as recommended in **Chapter 9**) will facilitate enforcement, as vehicles are more likely to stop illegally at the ends of the curb, where drivers perceive less enforcement.

Dwell times of authorized vehicles should also be enforced. Commercial vehicles (i.e. buses) should be encouraged to minimize their dwell times, and officers should enforce adherence. ACRP 40 notes that some airport operators employ Traffic Control Officers (TCOs) in lieu of law enforcement officers because they can focus directly on traffic control without distraction by other issues, and because they are lower cost[70].

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[69] L. Dantas, personal communication, January 18, 2013

[70] ACRP 40: Airport Curbside and Terminal Area Roadway Operations, page 68, 2010

6.10.6 Reallocation of Private Vehicles to Upper Level

The airport roadway system could be rearranged to direct all private vehicles to the upper level of the terminal and all commercial traffic (such as buses, shuttles, deliveries and other authorized vehicles) to the lower level.

This new system would have the following advantages:

- The decrease in vehicle volumes on the lower level would reduce congestion and improve the running time for buses; this would be a clear way of prioritizing airport roadway capacity for HOV uses
- Conflicts between private and commercial vehicles would be eliminated
- The change would be very easy to communicate on roadway signage leading to the airport
- Having a single area for pick-up and drop-off would decrease complexity and confusion for all users
- Separating vehicle travel between levels would support the recommendation in **Chapter 9** to implement a consolidated Rapid Transit Zone on the curb at each terminal
- Consolidating all private vehicle travel on the same level would facilitate enforcement of parking and stopping infractions

This reallocation of vehicles would result in some passengers needing to switch between terminal levels. As with the existing arrangement, passengers arriving at the airport by transit would need to go up one level to check-in, while passengers arriving by private vehicle would arrive directly on the upper check-in level. Passengers getting picked-up by private vehicle would need to go up from the baggage carousels on the lower level to the upper level with their luggage. Passengers who do not need to collect checked luggage from the baggage carousel could stay on the upper level and proceed directly to the pick-up area after deplaning.

This reallocation of vehicles would be especially beneficial at Terminal B, which is a particularly space-constrained location at Logan Airport. Each side of the terminal has only 4 lanes to accommodate all stopping vehicles and all through traffic. Although this recommendation would require an analysis of the impact to airport roadway operations, it is worth further consideration by Massport.

6.10.7 Capacity Expansion

Capacity expansion such as roadway widening can also alleviate congestion, but is problematic for the following reasons:

- Logan Airport is space-constrained, and in several locations it is infeasible to increase roadway capacity
- Regardless of increases to on-airport roadway capacity, access to Logan Airport is constrained by the Ted Williams Tunnel and Sumner / Callahan Tunnel
- Increasing capacity is expensive
- Increasing capacity for general purpose lanes will encourage more single-occupant vehicle travel and may reduce demand for transit services
- It is challenging to maintain efficient airport operations during construction

Recommendation: In order to manage airport roadway capacity and reduce on-airport transit travel times, Massport should consider the following recommendations for further study:

- Implementing tolls on airport roadways or on major roadways leading to Logan Airport
- Gradually restructuring and / or increasing parking fees as parking demand continues to increase
- Studying a re-structuring of the airport taxi service to reduce taxi queues and VMT
- Continuing to consolidate courtesy shuttles
- Continuing to enforce illegal stopping / parking and excessive dwell times
- Re-directing all private vehicle traffic to the upper level and designating the lower level for commercial vehicle traffic

Large-scale roadway capacity increases are not recommended as a result of the space constraints, cost and disruption to airport operations during construction.

6.11 Express Service from South Station to Logan Airport

An express service could be run from South Station to Logan Airport, bypassing the intermediate stations: Courthouse, World Trade Center and Silver Line Way. This section discusses the advantages and disadvantages of this concept.

6.11.1 Travel Time Savings

The primary advantage of introducing this service would be to reduce travel time. Based on the travel time summary of the Silver Line presented in **Chapter 3**, the following travel time savings (**Table 6-42**) could be achieved by eliminating the dwell at Courthouse, World Trade Center and Silver Line Way

Table 6-42: Maximum Possible Reduction in Travel Time by Removing Intermediate Stops

	Inbound to Logan	Outbound from Logan
AM Peak (6:30 to 9:30 AM)	3:14	2:57
PM Peak (4:00 to 7:00 PM)	3:14	3:36
Late Evening (after 10:30 PM)	2:48	3:12

It is important to note, however, that a large portion of the dwell time at Silver Line Way is associated with the driver addressing the technology transition. Even if intermediate stops are removed, the bus will still need to stop to transition from catenary overhead to diesel, unless the recommendation from **Section 6.4** to procure a new vehicle technology is implemented.

Furthermore, the South Boston Transitway does not have any passing lanes between stations, so express SL1 buses may have to wait behind SL2 or peak period shuttles that are dwelling at Courthouse or World Trade Center. Bus bunching has been observed at D Street, indicating that SL1 and SL2 buses sometimes travel quite close together in the Transitway. Stricter headway control could address bunching by forcing SL1 buses to wait at South Station until sufficient spacing from the preceding bus has been achieved; however, this additional layover time at South Station will also increase total travel time to the airport.

Additionally, strict adherence to an "Express" service for the SL1 could lead to some inefficient operational practices. Consider a scenario where a full SL2 bus heading to South Station is trying to pick-up passengers at World Trade Center during the PM Peak. An SL1 bus may arrive behind it, and have to wait as passengers try to squeeze into the SL2 bus. Even if there is capacity on the SL1, it will not be permitted to let passengers board. Thus, the SL1 bus will have to wait as the SL2 dwells and passengers try to board, but will not be able to take any of the passengers. From a system perspective it would be much more efficient for overflow passengers to board the SL1. This would decrease the dwell time for both buses.

6.11.2 Impact to South Boston Waterfront Passengers

Removing the intermediate stops would also increase the travel time for airport passengers who need to board or alight at Courthouse, World Trade Center and Silver Line Way. To illustrate, an airport-bound passenger at World Trade Center would have to wait for an SL2 bus, travel to South Station, switch to the SL1 at South Station, and then travel through World Trade Center again on the SL1 express bus.

The MBTA 2010 Blue Book provides a summary of the number of SL1 boardings and alightings at the intermediate stations, as summarized in **Table 6-43**. While it is possible that some of these trips were to destined to intermediate stations (i.e. a boarding at Courthouse destined to Silver Line Way), it is likely that almost all these trips were Logan Airport trips.

Table 6-43: SL1 Week Day Ons and Offs – from MBTA 2010 Blue Book[71]

Stop / Station	"Ons" – Inbound to Airport	"Offs" – Outbound from Airport
Congress at World Trade Center (surface street)	N/A	137
Silver Line Way	100	70
World Trade Center	81	15
Court House Station	54	36
Total	**235**	**258**

These totals show that travel demand to the airport from the South Boston waterfront is by no means negligible. Based on the general growth in Silver Line travel between 2009 and 2012 (see **Section 3**) it is expected that existing demand is greater than this. Further, the anticipated growth in the South Boston waterfront will further increase demand for airport travel at these stations.

6.11.3 Airport Service on I-90 or Surface Streets

Given the operational constraints of operating an SL1 express service in the South Boston Transitway, an alternative would be to designate a new airport service running on I-90. This would be a fundamental change to the existing nature of the SL1; the new service could use new vehicles without the constraint of operating in the tunnel and could even be branded as something distinct. A service using I-90 would have to depart from the South Station bus terminal, as the Transitway is not connected to any surface streets.

The service would run on I-90 for the inbound and outbound directions; there is a direct connection from the South Station bus terminal to the highway. The routes are illustrated in **Figure 6-31**.

[71] MBTA 2010 Blue Book, page 39

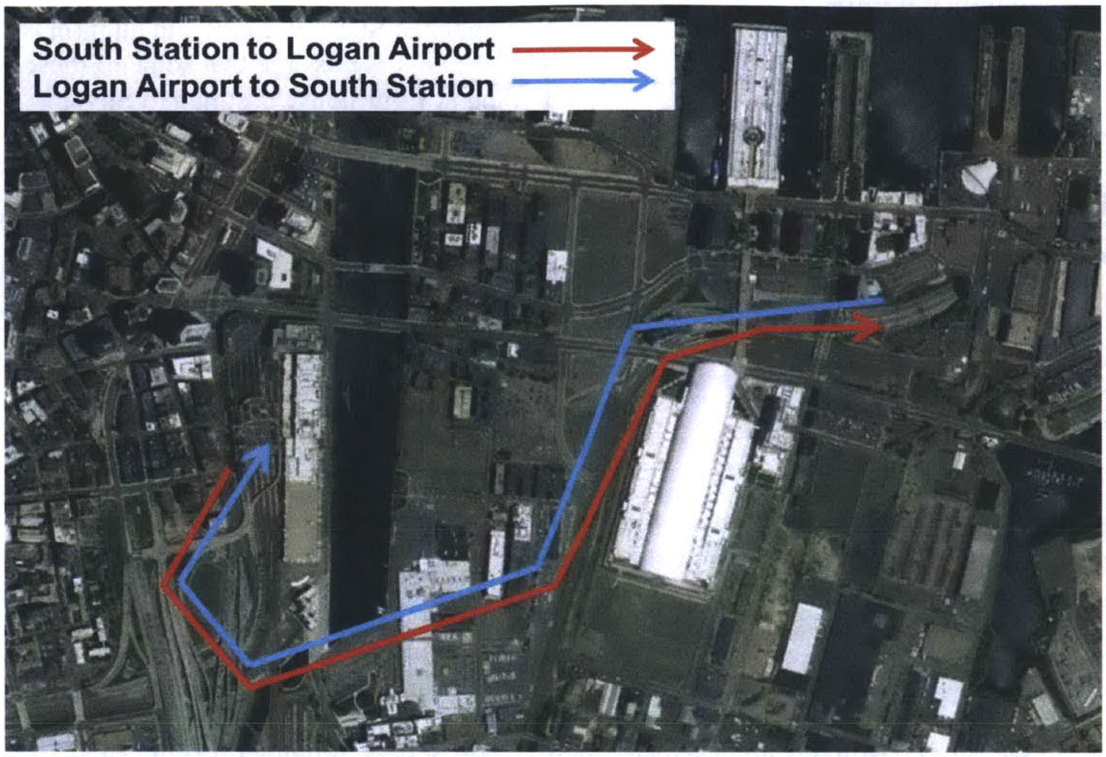

Figure 6-31: Potential Routes for South Station to Logan Airport Service

However, running buses on I-90 (instead of using the transitway) would expose buses to congestion, which is expected to increase as development of the South Boston waterfront area continues. Alternately, elements of BRT (such as dedicated lanes and transit signal priority) could be provided on streets through the South Boston waterfront; however, the bus would need to make several right-turns on the trip to Logan Airport, which will be slow as a result of pedestrian volumes crossing the intersection. Further, there is competition for capacity between pedestrians, cyclists and vehicles in South Boston, and providing bus-only lanes on surface streets replicates capacity presently available in the South Boston Transitway.

Another significant constraint is the required transfer time to buses in the South Station Bus Terminal. Passengers would no longer be able to board the airport bus at the existing Silver Line platform above the Red Line. Rather, passengers would have to transfer to the bus terminal at South Station. This transfer distance would increase the total trip time, and would be particularly challenging for riders with luggage. The existing transfer from the Red Line to the Silver Line platform is direct and convenient for travelers to the airport.

The introduction of a complementary service on I-90 (in addition to the existing SL1) is not recommended at this point in time. It would require additional resources and could detract from the existing Silver Line service, essentially dividing the transit demand. Less demand on each service could lead the MBTA to provide longer headways on each, thus increasing the overall travel time to the airport.

6.11.4 Other Considerations

To decrease the travel time associated with stopping at World Trade Center and Courhouse, signage and platforms layouts could be used to encourage the exclusive use of the SL1 by airport passengers. This would reduce the dwell time at the stations. The recommendation to reconfigure the South Station platform (see **Section 6.6.3**) would encourage only airport-travelers to board the SL1.

The MBTA could consider running some express buses: for example, every third SL1 could skip Courthouse and World Trade Center. This would have less impact to airport passengers boarding and alighting at these stations, as they would be able to use 2 out of every 3 buses. However, this would also have less of a total travel time impact (as only one third of SL1 passengers boarding at South Station would benefit) and increases the complexity of using the system.

However, as growth continues in the South Boston Waterfront area, demand for the South Boston Transitway will increase. In a potential future scenario where the South Boston Transitway is reaching capacity, it may be necessary to put some transit services – such as the airport service – on surface streets to relieve congestion. In this scenario, the concept of an express SL1 service on I-90 should be revisited. Another future possibility would be to run the airport service from Broadway Station as part of the proposed Urban Ring.

Recommendation: At present, an SL1 "express" service that bypasses Courthouse and World Trade Center is **not recommended** as several passengers use these stations to access the airport. Further, it is not possible for buses to pass in the Transitway and putting an airport service on surface streets would increase transfer complexity at South Station, compete for capacity with other modes and subject passengers to peak period roadway congestion.

6.12 South Station Remote Check-In

A potential improvement to airport access would be permitting remote check-in at South Station. Conceptually, passengers could check-in and deposit their luggage at South Station. This would result in the following advantages:

- Passengers could complete their trip to the airport via the Silver Line / Express Bus unencumbered by luggage; this would reduce crowding on the buses and provide a more convenient trip for passengers.
- This could reduce space requirements for check-in areas at Logan Airport
- The option to check-in at South Station would likely attract more air passengers to come to South Station and then take the Silver Line / Express Bus; thus, it could increase the transit mode share to Logan Airport

Remote check-in services at South Station could also have some disadvantages:

- Reluctance on the part of passengers to part with their luggage further from the airport (perception of baggage getting lost)
- Inconvenience: passengers transferring from the Red Line would have to ascend three levels to the main South Station terminal and then return down two levels (passing through the fare arrays again) to reach the Silver Line platform
- Passengers anxious about finding Logan Airport, or arriving at Logan Airport on-time, may be hesitant to incur additional delay before travelling to the airport; waiting in line at the remote check-in site and potentially missing the next bus may create feelings of anxiety for passengers
- High cost of running the service

Case studies of remote check-in services that have been introduced in other cities prove instructive. A summary of the findings reported in Chapter 5 of **ACRP 4: Ground Access to Major Airports by Public Transportation** is presented in **Table 6-44**.

Table 6-44: Summary of Remote Check-In Services at International Airports[72]

Airport and City	Description of Service	Outcome
Downtown Check-In Services		
Heathrow Airport, London	▪ Remote check-in provided at Paddington Station in conjunction with rail service to the airport ▪ Check-in area centrally located within the station ▪ Conveyor system ▪ Check-in available for nearly all major airlines ▪ Management felt that remote check-in was a critical element to distinguish the Heathrow Express rail service from competing transit services	▪ When in full operation, 1 in 5 rail passengers used remote check-in ▪ Some airlines left as they felt the cost was too high; after September 11, 2001, bags could not be checked onto any American airline at the facility ▪ British Airways withdrew from the service in 2003, which prompted the full elimination of the service in 2004 ▪ The terminal has since been renovated ▪ No decrease to the rail mode share was detected after the discontinuation of the service
Gatwick Airport, London	▪ Remote check-in at Victoria Station for British Airways and American Airlines ▪ Check-in area on mezzanine, out of view of travelers on the main level ▪ Baggage transferred to train manually	▪ American Airlines discontinued service in 2001 ▪ No decrease in rail ridership after discontinuation of service ▪ Neither existence nor discontinuation of remote check-in impacted rail mode share
Barajas International Airport, Madrid	▪ Spacious downtown check-in facility with 34 check-in desks	▪ Service highly underused; usually only 3 kiosks were open at once, and on average only 30 bags were checked per day
Munich Airport, Munich	▪ In a corner of the main rail station, Lufthansa operated a small check-in service	▪ Service discontinued in the 1990s as a result of low usage
Narita Airport, Tokyo	▪ Downtown check-in location with luxury bus connection to airport ▪ Check-in and security screening available	▪ In 2001, service was eliminated for flights to the United States ▪ Added cost to remaining airlines resulted in full cancellation of service in 2002
Kansai Airport, Osaka	▪ Check-in service available at Namba City Airport Terminal; rail connection to Kansai Airport	▪ In 2000, Japan Airlines ceased operations as a result of a dispute about operating costs ▪ Complete service discontinued
Hong Kong International Airport, Hong Kong	▪ MTRC operates remote check-in at two stations connected to the airport express service ▪ Passengers can check-in at the downtown central station 90 minutes before the flight	▪ Hong Kong Airport Express officials estimate remote check-in used by 53% of passengers using rail ▪ MTRC reviewing options, including charging passengers to check-in, discontinuing the service and allowing private contractors to use the existing infrastructure
Vienna Airport, Vienna	▪ Remote check-in available for City Airport Train	▪ Approximately 1 in 5 rail passengers use the service (approximately 10,000 passengers per month)

[72] Table summarizes findings from ACRP 4: Ground Access to Major Airports by Public Transportation, pages 107 – 134, 2008

Airport and City	Description of Service	Outcome
Kuala Lumpur International Airport, Kuala Lumpur	▪ New rail service between Kuala Lumpur Airport and Sentral Station; remote check-in available at Sentral Station	▪ Approximately 1 in 3 passengers leave their bags at the downtown facility
Near-Terminal Check-In Services		
Dusseldorf Airport Rail Station	▪ Remote Check-in provided in the high-speed rail station on the airport side of the trip ▪ Passengers have the option to check-in their bag at the rail station and then ride an automated people mover to the main terminal	▪ Passengers "overwhelmingly" opted to take their baggage to the main terminal instead of checking it in at the rail station ▪ Service discontinued in 2004
Newark Liberty International Airport, Newark (New York City)	▪ Baggage check-in service provided at Newark Airport rail station (connection between rail services at Airport AirTrain) ▪ Check-in area situated directly between rail platforms and AirTrain station	▪ Service started in November 2001 ▪ 80% of passengers took their luggage to the traditional check-in area of the airport ▪ Service discontinued in 2003
JFK Airport, New York City	▪ Shell for remote check-in area provided at AirTrain transfer facility at Jamaica Station	▪ Service never started, as no airline was interested in operating remote check-in

Recommendation: The introduction of remote check-in services in other cities has generally been unsuccessful. Air passenger interest in remote check-in services has been marginal, and airlines have balked at the cost of operating the service. While Massport or the MBTA could subsidize a service in Boston, this would reduce funds available for other priorities. Notably, the remote check-in services have not proved popular in cities such as New York and London, which are more similar culturally and socioeconomically to Boston than are some of the other cities. Given the cost, questionable market demand and increased awkwardness of transferring from the Red Line to the check-in area to the Silver Line, remote check-in services at South Station are **not recommended** at this point in time.

If an express service between South Station and Logan Airport (see **Section 6.11**) is implemented in the future, then the concept of providing check-in at South Station should be re-visited. Remote check-in at South Station would complement this potential express service. While there is a large transfer distance between the Red Line platforms and the existing bus terminal, potential future upgrades to South Station may reduce this distance and increase the convenience of a transfer between the two services.

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7 Infrastructure Improvements at D Street and the South Boston Transitway

This chapter focuses specifically on opportunities to improve the existing intersection of the Silver Line Transitway and D Street, with a focus on eliminating the existing delays to the Silver Line at the signalized intersection and increasing its capacity. The best potential improvements from **Chapter 6** have been combined into service improvement alternatives and evaluated.

7.1 Introduction to Study Area

Rapid growth in the South Boston Waterfront has increased the demand for public transit, and the Silver Line service has become one of the most important transit routes in the area. While the Silver Line is poised to become the backbone of Boston's new Innovation District, several elements of its current operation make it less efficient, and thus less appealing than it could be for current and future residents, workers and visitors. Proposed alternatives, such as grade separation at D Street, would significantly improve the flow of Silver Line buses at the intersection. Multiple alternative solutions will be evaluated in this chapter to improve the service's efficiency as the district grows.

In December 2004, the South Boston Transitway, now known as Silver Line Phase II, began operations from South Station to the South Boston Waterfront. The service was further expanded to Logan Airport in June 2005[73]. Silver Line 1 and 2 operate between South Station and World Trade Center Station through a tunnel. After World Trade Center Station vehicles reach grade level through a ramp, cross D Street at-grade through a signalized intersection, and proceed through a tunnel under the John Hancock Insurance building to Silver Line Way stop. The Silver Line section within the tunnel operates on electrical power from overhead wires. The bus then switches to diesel power at Silver Line Way. Routes 1 and 2 separate at Silver Line Way: SL1 heads northeast to Logan Airport and SL2 heads southeast to Design Center then circles back.

Ultimately, MassDOT, Massport and the MBTA must help the 1,000-acre district prepare transportation solutions for an anticipated 16 – 21 million square feet of new development[74]. The area could gain 15,000 new residents, add 35,000 new jobs, and generate $100 - $120 million in property taxes for the City of Boston by 2030. Currently, at least 24 developments are under review or recently approved by the BRA in this district. As shown in **Figure 7-1**, Waterside Place[75] is directly adjacent to the Silver Line's access ramp and currently under construction. Construction is an ongoing reality that results in a challenging environment for pedestrians, cars, bicyclists, and certainly Silver Line passengers and drivers. To support this level of development with the constraint on auto capacity reflected in the South Boston Waterfront District parking freeze, additional Silver Line capacity will needed.

[73] June 1, 2007. Silver Line Waterfront Bus Rapid Transit (BRT) Project 2007 Evaluation

[74] http://www.abettercity.org/landdev/southboston.html

[75] http://www.watersideboston.com/

Figure 7-1: Construction of Waterside Place Development. Photo Taken on 10/10/2012

The following historical satellite images (**Figure 7-2** to **Figure 7-5**) represent the developments in the area since 2001, including construction of the Silver Line Transitway, D Street grade separation over Haul Road, and construction of the D Street Ramp to I-90.

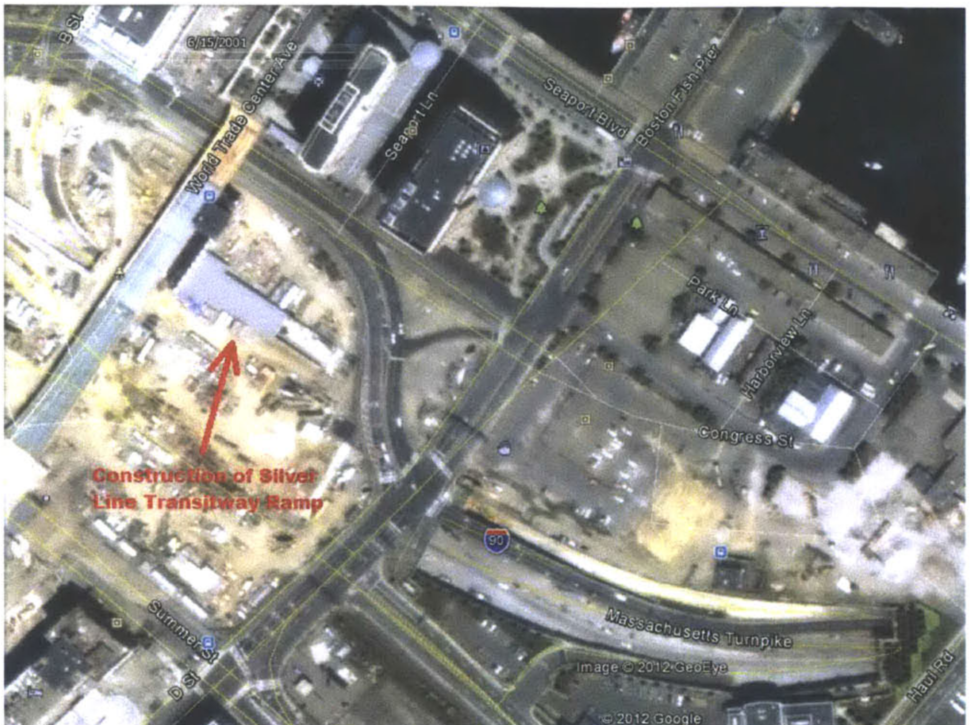

Figure 7-2: Silver Line Transitway Ramp Construction[76]

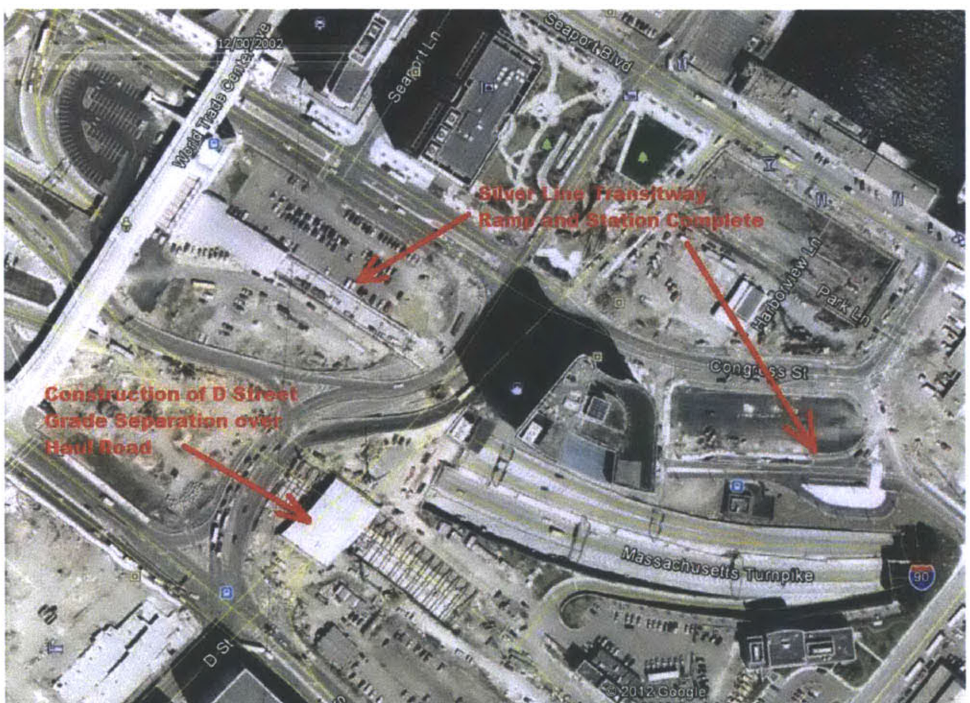

Figure 7-3: D Street Grade Separation over Haul Road Construction[77]

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[76] Google Earth Historical Imagery, Captured on 06/15/2001

[77] Google Earth Historical Imagery, Captured on 12/30/2002

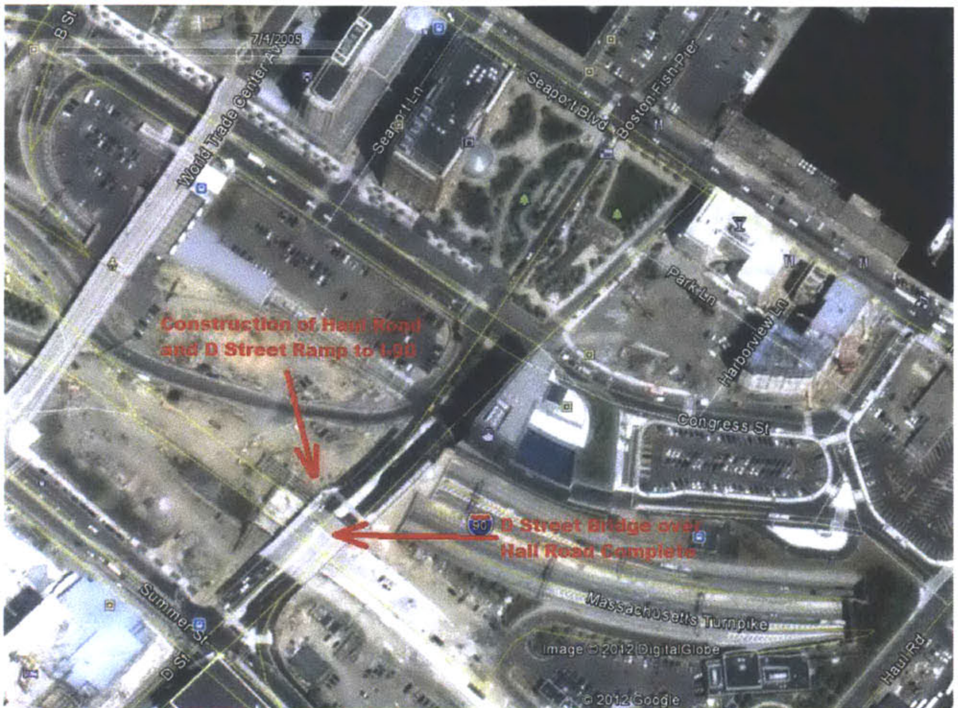

Figure 7-4: D Street Ramp to I-90 and Haul Road Construction Site[78]

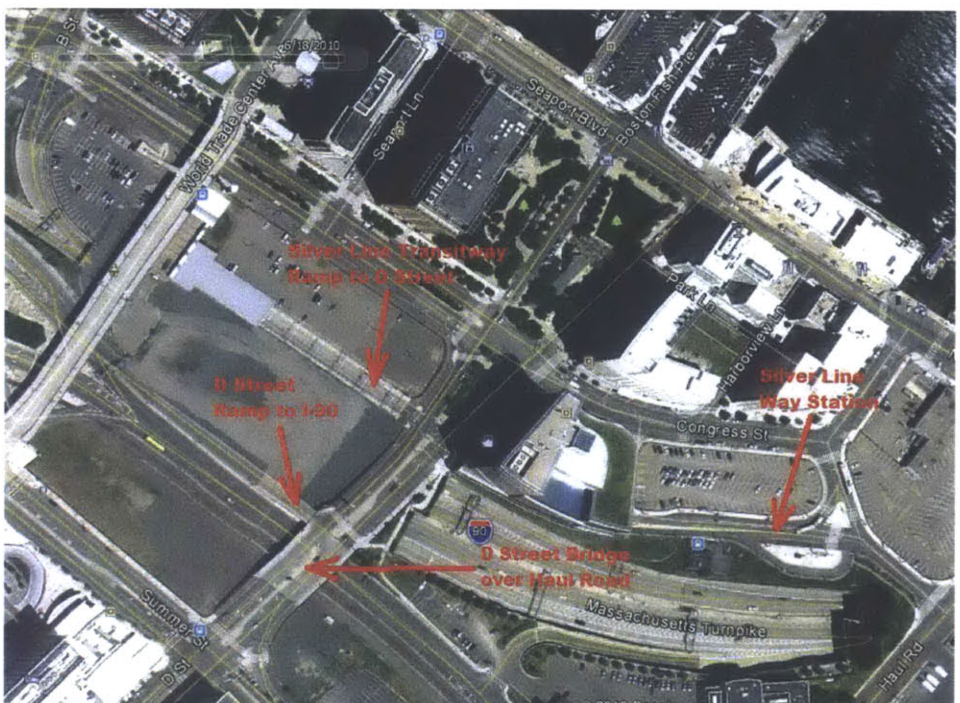

Figure 7-5: Existing Conditions near Silver Line Way[79]

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[78] Google Earth Historical Imagery, Captured on 07/05/2005

[79] Google Earth Historical Imagery, Captured on 06/18/2010

7.2 Existing Conditions

As discussed in **Chapter 6**, the SL1 turns right at Haul Road toward the west after Silver Line Way stop and makes a one-mile loop onto eastbound I-90, then approaches Logan Airport through the Ted Williams Tunnel. After looping the airport terminals, the SL1 returns to westbound I-90, exiting at World Trade Center onto eastbound Congress Street, then performs a half mile U-turn and returns to the Silver Line tunnel.

Due to the increasing demand for public transit to the airport, SL1 ridership is approaching capacity during peak hours. Decreasing the trip cycle time is the most direct way to increase transit efficiency and maximize ridership. The signalized D Street intersection is one of the most visible obstacles affecting trip times.

The average Silver Line wait time at the intersection for both the inbound and outbound direction is approximately 1 minute (see **Section 6.1** for more detail). However, several other less visible inefficiencies along the route contribute to longer trip times. Most buses stop 250 feet after the intersection to detach from the catenary and switch from electric to diesel power under the Manulife Financial John Hancock building, and 500 feet further, the buses stop again at Silver Line Way station to allow passengers to disembark and collect fares from boarding passengers. The operator will also get off the bus and check whether the technology transition has taken place properly. Occasionally all processes are performed at Silver Line Way stop. Depending on the conditions, the power transition, stops, decelerations and accelerations along the route take approximately 2 minutes in addition to the dwell time at Silver Line Way stop.

The "T under D" proposal is intended to extend the Silver Line tunnel under D Street and then reach Silver Line Way stop at grade level. Due to budget limitations when it was constructing the Silver Line tunnel, the state decided to make the D Street intersection at grade, and then grade-separate the intersection at a later date when funding was available. Since the D Street crossing is located in the redevelopment area with near constant construction including Waterside Place, a major project adjacent to the alignment, constructing the D Street grade separation would involve rerouting both the Silver Line buses and general traffic. **Section 7.4** provides detailed analysis of potential alternatives.

As shown in **Figure 7-6**, Massport owns a large amount of land near Silver Line Way, including D Street between Congress Street and Summer Street. As a result, Massport would be a direct beneficiary of Silver Line efficiency, street capacity improvements, and the enhanced urban realm along D Street that could be achieved through the grade separation of the Transitway. Further, this would benefit both airport travelers and transit users in South Boston, many of whom are traveling to or from developments on Massport property.

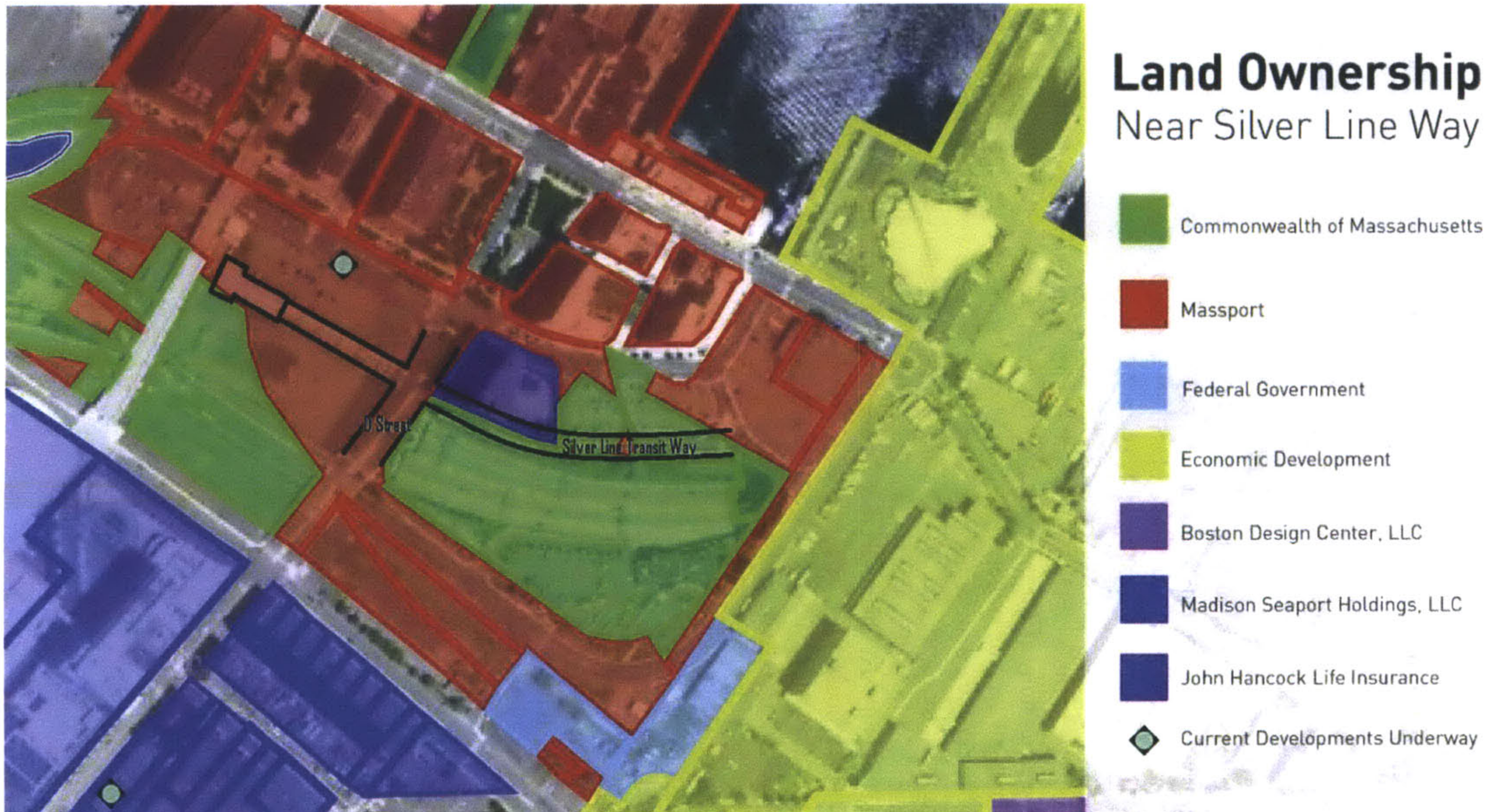

Figure 7-6: Current Land Ownership near Silver Line Way[80]

[80] Butts, Cao, Machlab, Masek, Oct 16, 2012, Grade Separation at D Street Analysis and Recommendations

7.3 Stakeholder Analysis

The following stakeholder analysis identifies parties potentially affected by this decision and their interests.

Table 7-1: Stakeholder Analysis

Stakeholder	Potential Concerns
MBTA	The MBTA operates the Silver Line and is interested in the operating characteristics of the route and possibilities for increasing efficiency and capacity as the district develops. Projected 2013 budget deficit of $185 million forced MBTA to identify inefficiencies, make service cuts, and raise fares in 2012. Resources are limited[81], but legislation is pending to increase transit funding.
Massport	Massport provides funding to the MBTA for the Silver Line and is attempting to increase the HOV mode split for travel to and from Boston Logan International Airport. Massport is therefore interested in the quality of transit service, and the ability of Silver Line buses to transfer airport passengers efficiently. Enhanced transit options reduce taxi and private automobile congestion at the airport[82]. Massport also owns the segment of D Street near Silver Line Way, which provides the opportunity for potential improvement within this area. Massport will also be concerned about proposed developments and transit access. As the primary landholder of the area, Massport earned $14.4 million in revenue from its Seaport properties in 2012[83]. Therefore continued auto access is also expected to be a concern in the short term to support the development and generate parking revenue. In the long term, its properties will generate more value if there are transit improvements and an improved urban realm along D Street.
MassDOT	MassDOT shares Board of Directors with MBTA, and the secretary is Chairman of the Massport Board. Silver Line buses utilize a MassDOT highway (I-90), and efficiency and road congestion is a concern for both parties. MassDOT is also under financial constraints[84]. MassDOT has committed to tripling the mode share for transit, bicycling, and walking across Massachusetts and will be interested in improving all non-automobile transportation options in the district.[85] MassDOT also oversees funding for transportation throughout the state of Massachusetts; it may view D Street in a regional perspective, considering its role and function within the larger context. It will also consider the funding and the opportunity cost of investing here versus elsewhere within the system.
City of Boston	Proposed changes to city streets, traffic lights or development may fall under the City's jurisdiction. The City will be supportive of redevelopment and revitalization of this area.
Boston Redevelopment Authority / EDIC	EDIC owns the Marine Industrial Park to the east and uses rents to finance their operations. Improved access may increase their rents. The BRA is involved in the "Innovation District" planning process and committed to seeing the district develop successfully.

[81] http://www.mbta.com/about_the_mbta/?id=23567

[82] http://www.massport.com/news-room/News/FreeSilverLinefromLoganAirporttoContinue.aspx

[83] http://multimedia.heraldinteractive.com/misc/seaport2.pdf

[84] http://www.metrowestdailynews.com/archive/x448230237/MassDOT-CFO-calls-state-transportation-budget-fictional?zc_p=0.

[85] http://www.massdot.state.ma.us/main/tabid/1075/ctl/detail/mid/2937/itemid/223/MassDOT-Announces-Mode-Shift-Goal-to-Triple-the-Share-of-Travel-in-Massachusetts-by-Bicycling--Transit-and-Walking-.aspx

Current / Future Residents of the District	The population of the district is small but fast growing. They seek reliable, efficient transit access to other points in Boston, a high quality pedestrian realm, parking availability, and strategies for mitigating major tourist events. Residents who need to access the airport are interested in having high quality transit service linking South Station to the airport
Employees in the District	Existing and future employees will be interested in the ease with which they can travel through the area. They are likely to be interested in improved transit service along the Silver Line, vehicle congestion and parking, cyclist facilities and the pedestrian realm along D Street. They may be in favor of continued redevelopment, or may fear that more development and intensification will increase noise, congestion and rent values.
Business Owners / Developers	Existing businesses will likely be concerned about parking and access for their employees and clients by automobile, transit, walking and cycling. Businesses will likely support increased development and densification but will also be concerned about their rents. Manufacturing and other businesses such as Gillette, Harpoon, Fedex need to move trucks in and out of the district as efficiently as possible. Congestion will adversely affect their operations. Existing property owners and developers will want to maximize the value of their properties. They will be interested in proposed improvements and how they will enhance, or potentially detract from, their properties in terms of accessibility, parking and urban design.
Businesses in the Greater Boston Area	Many in the Greater Boston Area are interested in the successful redevelopment of the South Boston waterfront into a place with major cultural and recreational destinations. Those utilizing the existing bus routes through the district will be concerned about transit frequency, capacity, and road congestion.
Tourists / Concertgoers / Conventioneers	The primary concerns will be the ease of access, pedestrian experience, and way-finding. People driving in via 93 or I-90 will be concerned about parking. Efficiency will be the concern for people arriving via public transit. The Boston Convention and Exhibition Center will likely be interested in improved multimodal accessibility.
Airport Travelers	Travelers to Boston are interested in an efficient, accessible, reliable and intuitive transit service linking the airport to hotels and destinations in Boston. The primary concerns include reliable service, comfort on the buses, dwell time, bus frequency, and road congestion.
Auto users and passengers on the I-90	Auto users and passengers on the I-90 will be interested in any proposed changes that impact the travel time, reliability and safety of travel on this highway. It is also important that increased real estate development in the area be sufficiently transit-focused to not overload the capacity of I-90 and cause congestion.

7.4 Potential Alternatives

This section describes in detail the potential alternatives for improving transit operations at D Street and the South Boston Transitway. Intersection layouts and simplified 3D models of the area have been generated to compare five alternatives:

- Alternative 1: Transit Signal Priority at D Street
- Alternative 2: Transit Signal Priority with Future Vehicle Technology
- Alternative 3: Right Turns at D Street
- Alternative 4: Grade Separation at D Street
- Alternative 5: Grade Separation with I-90 Connections

7.4.1 Alternative 1: Transit Signal Priority at D Street and Use of South Boston Emergency Access Ramp

Alternative 1 maintains the surface connection of Silver Line Transitway to D Street, and is comprised of the following two major improvements identified and recommended in **Chapter 6**.

- A Transit Signal Priority system will also be installed at D Street to minimize the delay at the intersection. A detailed analysis was presented in **Section 6.2**.
- Outbound vehicles will use the emergency access ramp to enter the Ted William Tunnel

In order to effectively compare the potential time saving with other alternatives, assume the Transit Signal Priority (TSP) system is implemented at D Street under existing conditions (see **Figure 7-7**). As the traffic volume grows, the time savings will decrease slightly due to the potential congestion within the area. The total potential time savings that would result from Alternative 1 are shown in **Table 7-2** and **Table 7-3**.

Figure 7-7: Silver Line Transitway and D Street Signalized Intersection

Table 7-2: Silver Line Average Delays at D Street under Existing Condition

	Trip to Logan	Return from Logan
Ave Delay w/o TSP	48.9 sec	47.9 sec
Ave Delay w/ TSP	6.9 sec	4.4 sec
TIME SAVINGS	42 sec	43.5 sec

Based on project team field observations, the potential time savings based on existing traffic conditions for each strategy are summarized in **Table 7-3**.

Table 7-3: TSP Scenario Potential Time Savings

PARAMETERS	TIME SAVINGS		Data Source
	Trip to Logan	Return from Logan	
Implement TSP	42 sec	43.5 sec	TransModeler model analysis; see **Section 6.2**
Utilize Emergency Ramp	2 min	0	Field observations and Massport study; see **Section 6.5**
TOTAL TIME SAVING	**2.7 min**	**0.7 min**	

As the South Boston Waterfront continues developing, network congestion will increase. The total delay within the modeled network is summarized in **Table 7-4** (based on the microsimulation analysis presented in **Chapter 6.2**). The Moderate Travel Growth case has a scale factor of 1.1 on the vehicle travel matrix and the High Travel Growth case has 1.2. Existing signal timings are used in these cases. Notably the total delays in the network are expected to be double under the Base Case with 20% travel growth. Therefore, further improvements need to be considered for the long-term condition.

Table 7-4: Total Delay and SL Waiting without TSP

CASE	Total Delay (hours)	Average SL Waiting (seconds)
1.2 Existing Conditions	64.5	48.4
2.2 Moderate Travel Growth	89.4	46.9
3.2 High Travel Growth	123	43.6

Table 7-5 shows the total delay in the network and Silver Line wait time at D Street with TSP applied. The results clearly show that TSP significantly decreases the Silver Line wait time at D Street. However, network congestion will increase as travel demand grows and due to the prioritization of Silver Line buses. All SL1 buses to South Station still need to travel on Congress Street and cross D Street. As the traffic grows, the congestion caused by TSP could potentially increase the SL1 travel time on Congress Street. Although TSP is the most cost-effective option that provides immediate benefit, the system will be insufficient to accommodate the future developments within the South Boson Waterfront District.

Table 7-5: Total Delay and SL Waiting with TSP Applied

CASE	Total Delay (hours)	Average SL Waiting (seconds)
1.3 Existing Conditions	66	5.65
2.3 Moderate Travel Growth	96.3	7.35
3.3 High Travel Growth	136	8.25

7.4.2 Alternative 2: Transit Signal Priority with Future Vehicle Technology

In addition to the improvements recommended as part of the Alternative 1, the following improvements recommended in **Chapter 6** should also be implemented once a suitable alternate vehicle technology for Silver Line buses is available:

- All Silver Line buses will no longer have the dual-mode power transition
- All SL1 buses will bypass Silver Line Way stop

Based on project team field observations, the potential time savings based on existing traffic conditions for each strategy are summarized in **Table 7-6**. The potential time saving from deceleration and acceleration, due to the elimination of the Silver Line Way station and power transition, have been calculated to be 5 seconds per full stop. There are two full stops for vehicles traveling to Logan Airport, while vehicles returning to South Station only stop once at Silver Line Way.

Table 7-6: Alternative 2 Estimated Time Savings

PARAMETERS	TIME SAVINGS		Data Source
	Trip to Logan	**Return from Logan**	
Alternative 1	2.7 min	0.72 min	See **Section 7.4.1**
Bypass SLW Station	1.5 min	1.65 min	AVL data; see **Table 3-5**
Eliminate Power Transition	30 sec	0	Field observations
Deceleration & Acceleration Time	10 sec	5 sec	Calculated values
TOTAL TIME SAVING	**4.8 minutes**	**2.4 minutes**	

While Alternative 2 will be able to improve trip times once a suitable alternative vehicle technology is available, Transit Signal Priority will not be feasible in the long-term as vehicle volumes increase.

7.4.3 Alternative 3: Right Turns at D Street

This alternative investigates the potential time savings that could result from having SL1 buses turn right at D Street:

- Return trip to South Station from Logan Airport: turn right from Congress Street to D Street to access the Transitway tunnel
- Trip to Logan Airport: turn right onto D Street after exiting the Transitway, and then turn right on the I-90 ramp to Logan

Right turns would require a vehicle that does not need to disconnect from the catenary wires at Silver Line Way. This scenario also includes the recommendations of bypassing the stop at Silver Line Way for the SL1. **Figure 7-8** shows the potential SL1 routes with right turns at D Street.

The study team performed field runs during the PM Peak on Friday, April 12, 2013 to determine the additional time that would be incurred for buses to make the right-turn from Congress Street to D Street. It was clear from the field runs (see **Table 7-7**) that the right-turn waiting times from Congress Street to D Street were significantly higher than the travel time on D Street between Congress Street and the Transitway portal. Congestion on the ramp connecting D Street to Haul Road was also observed during the visit. This also indicates that buses could incur higher travel times than they do under existing conditions without exclusive bus lanes. Therefore, a scenario without exclusive bus lanes has not been formally assessed.

Table 7-7: Time of Right Turns from Congress to D Street

Run Start Time	Wait for Turn	Travel On D Street to Portal	Total Time
5:40 PM	1:20	0:20	1:40
5:54 PM	2:45	0:07	2:52

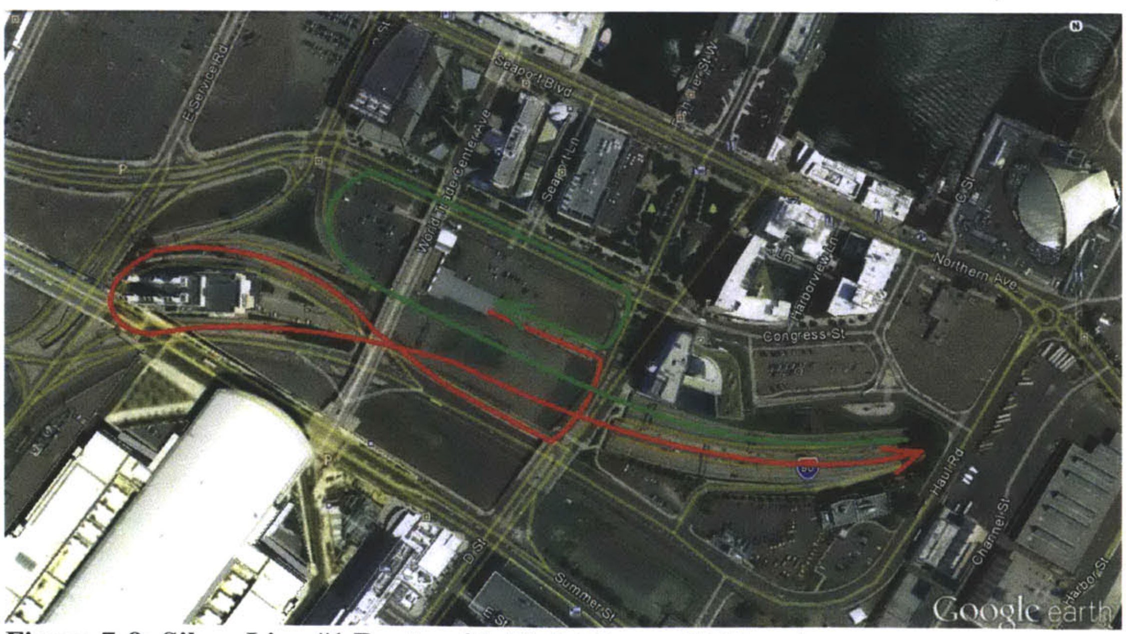

Figure 7-8: Silver Line #1 Route with Right Turn at D Street

As the existing roadway conditions are unable to provide buses enough clearance for right turn movements at D Street, channelized right-turn lanes are included as part of this alternative to accommodate the right turns, which could also require D Street roadway realignment. MassDOT could work with Massport, the owner of the adjacent properties, and MBTA for funding and construction considerations, since the improvements would benefit all authorities. A preliminary intersection layout design with exclusive SL1 turn lanes was prepared (see **Figure 7-9** and **Figure 7-10**) to eliminate the delay at the Congress and D Street intersection and the I-90 ramp. The exclusive right-turn lanes would allow the SL1 to bypass the lengthy right-turn vehicle queues both on D Street and on Congress Street. All non-airport Silver Line buses still need to cross the signalized D Street at grade.

All pedestrian sidewalks on the west side of D Street will be removed to build the channelized turns. The layout of D Street would be modified to accommodate the exclusive lanes for SL1 vehicles. An overpass bridge will also be needed for turns from D Street to the I-90 ramp. The basic design parameters for the layout (shown in **Table 7-8**) are based on those contained in the Silver Line Access Study about use of the South Boston Emergency Access Ramp by the Silver Line.

Table 7-8: Preliminary Roadway Layout Basic Parameters

DIRECTION	TOTAL LENGTH	TURN RADIUS[86]	DESIGN SPEED
Congress to SLW Portal	200'	75'	15 mph
Portal to I-90 Ramp	300'	75'	15 mph

The project team also observed the travel time between the first and second time SL1 passed D Street during PM peak hours on Friday, January 11, 2013 (see **Table 7-9**). The current travel time varies as a result of multiple factors. Based on the basic parameters, the new travel time on D Street would be approximately 10 seconds on the return trip from Logan and 15 seconds on the trip to Logan. To be conservative, the expected time savings by implementing right turns at D Street is **4 minutes** for buses returning to South Station and **3 minutes** for buses traveling to Logan Airport. The cost estimation for the conceptual design is $10 million[87]. Further analysis would be required for the actual design layout.

Table 7-9: Right-Turn Travel Time Savings at D Street Observation

Trip to Logan					Trip to South Station				
Time	**Bus ID**	**Time from D St to Haul Rd**	**Wait at D**	**Total Time**	**Time**	**Bus ID**	**Time from Congress St to D St**	**Wait at D**	**Total Time**
5:25	1125	3:11	0:20	3:31	5:39	1127	2:10	0:58	3:08
5:36	1128	3:45	0	3:45	5:40	1121	3:12	1:08	4:20
5:45	1129	3:15	0:50	4:05	5:51	1125	3:11	1:03	4:14
5:55	1124	2:07	0:26	2:33	6:03	1128	7:13	0:10	7:23
6:05	1127	2:55	0:55	3:50	6:11	1129	2:06	0:46	2:52
			Average Time	**3:32**				Average Time	**4:23**

[86] SL Ramp Study Tech Memo (Final)

[87] Cost Estimating Guide for Road Construction, March 2012

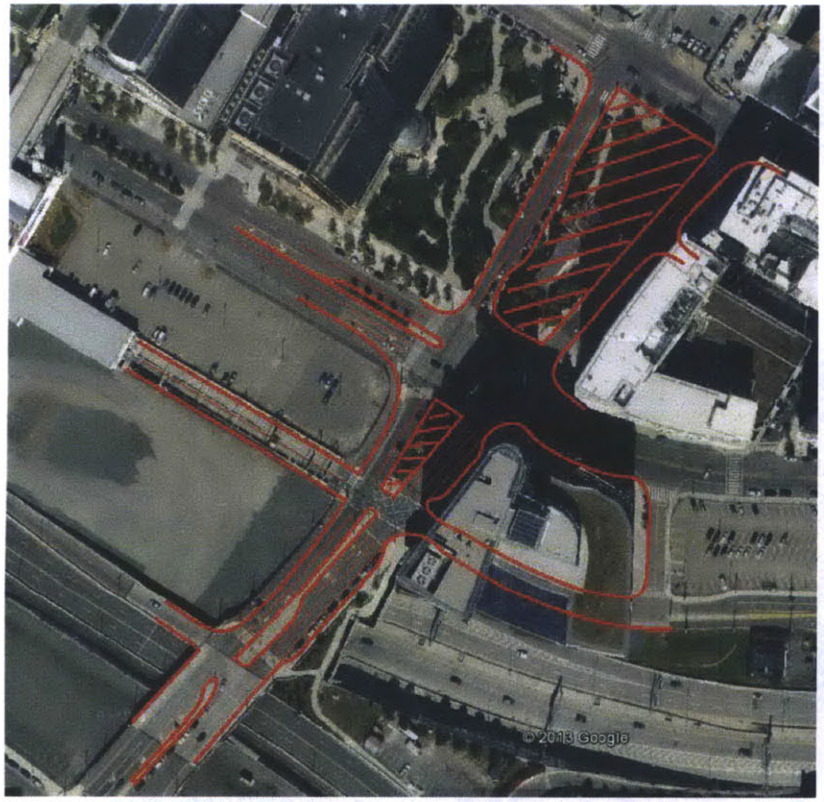

Figure 7-9: Existing Roadway Layout at D Street and the South Boston Transitway

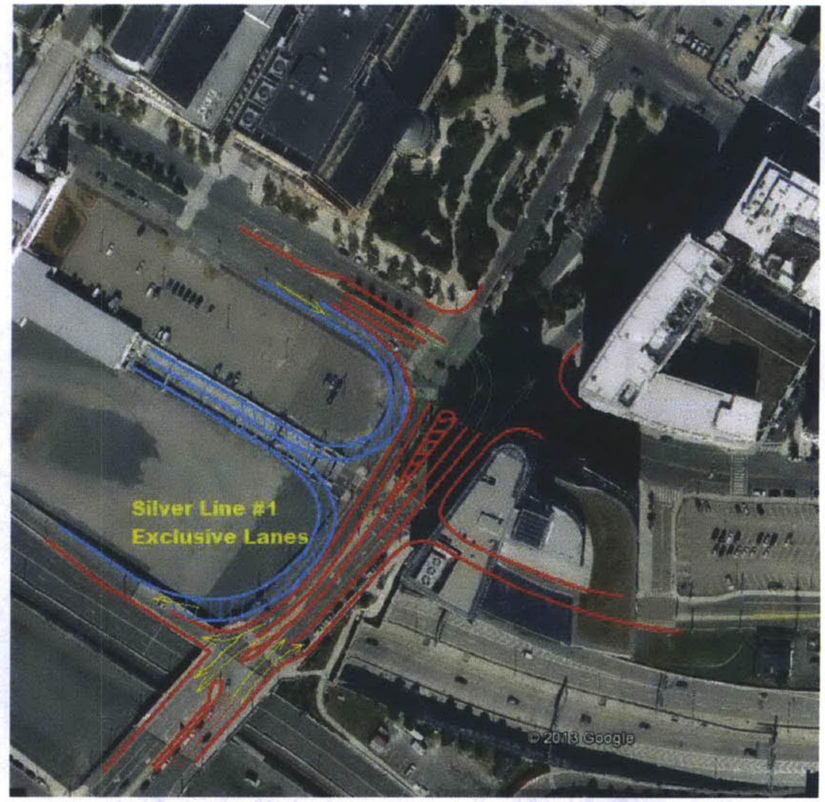

Figure 7-10: Conceptual Roadway Layout Design with Exclusive Turn Lanes

7.4.4 Alternative 4: Grade Separation at D Street

The grade separation alternative extends the Silver Line Transitway tunnel under D Street, and then connects to the surface near the Silver Line Way (SLW) stop. An aerial map of the proposed alignment and simplified 3D model are presented in **Figure 7-11** and **Figure 7-12**. For the 3D model, the surface areas above SLW are made transparent for better visual effect. Again all SL1 buses will bypass SLW station and buses to Logan Airport will use the emergency access ramp to reduce trip time. This alternative shifts the transitway portal east to SLW station. However, SL1 buses traveling from the airport to South Station would still need to cross D Street once at Congress Street. According to team field observations, Congress Street is often congested during peak hours. The future travel growth and the increasing Silver Line vehicles could potentially decrease the service efficiency due to surface congestion.

SLW stop will maintain the existing configuration with two lanes in each direction at the surface. Non-airport Silver Line buses shall always use curbside lanes so that SL1 buses can pass SLW station without delay. The grade separation design should also accommodate the dual mode technology transition at SLW if the procurement of a new vehicle technology is not possible.

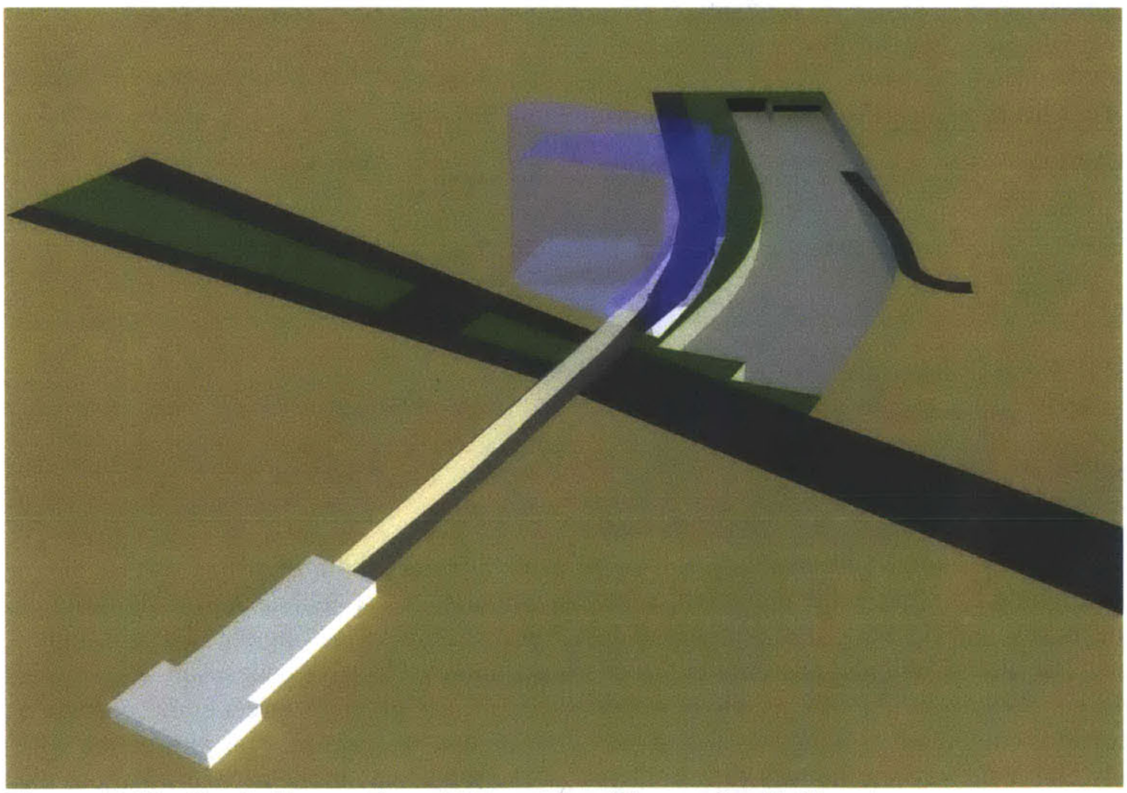

Figure 7-11: Grade Separation of Silver Line Way under D Street

According to previous observations, the average waiting time at D Street is approximately 1 minute. Assume Silver Line buses maintain 15 mph average speed travelling through the tunnel. Based on the analysis in the Base Case Scenario, one extra full stop at D Street will result in 5 seconds of time savings for both inbound and outbound directions.

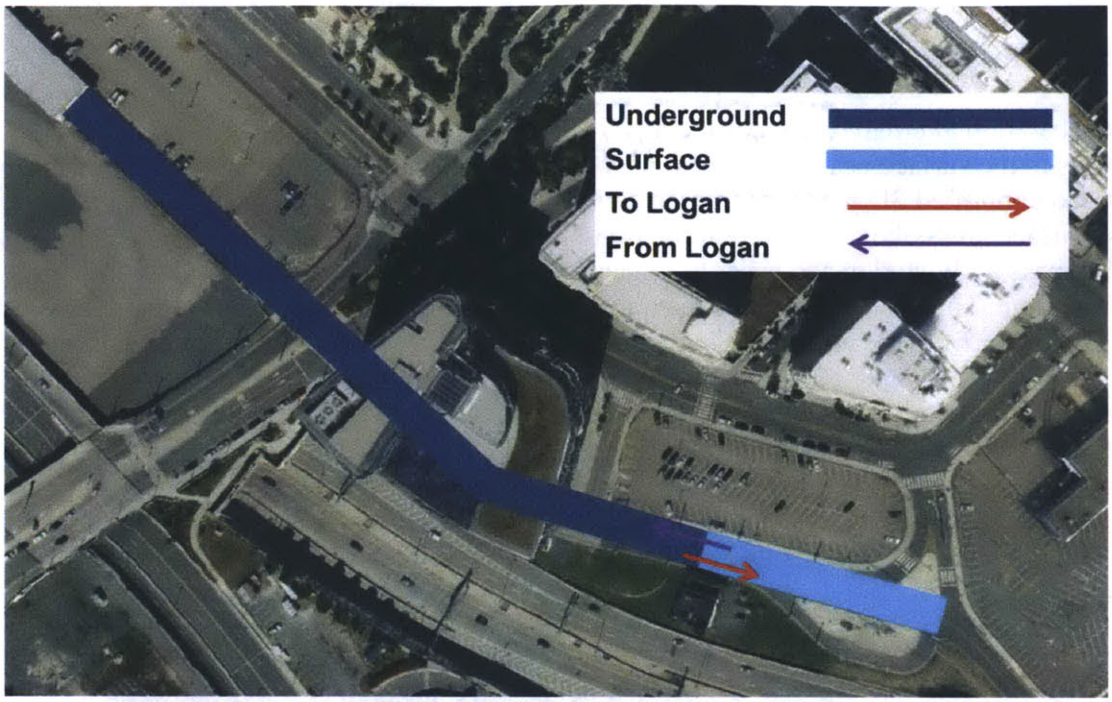

Figure 7-12: Aerial View of Grade Separation

Table 7-10: Grade Separation Scenario Potential Time Savings

PARAMETERS	TIME SAVINGS		Data Source
	Trip to Logan	Return from Logan	
Alternative 1	2.7 min	0.7 min	See **Section 7.4.1**
Signal Delay @ D	15 sec	15 sec	See **Section 6.2**
Acceleration & Deceleration @ D	5 sec	5 sec	Calculated values
TOTAL TIME SAVING	**3.0 min**	**1.0 min**	

Table 7-11: Total Delay with Grade Separated SLW

CASE	Total Delay (hours)
1.1 Existing Conditions	62.8
2.1 Moderate Travel Growth	79.2
3.1 High Travel Growth	113.8

The extension of the exclusive transitway will significantly improve the Silver Line service. Grade separation will improve the potential issues that will arise due to increasing traffic flow, Silver Line buses, and ridership. From an urban design perspective, extending the underground Silver Line Transitway will also increase D Street's functionality, improve pedestrian accessibility and safety, and enhance neighborhood vision. In particular, D Street could become a unified corridor that connects South Boston to the South Boston Waterfront. This alternative will completely eliminate Silver Line wait time at D Street. The total delay in the network without the surface intersection of SLW and D Street are shown in **Table 7-11**. Compared to the total delays in Alternative 1, the results show that grade separating Silver Line Transitway and D Street can mitigate the potential surface congestion in the area. As analyzed in **Chapter 6.2**, optimization of the signal timing at D Street and Congress Street can also improve traffic flow.

7.4.5 Alternative 5: Grade Separation with I-90 Connections

This alternative considers the grade separation with direction connection from westbound I-90 through a continuous tunnel to the South Boston Transitway. Silver Line buses traveling to Logan Airport use the emergency access ramp. A map of the proposed alignment is provided in **Figure 7-13**.

In the 3D model shown in **Figure 7-14** and **Figure 7-15**, the surface area around Silver Line Way station was made transparent in order to show the underground I-90 connection tunnel clearly. Three lanes would be constructed under the Manulife Financial John Hancock building: a two-lane ramp to the surface for all Silver Line buses traveling to Logan and for inbound non-airport Silver Line buses from the surface to the transitway portal, and one lower lane for SL1 buses returning from Logan Airport.

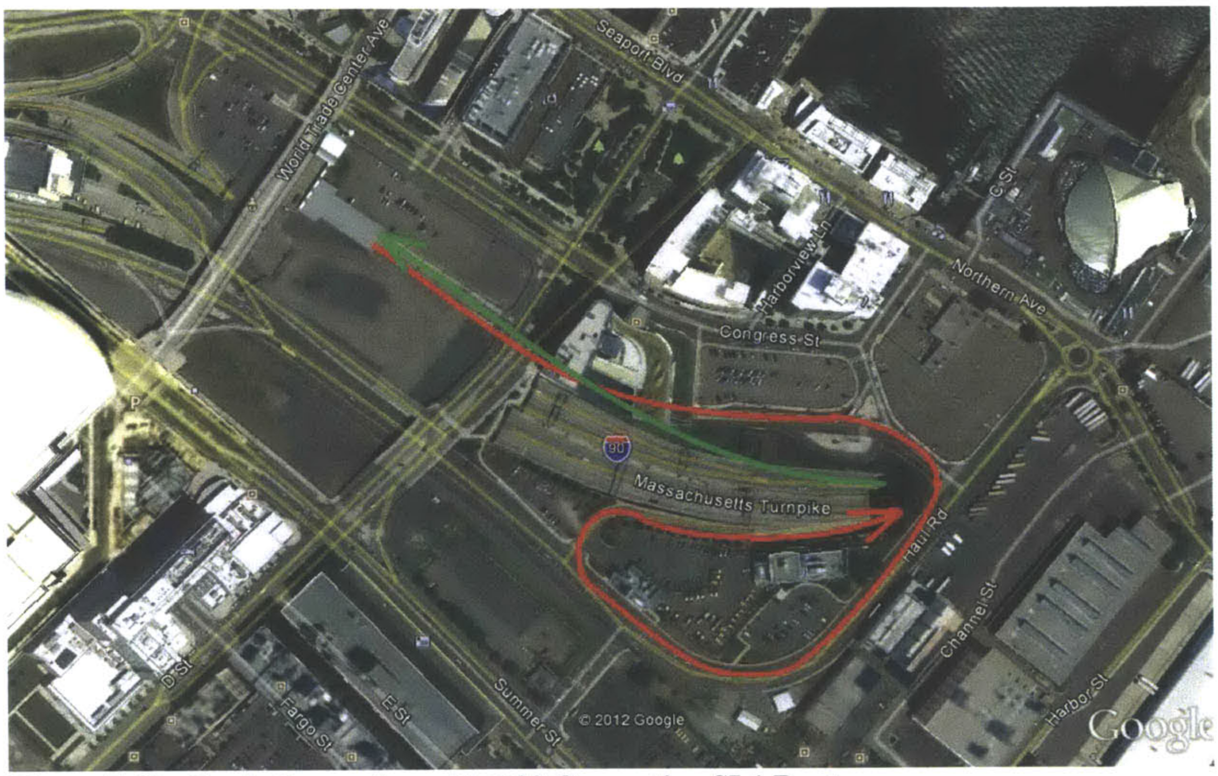

Figure 7-13: Grade Separation with I-90 Connection SL1 Route

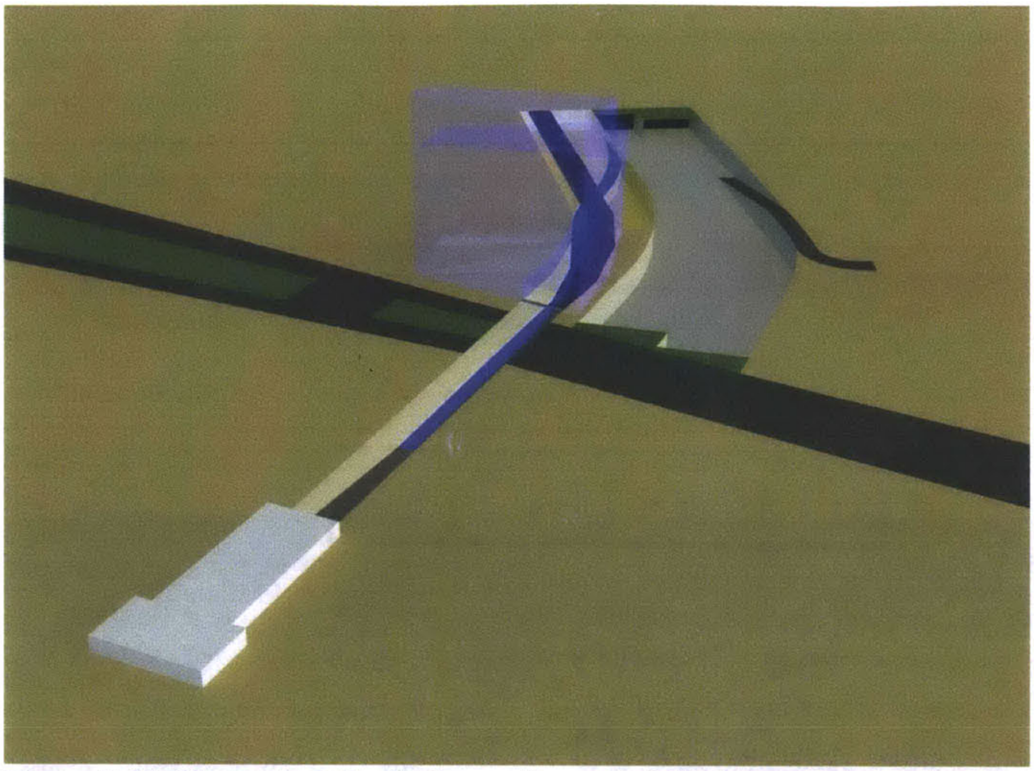

Figure 7-14: Conceptual Grade Separation with I-90 Connection, Facing East

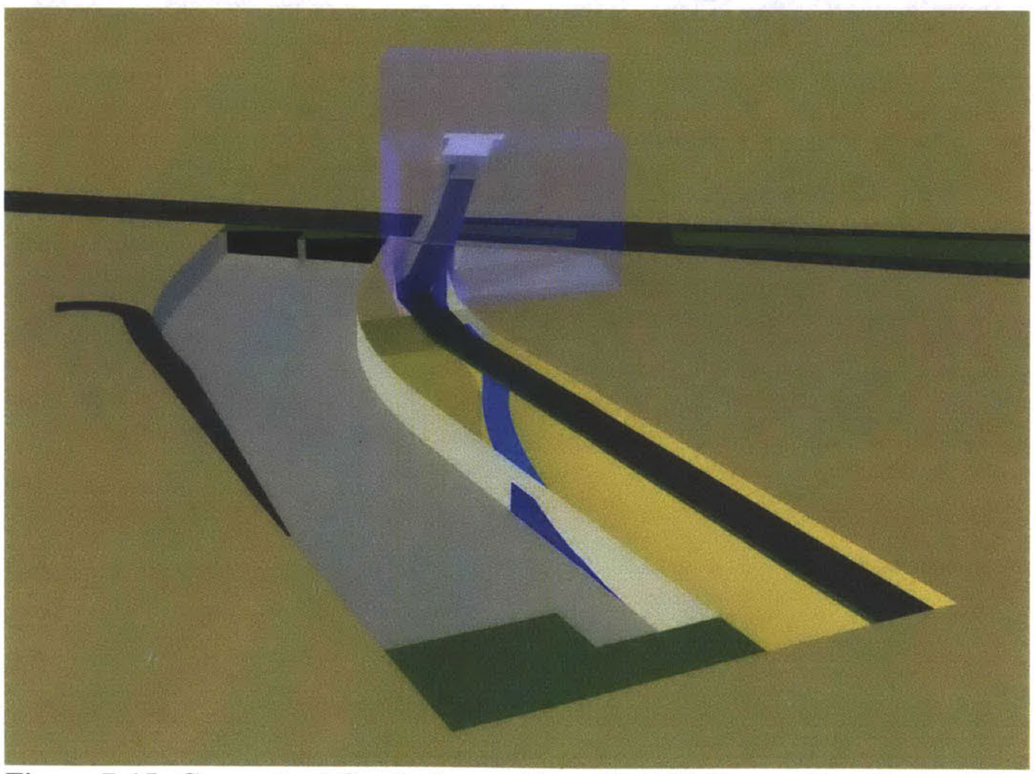

Figure 7-15: Conceptual Grade Separation with I-90 Connection, Facing West

According to field observations, Congress Street experiences congestion during peak hours. The tunnel directly connecting I-90 to Silver Line Transitway will allow buses returning from Logan Airport to effectively bypass surface congestion. In addition to the time savings listed in Alternative 4, this configuration also saves time for buses returning from Logan Airport: returning buses save the travel time from the Ted William Tunnel to SLW station (approximately 3,700 feet) including the Word Trade Center surface stop and the wait time at the signal at Congress at D Street.

Assuming average speeds 40 mph on the I-90 and Congress Street, the extra time savings are estimated to be **60 seconds** for the return trip from Logan. The travel time savings for this alternative are shown in **Table 7-12**. The total escalated construction cost for the conceptual design is estimated by the similar Red Line/Blue Line Connector project[88] (provided in **Table 7-13**). This alternative offers the greatest benefit, reducing Silver Line travel times and improving both traffic flow and urban design potential on D Street. To be conservative, the preliminary cost estimate of Grade Separation with the one-way I-90 connection is $180M to $250M. Massport and MassDOT own the affected right of way which would facilitate construction. Interim services shall be provided during construction, such as potentially running Silver Line buses on surface streets through the South Boston waterfront.

Table 7-12: Potential Time Savings of Grade Separation with I-90 Connection

PARAMETERS	TIME SAVINGS	
	Trip to Logan	Return from Logan
Grade Separation Scenario	3.0 min	1.0 min
Travel Time Saving	0	60 sec
D Street and Congress Street Signal	0	45 sec
Surface Word Trade Center Dwell	0	30 sec
TOTAL TIME SAVING	**3.0 min**	**3.2 min**

Table 7-13: Grade Separation with I-90 Connections Conceptual Cost Estimate

Grade Separation at D		$ 50 M
Tunnel from I-90 to Transitway		$ 50 M
Systems		$ 5 M
	Construction Cost Subtotal	**$ 105 M**
GC Overhead and Profit	10%	$ 10.5 M
Conceptual Design Contingency	40% - 100%	$ 42 - 105 M
Mid-Construction Escalation	20%	$ 21 M
Estimated Escalated Construction Cost for One-Way Connection		**$ 180 – 250 M**

7.5 Evaluation of Alternative Solutions

This section provides detailed evaluations of each alternative from multiple perspectives.

[88] Red Line/Blue Line Connector Cost Summary, Jan-2010

Table 7-14: Alternative Evaluations

Evaluation Criteria		1. TSP and Access Ramp	2. TSP with Future Vehicle Technology	3. Right Turns at D	4. Grade Separation	5. Grade Separation with I-90 Connection
Capital Cost		\$35,000[89] for TSP and approximately \$150,000 to retrofit Emergency Access Ramp	Cost of Alternative 1 plus cost to procure new bus technology	\$10 Million	\$100 - \$150 Million	\$180 - \$250 Million
Travel Time Savings	**To Logan**	2.7 minutes	4.8 minutes	3.0 minutes	3.0 minutes	3.0 minutes
	From Logan	0.7 minutes	2.4 minutes	4.0 minutes	1.0 minutes	3.2 minutes
Primary Advantages		**Immediate benefit** with low capital cost	**Priority access** for all SL buses crossing D Street	**Exclusive turn lanes** for SL1 buses on D Street, bypass right-turn congestion	**Eliminate surface connection** with D Street	**Bypass congestion** on Congress Street
Future Traffic Conditions with Travel Growth		**Congestion** expected as development increases	**Significant congestion** in network with transit signal priority	**Severe congestion** at intersection with complex layout	**Decreased total delay** with intersection elimination, **Moderate congestion** at Congress St	**Bypass all potential congestion** on South Boston Waterfront District local streets
Transit User Experience		**Slightly Improved** with less stopping and dwelling at SLW station	**Improved** with priority access at D Street	**Improved** with less distance traveled and less stopping. Benefits **SL1 users only**	**Improved** with non-stop travel from WTC to Logan	**Significantly Improved** with direct link from the I-90 to the Transitway
Design Complexity and Ease of Implementation		**Low level** of design complexity; TSP system installation and professional support	**Low level** of design complexity; TSP system installation and professional support; requirement for acceptable vehicle technology	**Medium-High complexity** of design including roadway reconstruction, channelized bus lane construction, land acquisition and co-ordination with existing developments	**Moderate level** of design complexity including major reconstruction of D Street, diversion of Silver Line, traffic detour, and pedestrian accessibility impact	**High complexity** of design including major reconstruction of D Street & SL Transitway, surface diversion of all SL buses, and impact to I-90 traffic

[89] TSP Report

Evaluation Criteria	1. TSP and Access Ramp	2. TSP with Future Vehicle Technology	3. Right Turns at D	4. Grade Separation	5. Grade Separation with I-90 Connection
Capacity Impact	**No impact**	**Slightly increased** capacity for all SL buses due to prioritized signal	**Increased capacity** for SL1 buses due to exclusive turn lanes, however **decreased capacity** for roadway	**Highly improved** capacity for SL buses travelling through the transitway due to grade separation	**Significant capacity improvement** due to the direct connections to I-90
Operational Impact	Vehicle queuing at intersection as bus frequency increases		Improved operation for SL1 buses; no change for SL2 and shuttle buses	Grade separation will allow for **more efficient operations**	Expected **ridership increase** due to improved service
Urban Design and Neighborhood Vision	**No impact**	**No impact**	Current landscaping in roadway medians will be **removed** for traffic lanes	Opportunity for **linear park with public art** and landscaping over existing Transitway portal	
Impact on D Street Users (vehicles, pedestrians, cyclists)	**No impact**	Potential **negative impact** to auto users and **unsafe condition** for pedestrians crossing SLW due to prioritized signal for buses	New layout might cause **confusion** to auto users; **Restricted access** due to street parking and sidewalk removal	Significant **traffic improvement** for D Street auto users, increased pedestrian accessibility due to intersection elimination.	
Community Impacts	Better access due to **improved service**		**Inconvenient access**; Continued **safety risk** at wider intersection crossings; increased noise	**Decreased noise** level as Transitway is underground; **Increased safety** due to surface crossing elimination; **Improved accessibility** for the development area; **Enhanced functionality** of D Street	
EVALUATION	**Immediate Short-Term Benefit**	**Cost-Effective Short-Term Solution, Not Feasible for Long-Term**	**Not Recommended**	**Significant Improvement for Long-Term**	**Greatest benefit; significant improvement for long-term**

7.6 Recommendations

The short-term improvement package includes the use of the emergency ramp and the Transit Signal Priority system (**Alternative 1**). Based on the evaluation in the previous section, this could potentially result in immediate benefits under existing conditions with minimal capital cost and low complexity of design. It is therefore recommended for the short-term. However, once traffic volumes and Silver Line volumes increase, excessive delays in the surrounding roadway network will eventually render TSP infeasible (see **Section 6.2**). Silver Line 1 vehicles should also bypass SLW station and eliminate the vehicle mode transition once an acceptable bus technology is available.

Alternative 3, to reconstruct D Street to provide exclusive bus lanes that allow Silver Line buses to make right-turns and bypass existing queues, is **not recommended** as a result of the detrimental impact that roadway widening will have on urban form in the area. It also offers no advantage to the SL2, short-turn shuttle and any potential future bus routes that may use the Transitway (such as the Silver Line 6)

Since the short-term strategies are infeasible as the neighborhood development intensifies, **Alternative 4** becomes critical for the future development. Grade Separation at D Street will result in significant transportation and equity improvements in the long-term and is an ideal solution to accommodate the transit demand of future developments. The team recommends that the Grade Separation be implemented before the extensive developments within the South Boston Waterfront District are complete. Growth in the area will significantly increase the construction complexity and budget as time passes.

However, the congestion on Congress Street will have a negative impact on the SL1 operating speeds on its return trip from Logan Airport. **Alternative 5**, with the one-way tunnel connection from the WB I-90 to the Silver Line Transitway could effectively address this concern. This alternative should be studied further.

Improving Silver Line services will benefit Massport directly. Considering Massport's interest in airport transit access and its ownership of several properties in the surrounding area including D Street, Massport would be an ideal candidate to contribute to the financing of this improvement. Considering the ongoing development in the South Boston Waterfront District that will increase the construction complexity and cost in the future, Massport should initiate the planning and design work for grade separation immediately.

8 Massport Transit Services

This chapter focuses in particular on two services primarily run and managed by Massport:

- The airport shuttles which provide the critical connection between Airport Station on the Blue Line and the Logan Airport terminals
- The Logan Express service which currently provides service to Braintree, Framingham, Peabody and Woburn. It is an important part of the system that serves trips beyond the MBTA's service area, and has a role in the transport of both employees and passengers

8.1 Airport Shuttles

Massport operates an extensive shuttle service to connect areas of the airport:

- Route 11: serves all terminals only
- Route 22: serves Terminal A, B and Airport Station (afternoon and early evening)
- Route 33: serves Terminal C, E and Airport Station (afternoon and early evening)
- Route 44: serves cargo area and Airport Station
- Route 55: serves all terminals and Airport Station (morning and late evening)
- Route 66: serves terminals, Airport Station and Logan boat dock
- Route 77: serves the employee parking garage in Chelsea
- Route 88: serves the economy parking lot
- OFP: serves the overflow parking area
- LOC: connects to the Logan Office Center

With the opening of the Consolidated Rental Car Facility (Conrac) in Fall 2013, Massport will also start a shuttle between the terminals and this facility.

Shuttle routes 22, 33 and 55 provide the critical connection between Logan Airport and Airport Station on the Blue Line. While several airports – both domestically and internationally – are constructing rail connections to airports, Logan Airport is already served by the reasonably proximal Airport Station on the Blue Line. The transfer between the terminals and Airport Station, however, adds another step to the trip and decreases the convenience of using the Blue Line. The need for a shuttle transfer dissuades travelers from using the service; however, an effective and efficient transfer will enhance the experience of using transit to access Logan Airport. As opportunities to improve the wayfinding and stop location for the shuttles are discussed in **Chapter 9**, this chapter focuses on five operational alternatives:

- Existing Conditions / baseline
- Alternative 1: Separate pick-up and drop-off services
- Alternative 2: Separate Conrac and Airport Station services
- Alternative 3: Combined Conrac and Airport Station services
- Alternative 4: Rail connection

Three key criteria will be used to evaluate the operational alternatives:

- Total Daily Vehicle Hours: This serves as a proxy for the cost of operating the service to Massport
- Scheduled Headway: The scheduled headway serves as a proxy for the expected passenger wait time

- Round-Trip: The round-trip travel time provides an indication of the passenger in-vehicle travel time. This value does not include dwell / recovery at Airport Station, and is based on data collected on Thursday, January 10th, Thursday, January 31st and Friday, February 1st, 2013.

8.1.1 Existing Conditions

Under the existing operations, Route 55 serves all terminals and Airport Station in the morning and the evening. During the afternoon, when there is more demand, branch routes are run to reduce travel times for passengers: Route 22 serves Terminals A, B and Airport Station and Route 33 serves Terminals C, E and Airport Station. A more detailed assessment of the existing operation of the Airport Shuttles is provided in **Chapter 3**, and the headways and round-trip travel time for each route are summarized in **Table B-1** of **Appendix B**.

In summary:

- Headways range from 4 to 6 minutes
- Round trip time ranges from 9.5 minutes to nearly 13 minutes
- Total weekly vehicle hours for these three routes is 317

These statistics serve as a baseline against which the alternative operational scenarios are compared. The branch routes (22 and 33) are included in Alternatives 1, 2 and 3.

8.1.2 Alternative 1: Separate Pick-Up and Drop-Off Services

Massport outlined a proposed new shuttle operation concept in January 2013[90]. This concept includes the following features:

- Pick-Up shuttle that picks-up passengers on the lower level of the terminals, then connects to Airport Station and the new consolidated rental car facility (Conrac) to drop passengers off
- Drop-off shuttle that picks-up passengers at Airport Station and then picks-up passengers at Conrac before heading to the upper level of the terminals to drop all passengers off. Dropping passengers off at the upper level provides a minor travel time advantage over dropping passengers off at the lower level.

These concepts are illustrated in **Figure 8-1** and **Figure 8-2**.

[90] Personal communication, Massport, January 18, 2013

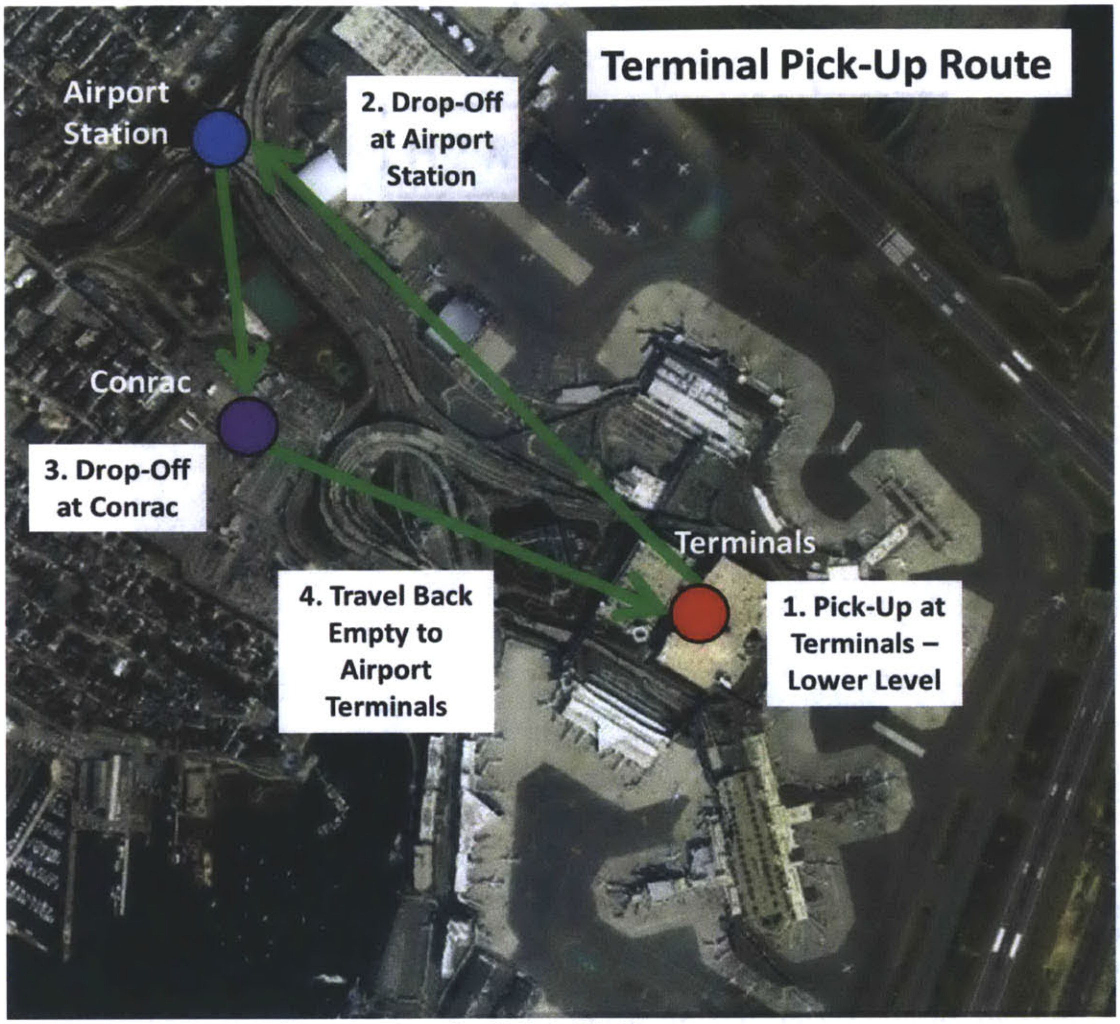

Figure 8-1: Airport Shuttle Terminal Pick-Up Route

Figure 8-2: Airport Shuttle Terminal Drop-Off Route

This essentially represents a doubling of the existing service: instead of using one bus for all pick-ups and drop-offs, there would now be a pick-up bus and a drop-off bus. Furthermore, the additional stop at Conrac will add travel time and dwell time to the service, estimated to be 2 minutes. Although there may be a marginal dwell time savings on each bus because conflicts between boarding and alighting passengers have been eliminated at the terminal stops, this is expected to be outweighed by the new stop at Conrac. Further, as the shuttles are rarely congested and all-door boarding is possible because passengers do not need to pay fares, conflicts between boarding and alighting passengers at the terminal stops is not a significant concern.

To maintain the same headways as under existing conditions, the total vehicle hours would need to double from 317 to 634. Furthermore, this would result in an approximate travel time increase on the shuttles of 2 minutes as a result of the new stop at Conrac. This additional travel time may result in less recovery time, slightly longer headways, or an increase in vehicle hours beyond 634 hours per week. This proposed operational scenario would also reduce ease of usage for passengers. Directing rental car passengers to the proposed "Rapid Transit" zone (see **Chapter**

9) to pick-up the shuttle could be confusing to users. Further, the introduction of pick-up and drop-off shuttles at Airport Station could confuse and frustrate users (customer confusion about the branch routes that operate during the afternoon has been observed). After shuttles drop passengers off, passengers may try to board them to go to the airport; however, they will have to wait for the appropriate "pick-up" shuttle to arrive. This operational scenario also results in buses travelling empty for a portion of the trip.

This scenario results in a substantial investment by Massport to operate more buses, but it does not translate into any benefits for passengers. Passengers would experience the same wait times but increased travel times as a result of the new stop at Conrac. This scenario therefore does not improve transit access to Logan Airport.

A service that first drops passengers off on the upper level and then deadheads back to the lower level to pick passengers up would improve the efficiency of this alternative: under this operational scenario, only one bus would be required for both the pick-up and drop-off. However, this scenario still results in negative impacts to air passengers traveling between Airport Station and the terminals.

8.1.3 Alternative 2: Separate Conrac and Airport Station Services

In recognition of the need for Massport to provide shuttle services to Conrac, it is clear that additional resources are required. Instead of combining the services and separating pick-ups from drop-offs, Massport could retain the existing operation of the Airport shuttle service and introduce a parallel service for Conrac. The headways, operational hours and cycle time for the Airport Station service would be unchanged over the existing scenario.

The characteristics of the new Conrac shuttle service would be very similar to the existing Airport Station service. The total cycle time is expected to be similar, as the route is very similar and the time required for passengers to board and alight at Conrac is expected to be similar to the time required for passengers at Airport Station. According to the 2010 Logan Airport Air Passenger Ground Access Survey, 10.9% of passengers arrive at Logan Airport by rental car, compared to 7.6% by transit[91]. Therefore, the headways for the Conrac service should not be less than the existing Airport Station service (which also serves many employees). Therefore, introducing a separate and parallel Conrac shuttle service would require approximately as many resources as are required to run the existing Airport Station service.

While the cost to operate this alternative is similar to the cost for the separate pick-up/drop-off alternative, this alternative does not increase the travel time for passengers travelling between Airport Station and the Logan terminals. It also provides a more direct connection for passengers travelling to Conrac, as they do not need to wait on the bus at Airport Station. Buses also tend to dwell at Airport Station to wait for the next Blue Line train to arrive, which would increase travel time for the passengers travelling to Conrac. This alternative would be easier from a signage and wayfinding perspective at the terminal curb: the Airport Station bus would stop in the proposed "Rapid Transit Zone" and the Conrac bus would have a separate "Rental Car" area on the curb. Conrac services could serve the upper level of the airport terminals, improving service for passengers flying out and reducing congestion at the lower level.

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[91] Massport 2010 Environmental Data Report, 5-27

8.1.4 Alternative 3: Combined Conrac and Airport Station Services

In Alternative 3, one bus service for both Conrac and Airport Station is proposed. This bus would handle both the pick-up and drop-off and use the lower level as the shuttles do today. This service would result in additional travel time with the stop at Conrac, and potentially lengthened dwell times to accommodate the increased number of boardings and alightings.

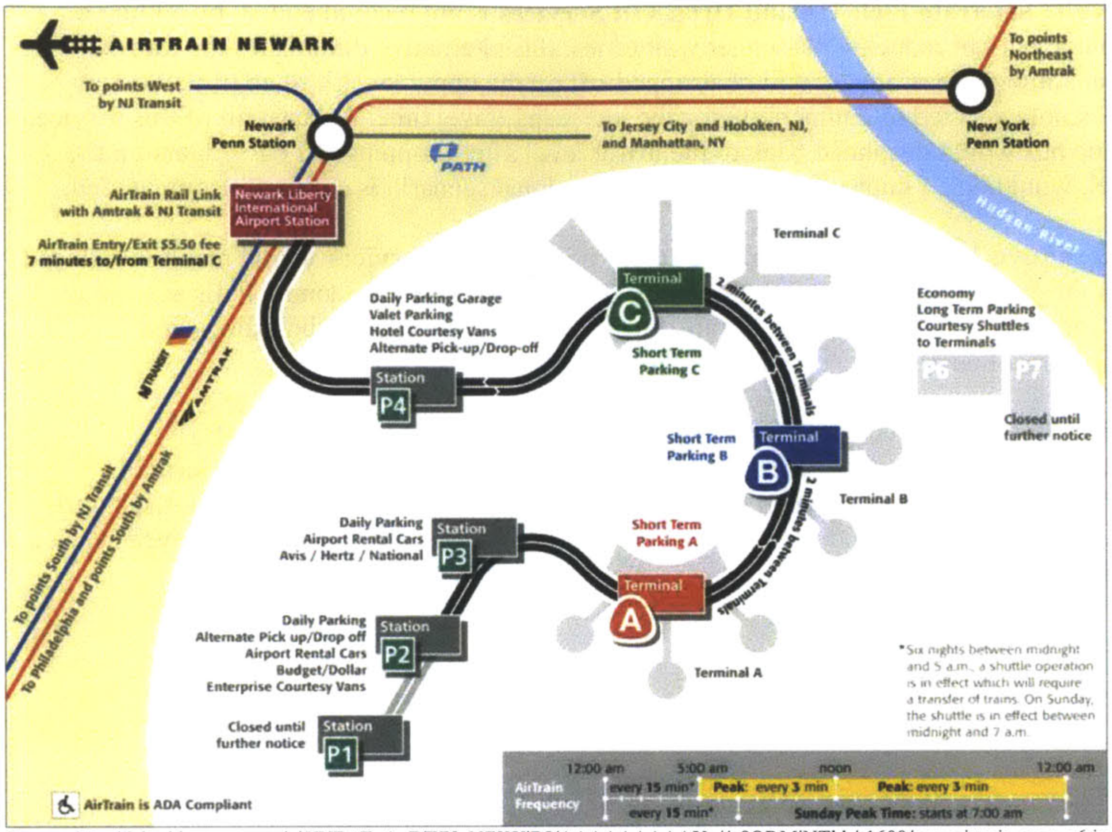
The potential advantage, however, derives from the increased service level that could be provided. Doubling the operating hours for the service from 317 to 634 (as would be required for Alternative 1 and 2) could translate into significantly reduced wait times. Headways could be halved from the existing 4-6 minutes to 2-3 minutes, resulting in a very high-frequency service. As users tend to perceive wait time more negatively, this would result in a greater increase in utility than would the same reduction in in-vehicle travel time. Furthermore, the waiting areas at Airport Station and the terminal curb are exposed to the elements and are somewhat uncomfortable: increasing frequency would decreasing the amount of time passengers and employees must wait there.

The larger volume of people using the service – both Airport Station users and Conrac users – would help justify the positioning of the bus stop near the central doors at each terminal. Further, it would provide justification to lengthen the period of time during the day when the branch routes (Shuttles 22 and 33) operate. This would also result in in-vehicle travel time savings to users, although would require slightly longer headways or slightly more cost.

Additionally, any bus travelling from the terminals to Conrac must travel past Airport Station, regardless of whether or not it needs to stop there – there is no alternative route to connect the terminals to Conrac. Thus, the travel time between the terminals and Conrac is unchanged by adding a stop at Airport Station (aside from the additional dwell time).

8.1.5 Alternative 4: Rail Connection

The Logan Airport terminals could be connected to Airport Station via a rail service, similar to the AirTrain at Newark Liberty International Airport. Newark Airport is not unlike Logan Airport in that both airports have a decentralized terminal structure and are relatively near to a rapid transit station. The AirTrain at Newark Airport connects the terminals to parking lots, rental car facilities and a rail station (Newark Liberty International Airport Station) on the northeast corridor with rail connections to Penn Station in New York City. The AirTrain has a peak period headway of 3 minutes. The system map for this service is shown in **Figure 8-3**. A service at Logan Airport could loop around the terminals and connect to Airport Station and Conrac.



Source: http://2.bp.blogspot.com/_jXUFutT_AgE/TF8zNZKXjDI/AAAAAAAAAXo/4r8ORMjNTkk/s1600/ewr_airtrain_map_r6.jpg

Figure 8-3: Newark Airport AirTrain Service

Alternately, a new branch of the Blue Line could be extended to Logan Airport; this would eliminate the need to find and use a new technology, and would provide passengers with a transfer-free ride from Logan Airport to downtown Boston.

While it would improve the connection to Airport Station, a rail link would also be expensive and complex to construct given the spatial constraints at Logan Airport.

8.1.6 Recommendations

Recommendation: As a result of the new Conrac facility, Massport will need to allocate additional resources to run a shuttle service. Among the discussed alternatives, the recommended operational plan is **Alternative 2: Separate Conrac and Airport Station Services**. This alternative protects transit users from delays that would be associated with a stop at Conrac from the additional travel time and dwell time. Further the likelihood of families boarding (with strollers and large luggage) could result in longer dwell times. This additional stop would take place on the higher anxiety inbound trip to Logan Airport when passengers are more concerned about arriving on time. This alternative maintains the status quo for existing travelers and would provide a similar quality service for rental car passengers. This alternative also provides a time for buses to layover on each service. A variant of this operational scenario could introduce upper level drop-off at the airport terminals with a deadhead loop to pick up passengers at the lower level. This would improve service level, but at added cost.

Alternative 1: Separate Pick-Up and Drop-Off Services is not recommended: by adding a stop at Conrac but not reducing passenger wait times, this alternative diminishes the transit experience. Although passengers will be dropped-off on the upper level instead of the lower level, this is not expected to compensate for the increased travel time. A variation of this service, whereby the bus would deadhead back to the lower level after dropping-off passengers on the upper level, would be an improvement, but this operational scenario is still not recommended.

While **Alternative 3: Combined Conrac and Airport Shuttle Services** would result in reduced wait times for passengers by doubling the frequency, but bus bunching, long dwells at Conrac, crowding and increased dwells at the terminal to accommodate increased boardings and alightings could all degrade the transit user experience.

As a result of the cost, expected ridership and spatial constraints, **Alternative 4: Rail Connection** is not recommended at present. The concept should be re-visited and formally assessed in the future, however, when transit ridership has increased to the point that the shuttle service is no longer suitable and the number of users who will benefit from the improved service has increased.

8.2 Logan Express

8.2.1 Introduction

Massport provides four nonstop bus services to and from Logan Airport. The four bus terminals are located within suburban park-and-ride facilities in Braintree, Framingham, Woburn, and Peabody. Woburn and Peabody are the two most recent locations where Logan Express services were implemented, in November 1992 and September 2001 respectively[92]. As discussed in **Section 3.4**, the Logan Express services generally operate every 30 minutes during weekdays and hourly during weekends. The travel time is approximately 30 to 45 minutes per trip, depending on traffic conditions. **Figure 8-4** shows the Logan Express routes.

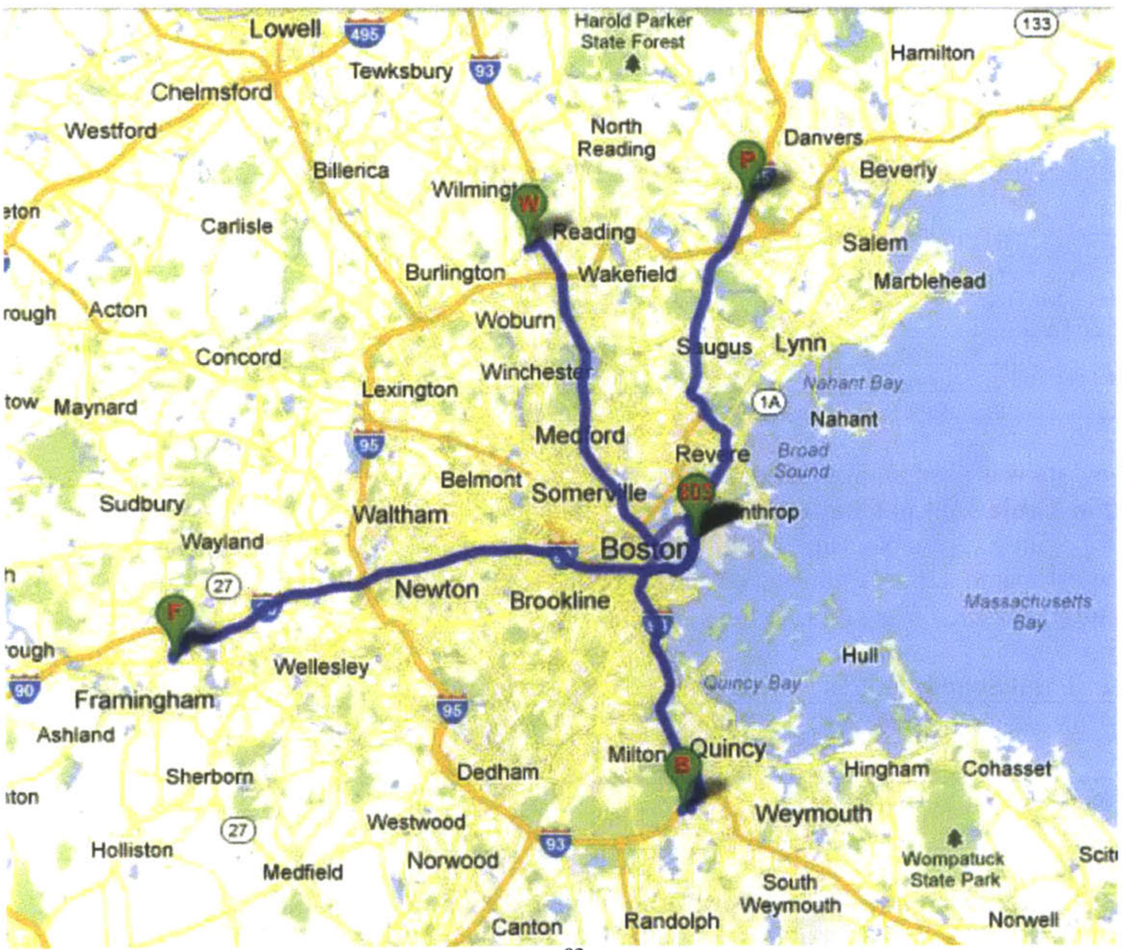


Figure 8-4: Current Logan Express Route[93]

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[92] Boston-Logan International Airport 2010 EDR Appendix G

[93] Generate by Google Map Directions by Car

To improve sustainable transportation to Logan Airport, it is desirable to attract more passengers to the Logan Express service. However, as discussed in **Chapter 3**, the number of air passengers using the service has been declining since 2006. This section will review Logan Express passenger loads, transit fares, and parking prices to investigate the decline in passenger loads and provide recommendations for how to increase ridership on the Logan Express services.

8.2.2 Passenger Loads

2011 Logan Express passenger count summaries provided by Massport have been used to estimate average ridership per trip. The mean average loads for each location are calculated as follows:

$$\frac{(\text{Weekday}_{\text{inbound}} \times 5 + \text{Weekday}_{\text{outbound}} \times 5 + \text{Sat}_{\text{in}} + \text{Sun}_{\text{in}} + \text{Sat}_{\text{out}} + \text{Sun}_{\text{out}})}{14}$$

The average loads by route and by day of the week are shown in **Table 8-1**.

Table 8-1: Logan Express Max Load and Average Load per Trip in 2011

		Braintree		Framingham		Woburn		Peabody	
		In	Out	In	Out	In	Out	In	Out
Max Load in 2011		**55**	**55**	**49**	**49**	**42.5**	**34**	**29.5**	**21**
Max Load Time		3:15am Fri	1:00pm Sat	5:00am Sat	8:00pm Tue	4:00am Sat	1:00pm Sat	4:15am Mon	1:15pm Tue
Average Load per Trip	Weekdays	18.58	20.04	13.07	12.59	10.72	11.27	3.57	4.00
	Saturday	15.69	19.67	12.65	12.26	10.02	13.33	3.36	3.74
	Sunday	15.32	18.91	11.93	11.77	9.43	10.18	3.13	3.30

The above data was used along with the number of daily scheduled Logan Express trips (provided in **Table 3-24** in **Chapter 3**) to estimate the annual ridership on each route. The total scheduled Logan Express bus trips in 2011 are calculated in **Table 8-2**. In order to check these results, the estimated annual totals have been compared to the separately published annual ridership totals for each route (**Table 8-3**).

Table 8-2: Total Scheduled Bus Trips for Each Route in 2011

	Braintree		Framingham		Woburn		Peabody	
	In	Out	In	Out	In	Out	In	Out
Annual Scheduled Bus Trips	13919	12146	13241	12146	13606	12146	6670	6565

Table 8-3: Comparison of Estimated and Reported 2011 Annual Ridership

		Braintree	Framingham	Woburn	Peabody
Annual Ridership	Estimated	490,524	321,913	279,850	48,934
	Reported	519,036	340,529	269,261	57,296
Difference		-5.49%	-5.47%	3.93%	-14.59%

The estimated annual ridership for each route is within acceptable error range of the reported annual ridership. Therefore, the average loads per trip are considered valid. For Braintree, Framingham, and Woburn branches, the average ridership ranges from 10 to 20 people per trip.

These findings indicate that the decline in airport passenger use of Logan Express was not caused by crowding or a lack of capacity brought about by increased employee use of the service. Additionally, Massport has indicated that the availability of parking at the facilities is not an issue.

The Peabody route has the lowest ridership and the least scheduled service. The maximum load for Peabody route in 2011 was less than 30 passengers per trip. The daily peak ridership on Peabody branch generally happened around 4AM inbound direction, and 1PM outbound. Therefore it is reasonable to predict that most of the Logan Express riders are morning-shift airport employees.

The catchment area of each Logan Express is provided in **Figure 10-1** in **Chapter 10**. Notably the Peabody catchment area is adjacent to the bay area and overlaps with Woburn. This also explains the relatively low ridership in Peabody. It is clear that most Logan Express users coming from north and living in between will choose Woburn route since the service is more frequent and it is accessible by more highways.

The project team recommends that Massport consider a van or shuttle service instead of Logan Express buses for Peabody, increasing the van frequency during peak hours. This would result in the following advantages:

- Using smaller vehicles would allow the operator to deploy its larger buses elsewhere and would have lower fuel costs and emissions.
- Decreasing the vehicle size could also allow Massport to try increasing the frequency and test the sensitivity of the market to increased frequency.

This concept could also be tested on the more successful Braintree route, to see whether smaller vehicles at increased frequency stimulate increased demand. The intention is to test the service on the routes with the highest and the lowest demand to evaluate the performance and feasibility. Further decisions can be made based on the analysis of the trial services.

Massport could also consider implementing SuperShuttle, a will-call shared van service, instead of the fixed schedule transit service.

8.2.3 Comparison of Logan Express Price to Airport Parking Price

The price of parking at a Logan Express lot and purchasing a Logan Express ticket will also influence Logan Express ridership. Below are the basic transit fares and parking rates listed on Massport's website.

Logan Express Fares:

- Adult Round Trip Fare: $22
- Children under 17: Free

Daily Parking Rates:

- Logan Express Park and Ride Facilities: $7
- Logan Airport Economy Parking Lot: $18
- Logan Airport Economy Parking Weekly: $108
- Logan Airport Regular Garage Parking: $27
- Round-Trip Cash Highway Toll: ~ $6
- Round-Trip Extra Gas Price: ~ $10

Estimated One-Way Taxi Fares (including 15% tip)[94]:

- Between Braintree and Logan Airport $63
- Between Framingham and Logan Airport: $95
- Between Woburn and Logan Airport $60
- Between Peabody and Logan Airport: $63

Passengers consider alternative transportation modes to Logan Airport depending on their trip characteristics; three scenarios have been developed to illustrate the decision-making process for a particular traveler. Assume in each scenario that the passenger lives close to a Logan Express park and ride facility, has no preference for auto or transit and is motivated by low costs but will pay somewhat more for a more convenient service.

The scenarios show that in the case of one day trip with two travelers and a 7 day family vacation, the Logan Express will not be the most cost-effective mode to use.

[94] http://www.taxifarefinder.com

Scenario #1: 1-day Trip with 2 Travelers

	Airport Parking	Economy Parking	Logan Express
Cost	$27 + $6 + $10 = **$43**	$18 + $6 + $10 = **$34**	$7 + $22 x 2 = **$51**
Consideration	Most convenient, indoor connection to terminals	Require long airport transfer	Longest trip and most expensive
Decision	**Most likely**	Possible	Not likely

Scenario #2: 4-day Business Trip Drive Alone

	Airport Parking	Economy Parking	Logan Express
Cost	$27 x 4 + $6 + $10 = **$124**	$18 x 4 + $6 + $10 = **$88**	$7 x 4 + $22 = **$50**
Consideration	Convenient but expensive	Cheaper than airport parking and less travel time than Logan Express	Cheapest option with long transit trip
Decision	Not likely	Less likely	**Most likely**

Scenario #3: 7-day Family Vacation, Parents with 1 Child under 17 and 1 Child over 17

	Airport Parking	Economy Parking	Taxi (exclude Framingham)	Logan Express
Cost	$27 x 7+ $6 + $10 = **$205**	$108 + $6 + $10= **$124**	$63 x 2 = **$126**	$7 x 7 + $22 x 3 = **$115**
Consideration	Convenient but expensive	Inconvenient airport transfer	More expensive than Logan Express, most convenient door to door service	Cheapest, but longer travel time with multiple pieces of luggage
Decision	Not likely	Less likely	**Most likely**	Possible

While the comparison above was based on regular prices, Massport sometimes runs promotional events during times of peak airport parking demand to encourage usage of Logan Express. An example of a promotional event for Logan Express – the new Massport April School Vacation Discount – is illustrated in **Figure 8-5**. This is an excellent example of how Massport attempts to manage potential overflow parking demand during peak periods.

Figure 8-5: Massport April School Vacation Discount

Travelers in all scenarios will be more likely to use Logan Express during this promotion:

Scenario #1 Logan Express Discount Price: $7 + $11 x 2 = **$29** (Save $22)
Scenario #2 Logan Express Discount Price: $22 + $11 = **$33** (Save $17)
Scenario #3 Logan Express Discount Price: $22 + $11 x 3 = **$55** (Save $60)

Seasonal promotions effectively deal with parking over flow while attracting more passengers to use the service. Thus Massport should continue to implement creative seasonal discounts to mitigate parking demand and attract air passengers during times of peak parking demand.

8.2.4 Transit Fares

The analysis has shown that over-crowding is not likely to be the cause of declining air passenger volumes. Rather, it is more likely that the cost of Logan Express tickets and parking at Logan Express lots have resulted in passengers selecting other modes to access Logan Airport. As a result, the project team recommends free boardings at Logan Airport for the Logan Express. This is expected to reverse the decline in passenger volumes on Logan Express and encourage new ridership.

Two fare change alternatives are considered and compared to the 2010 Logan Express subsidy analyzed in **Table A-5** in **Appendix A**. Alternative #1 implements free boardings at Logan Airport to any destinations while maintaining inbound fares unchanged, while alternative #2 charges twice as much for inbound passengers to Logan Airport to compensate for the revenue loss of providing free outbound services. A comparison of the subsidy required from Massport is shown in **Table 8-4**. Massport has an existing arrangement with the airlines that the revenues / losses from Logan Express tickets are shared, but that Massport collects all revenue from Logan Express parking lots.

Table 8-4: Predicted Massport Subsidy under Fare Change Alternatives

	2010 Scenario	#1 Free Outbound, Inbound Fare Unchanged	#2 Free Outbound, Inbound Fare Doubled
Revenues by Fares	$ 7.0 M	$ 3.7 M	$ 7.3 M
Operation Cost	$ 11.1 M		
Massport Subsidy	**$ 4.1 M**	**$ 7.4 M**	**$ 3.8 M**

Free boardings at Logan Airport could potentially attract more passengers to use Logan Express services. However, doubling the inbound fares might discourage one-way passengers from using the service. The second alternative has minimal impact on park and ride users since the round trip fare does not change.

Based on the evaluation above combined with the analysis in previous chapters, free outbound Logan Express service is recommended. The free outbound Logan Express service is consistent with the free outbound Silver Line, free Massport Shuttles, and the recommended free Blue Line at Airport Station (see **Chapter 10**). Massport should further research adjustments of the inbound price to balance the subsidy and potential ridership impact. The inbound fare can be slightly increased or doubled to compensate for the lost revenue. Doubling the inbound fare, however, has only a marginal effect as the total out-of-pocket cost for a round-trip is unchanged.

8.2.5 Conclusions and Recommendations

This section has shown that the decline in Logan Express air passenger travelers is not a result of over-crowding or insufficient parking capacity arising from increased employee usage, but is likely a result of the pricing scheme for parking and tickets. Therefore, it is recommended that Massport implement free boardings of all public transit at Logan Airport, including Logan Express. Massport should further assess the ridership impact and subsidy allocations of adjusting the Logan Express fares for inbound trips to compensate for the lost revenue on the outbound trips. Massport should also continue seasonal promotions and discounts to mitigate parking flow and attract new transit users.

Massport should also investigate the feasibility of converting the existing Logan Express route to Peabody into a van or shuttle service as a result of its low ridership. This approach could also be tried on the Braintree route which has higher ridership to test user sensitivity to bus frequency. Using vans will allow Massport to test passenger sensitivity to frequency. Converting the Logan Express to a high frequency van service with lower parking costs may also attract new transit riders.

9 Ease of Transferring to Transit

While the previous chapters have focused on how to improve the passenger experience aboard transit services, this chapter focuses on the **ease of transferring to and using** transit and HOV services that serve Logan Airport. It assesses how intuitive and straightforward the airport / transit transfer is by reviewing the landside factors (at both Logan airport terminals and transit stations) that increase the utility of airport transit trips, documenting the existing conditions at Logan Airport and recommending potential improvements. In particular, it recognizes that the large number of non-Boston residents using Logan Airport will be much more likely to take transit if it is clear and intuitive to use. The chapter is organized as follows:

- Section 9.1: Characteristics of Intuitive Transfers
- Section 9.2: Best Practices at Domestic and International Airports
- Section 9.3: Existing Conditions
- Section 9.4: Potential Improvements
- Section 9.5: Conclusions

9.1 Characteristics of Intuitive Transfers

Independent of travel time and cost, transit services must be convenient and easy to use in order to be successful. Six core elements that contribute to the simplicity of an airport/transit transfer will be referred to throughout this chapter:

1. User Awareness of the Service

Is the service well-known, branded and established? Are local residents aware of the service? Is it straightforward and intuitive for unfamiliar users to learn about the service? Taxis – which are universally prevalent at North American airports – are an intuitive default choice for unfamiliar users. Travelers do not generally expect high-quality transit connections at airports; therefore, additional effort is required to promote transit services and build user awareness of this mode. This factor emphasizes the need for both guidance within the airport and marketing of the service outside the airport.

2. Wayfinding to Transit Services

Wayfinding to the transit service should be clear and intuitive, with minimal confusion on the part of unfamiliar users.

3. Directness of Transfer to Service

The transfers should be direct and should minimize walking distance and time. Changing levels, long corridors, large distances and inhospitable spaces all decrease the utility of transferring to transit. Further, awkward transfers and low quality transfer locations suggest to users that transit is marginalized or inferior compared to other modes.

4. Fare Payment

The means of paying for the fare and obtaining fare media should be user-friendly and able to accommodate surges of arriving passengers.

5. Comfort of Waiting Area

Comfortable waiting areas decrease the negative perception associated with waiting for transit service.

6. Ease of Using Service

The service should be easy to identify and contain information pertinent to travelers.
There are four discrete locations where the application of these principles should be considered:

- Within airport terminals
- At the terminal curb
- Within the transit vehicle
- At the connecting transit station

9.2 Best Practices at Domestic and International Airports

This section reviews best practices for straightforward and attractive connections to transit at domestic and international airports.

9.2.1 User Awareness of Services

In order to use transit services, users must first become aware of the transit modes that serve the airport. Some techniques to increase user awareness of services are discussed below:

- Naming: clear and descriptive names should be used for stations and routes that serve the airport
- Maps: airport stations and services should be illustrated clearly and unambiguously on transit system maps
- Branding and marketing: transit services should be branded and marketed as airport services
- Media: radio commercials, newspaper advertisement and other forms of publicity can advertise the services
- Websites: the website for both the airport and the transit agency should provide clear instructions about transit access to the airport; "trip planning" applications help travelers plan their trip to the airport
- Smart Phone applications: In response to high market penetration of smart phones, airports and transit agency can develop applications that present pertinent route information (schedules, routes, next arrival time, etc.)
- Airport signage: Clear signage in the airport should alert arriving passengers to transit services, as they may be unfamiliar with the system. Signage should include generic terms such as "public transportation" in addition to brand-specific symbols to aid user comprehension
- Airport staff and transit agency staff: Staff at airport Information Desks should be familiar with transit services and be able to help arriving passengers, while staff throughout the transit system should be able to help direct departing passengers access the airport
- Airport directories and maps: Maps and directories of the airport should clearly illustrate transit services
- Informational material: Informational material (i.e. system maps, fare information) should be distributed at airport Information Desks

- Travel guides: The airport and transit agency should co-ordinate with travel guides (online and in print) to ensure that transportation options to and from the airport are well-described

9.2.2 Wayfinding to Transit Services

This factor addresses how well information is presented at the airport to help travelers find transit services. Wayfinding has been identified as one of the most important elements that contributes to overall passenger level of service (LOS) at an airport[95], and transit connections have been identified as one of the most complex elements of wayfinding design at an airport[96]. Wayfinding guidelines and considerations specific to transit service wayfinding are outlined in **Table 9-1**, using ACRP 52, "Wayfinding and Signing Guidelines for Airport Terminals and Landside" as a primary reference.

Table 9-1: Wayfinding Guidelines and Considerations

System Design Guidelines / Considerations	
Pattern	▪ **Hierarchical** pattern recommended whereby only the most pertinent information presented at each **decision point** ▪ Messages should progress from the **general to the more specific**; for example, signs should say "Ground Transportation" until the baggage claim area; information about specific modes and services should not be presented until the baggage claim or curb ▪ The response to complexity is not to present every possible outcome, but rather to provide **just enough information to move the traveler to the next decision point**
Facility Design	▪ The most critical factor that influences wayfinding is the **design and layout of the building**, not the signage ▪ **Good signage** can help overcome non-intuitive building layout, but initial emphasis should be on facility design ▪ Building and signage should strive to meet **user expectancies**
Information Overload	▪ Excessive detail and information on signs can lead to **information overload** for travelers – if presented with too much information, they may absorb none of it ▪ The need to communicate detailed information to travelers must be **balanced** with the need to avoid overloading travelers with instructions and directions
Quantity of Signs	▪ **Increasing** the number of signs **does not necessarily improve** the wayfinding system if it leads to information **overload** ▪ More signs results in **larger capital costs and operating costs**
Consistency	▪ Developing and implementing **consistent signage design** (in terms of colors, fonts, etc.) that is **easily identifiable** increases **user confidence** in the system
Frequency of Signs	▪ Signs should be placed at a frequency that **reassures travelers they are on the right path** without overloading them with information
Curb Signage	▪ Given the high level of activity on the curb, consider using **less signage** in this area
Advertising	▪ Consider whether advertising **detracts from the clarity** of the wayfinding system or **encroaches** upon critical signage
Sign Design Guidelines / Considerations	
Location	▪ Information should be presented in a **logical sequence**
Terminology	▪ Language on the signs should be **clear, informative and accurate** ▪ Terminology should be **consistent** on all signs
Visibility	▪ Signs should be unobstructed by columns, advertisements, etc., and should be placed in **natural sight lines** with consideration of **viewer circulation patterns**
Legibility	▪ **Fonts and text sizes** should be selected such that users can read the sign from a distance

[95] ACRP 52: Wayfinding and Signing Guidelines for Airport Terminals and Landside, page 17

[96] ACRP 52: Wayfinding and Signing Guidelines for Airport Terminals and Landside, page 106

Symbols and Arrows	▪ Internationally recognized symbols can overcome language barriers and **increase traveler comprehension** ▪ Symbols and words are **mutually reinforcing** when presented together ▪ Arrows should **point directly** to the path without any potential for confusion
Color	▪ Color scheme should allow signs to **stand out** within the busy terminal area
Illumination	▪ Lighting (interior and exterior) should be planned to ensure that signs are **visible at all times of the day and the night**
Maintenance	▪ A sign in a state of disrepair suggests that the message is **outdated or unimportant**

9.2.3 Directness of Transfer to Service

This factor addresses how direct and convenient the transfer to the transit service is for arriving and departing passengers. The quality of the connection at the airport is an important factor that affects transit access to airports, as passengers will be less likely to use a high quality transit service if the transfer to and from the airport is lengthy and uncomfortable. Some general principles include:

- Single terminals are advantageous as they obviate the need for shuttle buses to connect transit services to the terminals and facilitate the centralization of transit services[97]
- Drop-off locations should be located adjacent to ticket counters and pick-up locations should be adjacent to baggage claim areas[98]
- Passengers tend not to use the curb area beyond the end of the doors[99]; consequently, these are less desirable pick-up and drop-off locations
- A center platform for a rail service requires travelers to go up or down a level. A side platform allows for a same-level transfer in one direction but may require two changes of level in the opposite direction[100]
- It is undesirable to have more curb levels than levels within the terminal building, because this introduces additional vertical circulation elements

As a guiding principle, travel time and travel distance between the baggage claim and the transit mode should be minimized, with consideration for comfort of the connection (i.e. indoors or outdoors) and any changes in levels which are more challenging for passengers with baggage. The most elegant designs can connect passengers to the transit mode directly after they have collected their luggage from the baggage claim.

Characteristics of transfers at other airports are discussed in **Table 9-2**, based on the research summarized in ACRP 4 "Ground Access to Major Airports by Public Transportation".

[97] ACRP 4: Ground Access to Major Airports by Public Transportation, page 65
[98] ACRP 4: Ground Access to Major Airports by Public Transportation, page 66
[99] ACRP 25: Airport Passenger Terminal Planning and Design, page 287
[100] ACRP 25: Airport Passenger Terminal Planning and Design, page 281

Table 9-2: Characteristics of Transit Transfers at US and International Airports

US Airports	
San Francisco International Airport	▪ Bay Area Rapid Transit (BART) Station is located within the structure of the new international terminal, on the departures level ▪ Automated People Mover (APM) connects the other terminals to the BART station
John F. Kennedy International Airport	▪ Challenging airport to serve with public transportation due to highly decentralized terminal structure ▪ AirTrain people-mover connects airport terminals to MTA New York City Transit subway and buses, Long Island Rail Road, parking lots, rental car facilities and hotel shuttle areas ▪ 8.1 mile service; at most terminals the station is located across the terminal roadway and is connected to the terminal by elevated walkways over the roadway ▪ Free service between internal airport destinations; $5 fare to connect to Jamaica and Howard Beach transit stations
Ronald Reagan Washington National Airport	▪ WMATA Yellow and Blue lines serve "Ronald Reagan Washington National Airport" station ▪ Moving walkways in enclosed pedestrian corridor connect the station directly to the concourse level of Terminal B and C; an airport shuttle bus connects Terminal A to the station. Users can also walk through the terminals from Terminal A. ▪ Metro connection is closer to the terminal concourse level than the parking lots
Oakland International Airport	▪ AirBART, a dedicated bus line with $3 fare, connects the airport to Coliseum BART Station, 3 miles from Oakland Airport ▪ The Oakland Airport Connector (OAC) project, a rail connection to replace the AirBART bus line, is in development
New Orleans International Airport	▪ Small, single-terminal airport; Shuttle Express departure locations are closer to baggage claim than are private vehicle pick-up locations ▪ Ticket purchase kiosks are on the path between the baggage carousel and the curb
Newark Liberty International Airport	▪ Newark AirTrain (monorail) connects the three terminals, rental car facility, parking lots and Newark Liberty International Airport Rail Station
Hartsfield-Jackson Atlanta International Airport	▪ A centralized Ground Transportation Center provides information about ground transportation options and allows reservations ▪ All buses, vans and shuttles have their own fixed parking spot, and do not circulate around the airport ▪ Passenger amenities provided within the center
Chicago O'Hare	▪ Chicago Transit Authority (CTA) Blue Line station is located within the central parking garage, about 1,000 feet from Terminals 1, 2 and 3. An Automated People Mover connects the international terminal to the station
International Airports	
Oslo Airport	▪ Designed to serve as an exemplary intermodal facility ▪ Airport is centralized, with all gates served by one landside terminal ▪ Rail station is in the basement level of the air terminal building, with escalators leading from the rail station to flight check-in
Hong Kong International Airport	▪ Airport designed as an integrated, multi-modal facility ▪ Deplaning passengers can access outbound train service on the same level as baggage claim ▪ Enplaning passengers alight the inbound train service on the same level as the check-in area
Narita International Airport	▪ Railway stations are located 500 feet away from the terminal, across from the access roadway ▪ Stations are accessed via a mezzanine level below the access roadway
Vienna International Airport	▪ Underground walkway leads to the rail station and parking facilities from the baggage claim area

Charles de Gaulle Airport	▪ In 1998 a rail station (with both High-Speed Rail and Regional Express Network) was opened in the new Terminal 2 complex ▪ Terminal 1 connected to rail services by shuttle buses, but long-term plans call for an Automated People Mover

The transit connections reviewed at US and international airports have been classified into four broad categories, as summarized in **Table 9-3**.

Table 9-3: Classification of Transfers from Airport Terminals to Transit Services

	Transit physically integrated into the terminal structure	Transit walking distance from terminals	AirTrains / APMs connect to transit network	Buses / shuttles connect to transit network
San Francisco	X		X	
JFK			X	
Reagan Washington		X		X
Oakland				X
Newark			X	
Chicago O'Hare		X	X	
Oslo	X			
Hong Kong	X			
Narita		X		
Vienna		X		
Charles de Gaulle	X			X

Physical integration of transit into the terminal structure and placement of transit within comfortable walking distance of the terminals provide the most direct connections, followed by AirTrains / APMs to transit and then by shuttles and buses.

9.2.4 Fare Payment

Obtaining fare media can be a complex task whereby users must take the following steps:

- Understand <u>fare policy</u>:
  - Fare required / free fare
  - Fare required at future transfer point
  - Flat fare / variable fare (i.e. by time of day, distance traveled, etc.)
  - Fare classes (i.e. student, senior, child, etc.)
  - Fare discounts or deals for travelers (i.e. 7 day travel pass, cheaper fares with a Smartcard, family discount, etc.)
- Determine <u>where</u> to obtain fare media, if required:
  - In the terminal
  - On the curb
  - On the transit vehicle
  - At future transfer point
- Determine <u>how</u> to obtain fare media:
  - Pay cash directly on transit vehicle or at transit station
  - Purchase token / ticket from a vendor or kiosk
  - Purchase fare electronically using a machine

    - Some combination of the methods listed above
- Determine how to validate:
    - Payment at the curb
    - On-vehicle payment
    - Proof-of-Payment: must validate at the curb or on-vehicle
    - Must present fare media to exit system

This set of tasks may deter unfamiliar users from accessing public transit. Fare payment for the competing taxi mode is more straightforward and more closely corresponds with user expectations: users simply pay the driver with cash or credit card at the end of the ride. A direct conversation with the taxi driver at the beginning of the ride can generally resolve any questions or concerns. Obtaining transit fare media can be more complicated, particularly when travelers must use electronic devices without any assistance available from staff. The potential for surges of customers arriving at once after baggage is retrieved, user confusion, language barriers, foreign currency and malfunctioning equipment can all result in queuing at electronic fare media devices. Users may feel frustrated or anxious about missing the connecting ground transportation mode.

To mitigate against these concerns airports and transit agencies can employ the following strategies:

- Assign staff to assist users
- Provide a sufficient number of electronic fare media machines (if this is the required technology) to accommodate surges of passengers arriving after a flight
- Develop user-friendly interfaces in multiple languages using internationally recognizable symbols
- If there are international flights at the terminal, provide currency conversion facilities
- Signage with clear instructions
- Consider free boardings of the transit mode to reduce complexity for users, or distribute fare media with one pre-paid fare

9.2.5 Comfort of Waiting Area

The quality of waiting areas for departing passengers is generally superior to the quality of waiting areas for ground transportation, partially resulting from the difference in expected waiting time for each mode. High-quality waiting areas for ground transportation include the following features:

- Climate controlled (i.e. heating in the winter, shelter from rain, air conditioning in the summer)
- Covered boarding areas for buses and vans
- Ticket sales / information centers
- Schedule, route and price information about different ground access modes so travelers can learn about the service most suited to their needs
- Real-time "next arrival time" and "next departure time" information. These should be located at the transit stop, and also in the terminal if it is far from the stop
- Restrooms
- Comfortable places to sit
- Kiosks or stands selling food, beverages, magazines, etc.
- Strong architectural expression

- Visibility of ground transportation mode from within the waiting area, so users know when their service arrives

9.2.6 Ease of Using Service

Transit vehicles designed with awareness of the unique characteristics of airport ground access can improve the experience for arriving and departing passengers:

- Low-floor vehicles with wide doors facilitate boarding and alighting for passengers with luggage
- Luggage racks within the vehicle provide a designated space for baggage and increase capacity and passenger comfort
- Clear presentation of the name of the service, route number and destination on the exterior of the vehicle
- Information about airlines serving each terminal within the bus
- Audio and visual messages announcing the final destination and the stops
- Comfortable seats
- Helpful vehicle operator who can assist with wayfinding

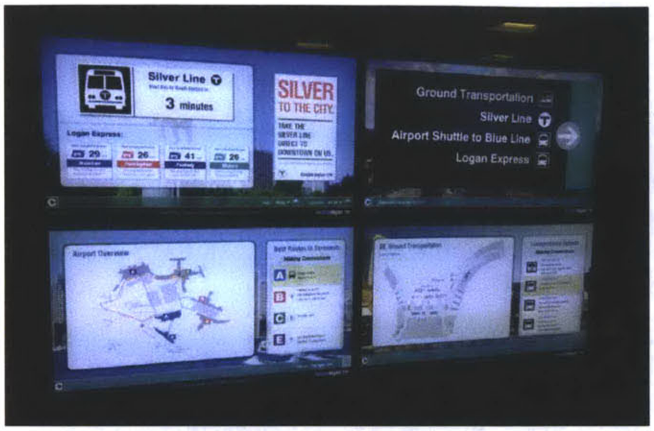
9.3 Existing Conditions

A site visit to Logan Airport, South Station and Airport Station was conducted on Friday, February 1st, 2013 to assess existing transit connections to and from the airport terminals.

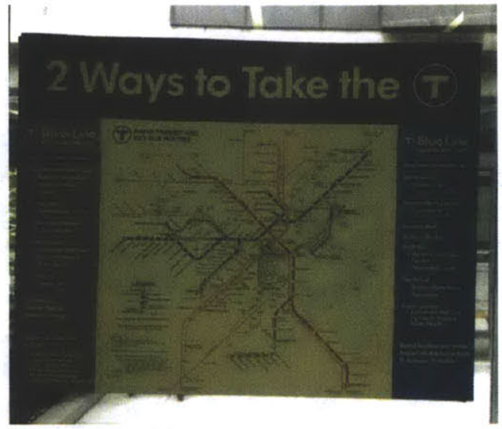
9.3.1 User Awareness of Services

Massport and the MBTA produce material that increases awareness of transit services at Logan Airport. The websites of both Massport and the MBTA contain detailed instructions for accessing Logan Airport by transit. Massport has developed an application called "GetUThere" that allows users to enter start and end locations and receive detailed information on the transportation options for completing the trip (i.e. by automobile, public transportation, Logan Express, etc.). The Silver Line 1 is becoming an established brand as the "Airport Bus", particularly because its main destination is Logan Airport. Further, "Airport Station" on the Blue Line is well-named, clearly communicating to users that this is the MBTA station that provides direct access to Logan Airport. The MBTA system map also helps build awareness of transit services, illustrating the SL1 connection to Logan Airport and showing the shuttle connection between Airport Station and the airport. Massport also runs radio commercials advertising the Silver Line, particularly when heightened parking demand is expected (such as prior to Thanksgiving).

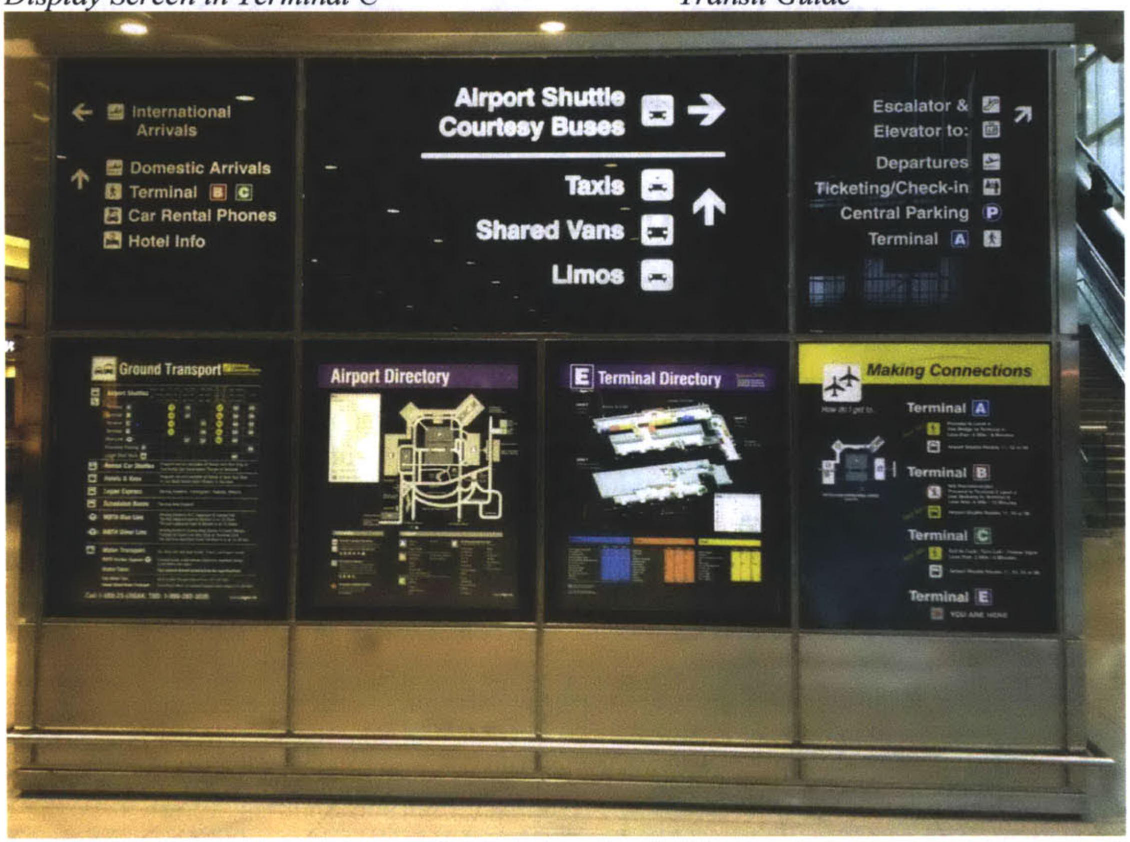
The terminals also include information that publicizes transit services to airport users. All terminals at Logan Airport have movable signs advertising the free Silver Line service to Boston displayed at the arrivals level and near the baggage claim. All terminals also include Ground Transport guides and Airport Directories which outline the different transit services, and many terminals include "2 Ways to Take the T" signs that explain in detail the destinations best served by the Silver Line and the Blue Line. All terminals also include information desks where staff can help new arrivals find ground transportation services. A new interactive screen that provides information about the various HOV modes to Logan has also been introduced at Terminal C. Photographs of some of this signage is provided in **Photo 9-1**.



Display Screen in Terminal C



Transit Guide



Information Display in Terminal E

Photo 9-1: Informational Displays in Logan Airport Terminals

Terminal C and the east side of Terminal B use the word "Public Transportation" on their signage in conjunction with the MBTA's symbol, which alerts unfamiliar users to the presence of public transit in the terminal area. However, the signage in Terminals A, B-West and E all refer more broadly to "Ground Transportation". Further, in most terminals it is not clearly explained that a free Massport shuttle can take riders to the Blue Line. New arrivals may not know that the Blue Line and the Silver Line are public transit routes to Boston, and may not realize that the MBTA "T" logo represents transit.

9.3.2 Wayfinding to Transit Services

<u>**Terminal A**</u>
The signage in Terminal A follows the "hierarchy" guidelines, by starting with the general (signs reading "Ground Transportation") and then progressing to the specific (the sign at the Silver Line stop contains more details about the service and its destinations). However, the signage in this terminal does not provide clear wayfinding to transit stops.

Photo 9-2: Internal Signage at Terminal A

Inside the terminal, the signage is well-illuminated and well-placed above the door (**Photo 9-2**). It provides directions for taxis and limos, and then simply refers to all other Ground Transport outside. There is a large Ground Transport sign outside the doors (**Photo 9-3**), but it is placed rather high up and does not fall within natural sightlines. Further, the sharp contrast between the dim terminal curb and brightness beyond the curb reduces the visibility and legibility of the sign. This sign refers to "Taxis", "Airport Shuttles", "Rental Cars", "Logan Express" and "Scheduled Buses". The Silver Line is classified as a "Scheduled Bus" and the shuttle to the Blue Line is classified as an "Airport Shuttle".

These are not effective terms to direct users to the transit services. "Airport Shuttles" is a vague term which does not clearly denote its important role in connecting the terminal to Airport Station on the Blue Line. Further, the term "Scheduled Buses" does not clearly denote the Silver Line Bus Rapid Transit service. At the area of the terminal for Airport Shuttles (**Photo 9-4**), the Blue Line is mentioned specifically; however, for an airport user unfamiliar with the terminology "Blue Line", the signage in this terminal does not clearly relate that this is a shuttle to a heavy rail service.

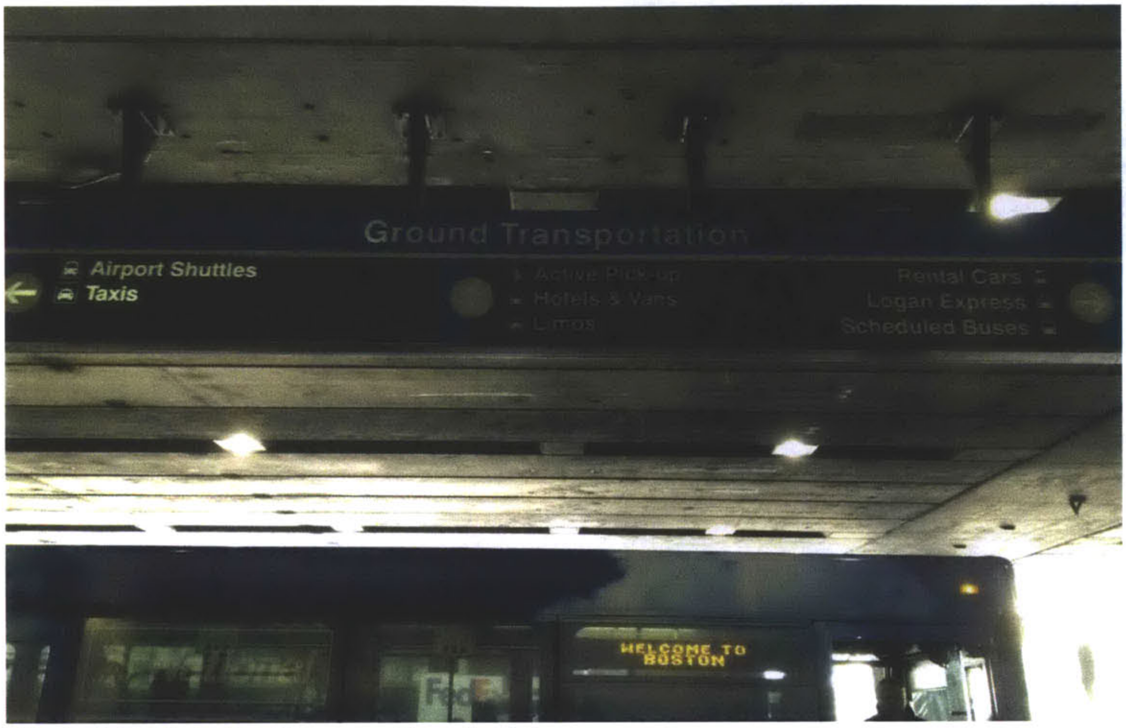


Photo 9-3: Exterior Signage, Terminal A

Photo 9-4: Airport Shuttle Sign, Terminal A

On the Terminal A curb, signs are attached to the columns, perpendicular to the roadway and the terminal building (**Photo 9-5**). These visible signs abet wayfinding along the terminal curb.

Photo 9-5: Silver Line Signage, Terminal A

<u>**Terminal B-West**</u>

In the west side of Terminal B, travelers can see a very clear, highly visible sign (**Photo 9-6**) that breaks out the Silver Line and Blue Line as separate elements from other Ground Transportation. Although this sign does not help unfamiliar users understand that the Blue Line and Silver Line are public transportation modes, it is very clear for users familiar with the system. The signage above the doors (**Photo 9-7**) preserves the same terminology. Well-placed "Free Silver Line" signs (**Photo 9-8**) are placed below the directional signage, so that travelers can follow the arrows if the sign attracts them to use the service.

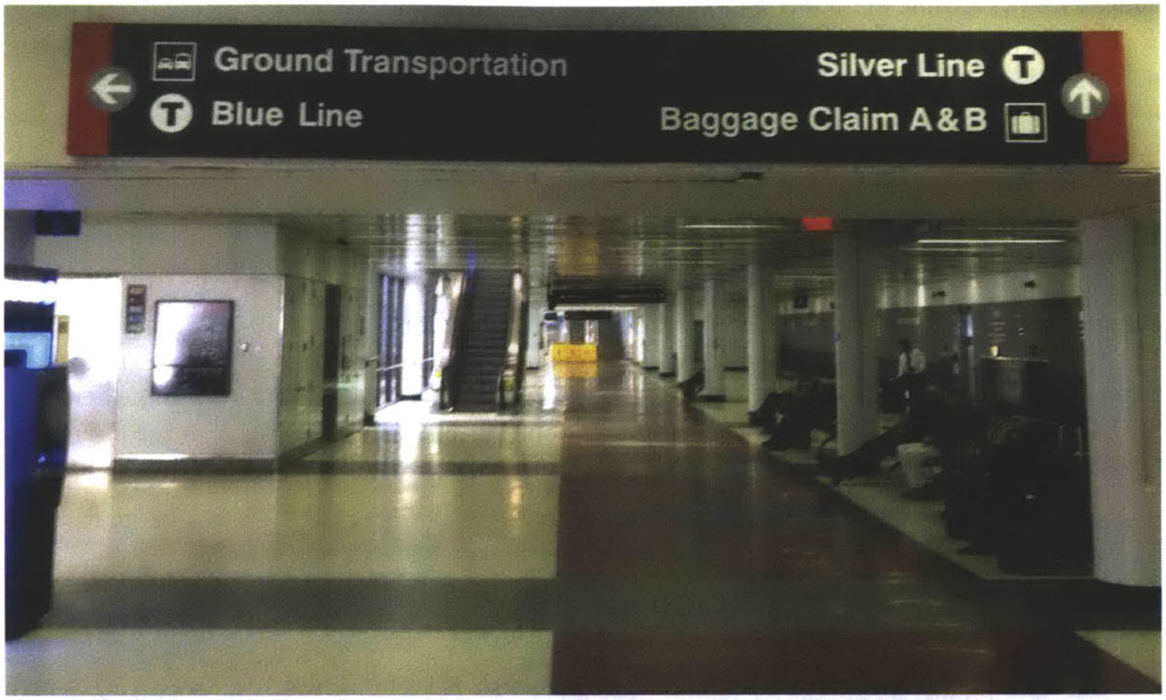


Photo 9-6: General Wayfinding in Terminal B-West

Photo 9-7: Signage above Doors, Terminal B-West

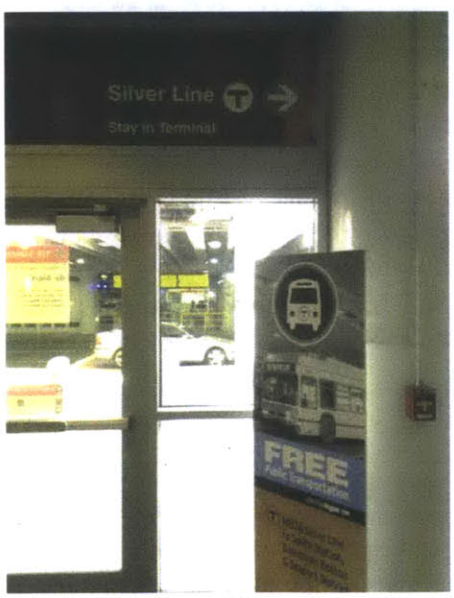


Photo 9-8: Free Silver Line Sign, Terminal B-West

The signage on the curb is more challenging for users to navigate. Color-coded plastic signs have been wrapped around the structural columns to delineate the curb into different zones (see **Photo 9-9** and **Photo 9-10**). The zones on the curb are:

- Taxi – yellow
- Scheduled / Shared Vans – yellow
- Courtesy Buses – green
- All Bus Pickup / Drop Off – blue
- Silver Line – silver

While the colored signs wrapped around the column are visible for travelers in the immediate vicinity, there are no directional signs to help travelers navigate around the curb if they are lost. For example, a user standing in the "Taxi" zone of the curb will not know how to find the "Bus Pickup" zone of the curb, as there is no larger wayfinding system and the signage on the columns is not visible from a distance.

Photo 9-9: "All Bus Pickup/Drop Off" Signage on Terminal B-West Curb

Photo 9-10: "All Courtesy Buses" Signage on Terminal B-West Curb

The curb signage system also lacks specifics about the transportation options. While there are signs inside the terminal that mention the Blue Line, once users are on the curb they need to wait near the generic "All Bus Pickup / Drop Off" signs for an Airport Shuttle to arrive. This is a very generic label (which comprises the Logan Express, all Airport Shuttles and scheduled buses) and it may be confusing to users. Further, the distinction between "courtesy buses" and "all buses" may be ambiguous for some users.

Terminal B-East

When travelers descend to the lower level in Terminal B-East, they immediately see a well-placed, highly visible sign mounted to the ceiling (**Photo 9-11**). This sign separates "Public Transportation" from "Ground Transportation" and associates public transportation with the MBTA's "T" logo. As travelers continue to move through the terminal, they next see secondary signage (**Photo 9-12**) that references the Blue Line and the Silver Line specifically while using the "T" logo which was identified as "Public Transportation" on the primary signage.

When travelers arrive at the curb, less guidance is provided. The color-coded signs wrapped around the exterior columns used at Terminal B-West are also used at Terminal B-East (see **Photo 9-9** and **Photo 9-10**), with similar advantages and disadvantages. A more global wayfinding sign is provided (**Photo 9-13**) on the curb, but it is not very visible due to the small font, poor illumination and outdated appearance, and is also overshadowed by the more visible color signage on the columns. The terminology "Buses to Subway" is quite clear, although this terminology does not appear on any of the newer signage.

Photo 9-11: Primary Signage on Lower Level of Terminal B-East

Photo 9-12: Secondary Signage on Lower Level of Terminal B-East

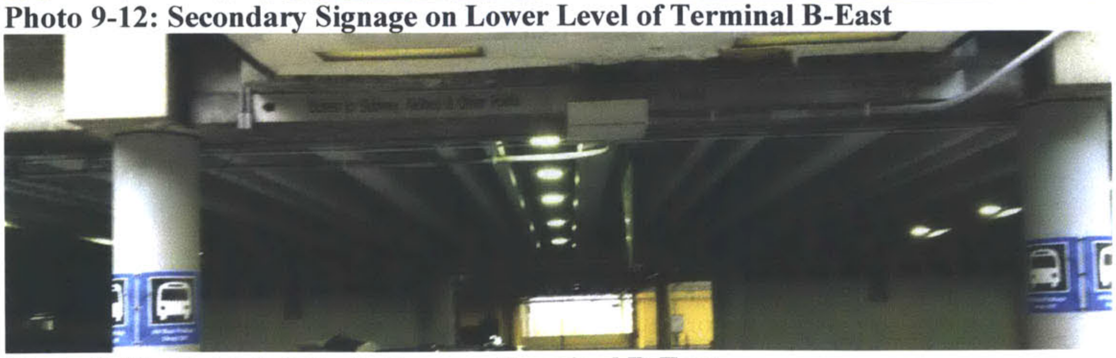


Photo 9-13: Outdated Curb Signage, Terminal B-East

Terminal C

Signage in Terminal C follows the principles of hierarchy. On the upper departures level, a sign (**Photo 9-14**) directs travelers to ground transport and the baggage claim; a distinctly shaped arrow clarifies for travelers that they should use the escalator behind the sign.

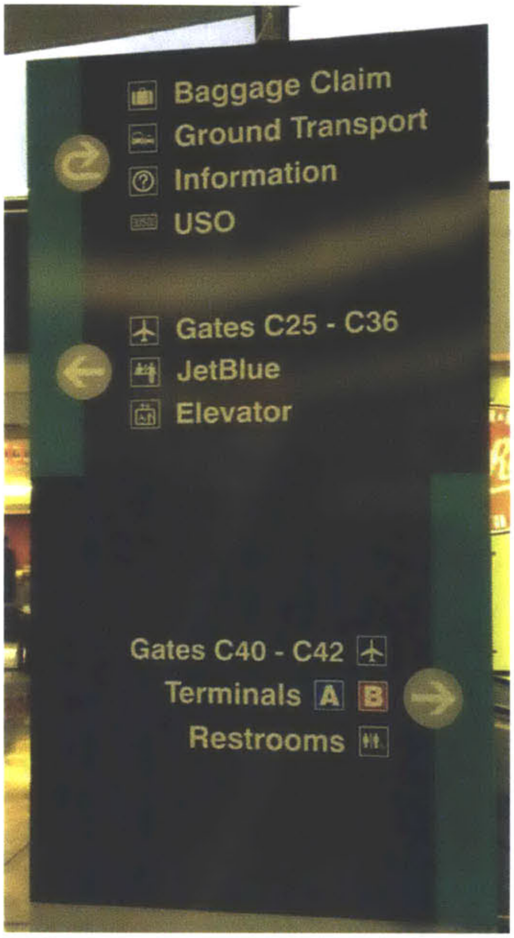


Photo 9-14: Departure Level Signage, Terminal C

After travelers go down the escalator, they see a well-placed and highly visible sign (**Photo 9-15**) that provides more information about the baggage claim and the ground transportation. Notably, "Public Transportation" is referenced separately from "Ground Transportation", and is associated with the MBTA "T" logo. This treatment both brings attention to public transportation as a distinct transportation mode, and associates the "T" logo with public transportation, thus helping users unfamiliar with the MBTA develop an understanding of this symbol.

As travelers progress through the terminal and come closer to the exterior doors, the next sign indicates the separate directions for Ground Transportation and Public Transportation (**Photo 9-16**). This sign is placed at an effective distance from the previous sign that reassures users they are on the right path without overloading them with information. Further, its visual consistency with the previous sign (in terms of its colors, terminology, location and size) strengthens wayfinding because users can easily identify it as the next element of a unified and continuous system. Locating public transportation and ground transportation in separate areas also improves wayfinding, as users can easily find the public transportation services without confusing them with other bus services.

In keeping with the principles of hierarchy, the signage above the exit doors provides additional detail at this decision point (**Photo 9-17**). Situating this somewhat detailed information inside the terminal helps users make decisions and find the right path before exiting to the curb. As the curb is a higher-energy, higher-activity environment, this allows users to make decisions within the less frenetic and climate-controlled terminal, with greater proximity to concessions and staffed information desks. The Blue Line and the Silver Line are mentioned specifically on this sign, with the T logo. As the earlier signs associated the T logo with public transportation, this should help unfamiliar users understand that the Silver Line and the Blue Line are public transportation modes. Finally, the "Free Silver Line" poster is well-placed: this poster includes a picture of the bus, mentions that it is public transportation, and uses the word "Free" – which is powerful at attracting attention. Users interested in the Silver Line based on this sign can easily see the directional arrow on the sign above the door.

Users who follow the directional arrow toward the Silver Line will see another well-placed and highly visible sign (**Photo 9-18**) that directs them toward the Silver Line. While the placement of the Silver Line stop so far from the other ground transportation modes is problematic (see **Section 9.3.3**), the wayfinding itself is very clear.

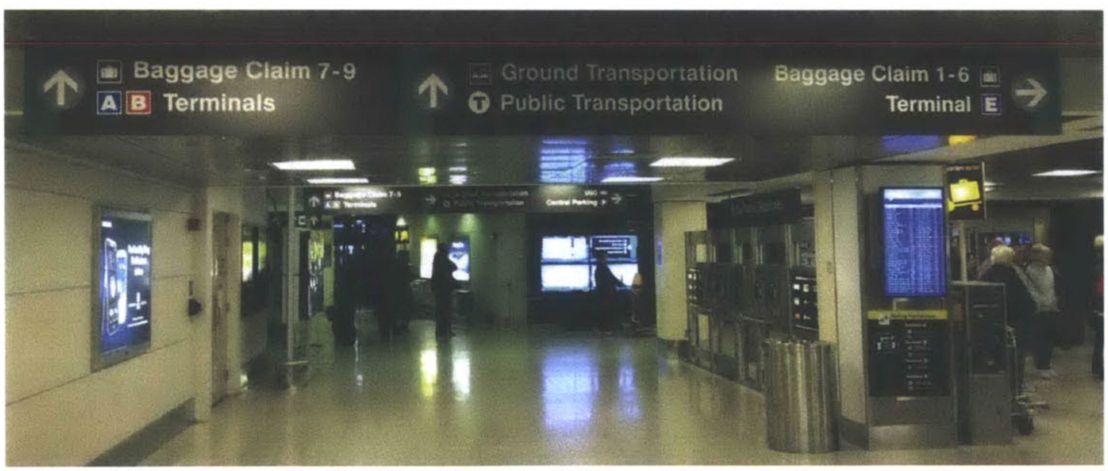


Photo 9-15: Lower Level Signage 1, Terminal C

Photo 9-16: Lower Level Signage 2, Terminal C

Photo 9-17: Signage above the Lower Level Terminal Doors, Terminal C

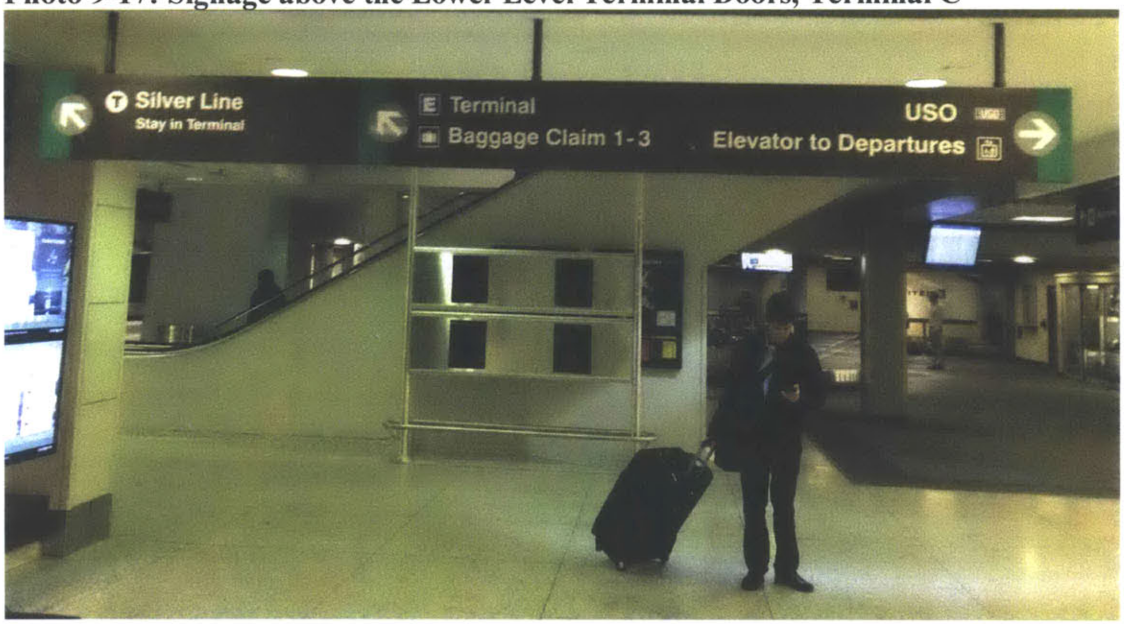


Photo 9-18: Signage Approaching Silver Line, Lower Level, Terminal C

Once on the terminal curb, large and highly visible color-coded overhead signs (**Photo 9-19**) effectively delineate the curb into different zones. The text "Blue Line" with the logo for the T is included beneath the somewhat generic title "Airport Shuttles" to help public transit users find the place on the curb to get the Blue Line shuttle. Once at this area on the curb, a sign attached to the column (**Photo 9-20**) provides information about the different shuttle routes, although there are opportunities to clarify the information presented on this sign.

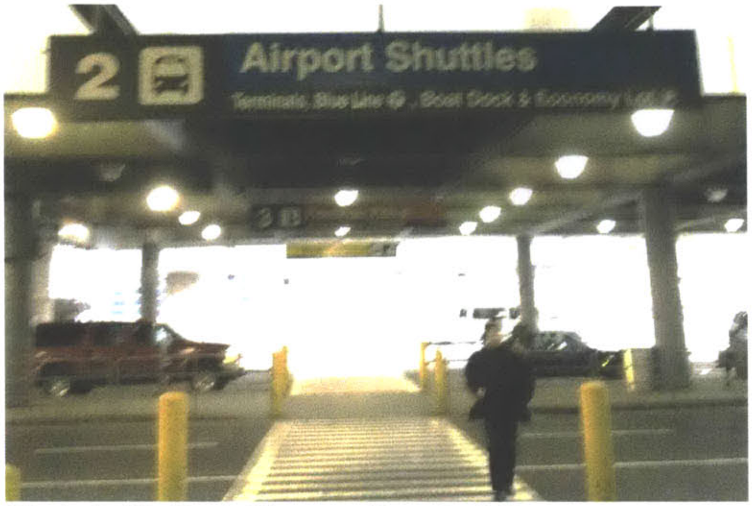


Photo 9-19: Curb Signage, Terminal C

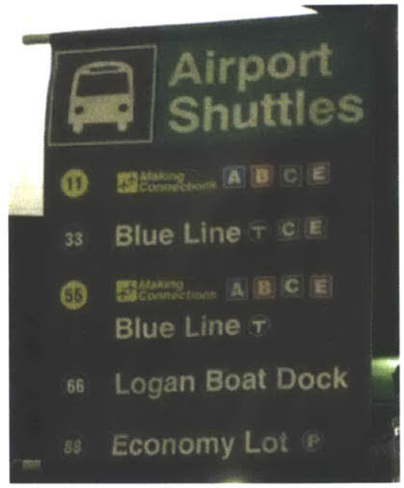


Photo 9-20: Sign at Airport Shuttle Stop, Terminal C

<u>**Terminal E**</u>

A variety of different signage is used in Terminal E and along the curb. Domestic arrivals are greeted by a sign that is very well placed and has excellent legibility (**Photo 9-21**); however, it mentions taxis, elevators and other terminals but does not provide direction regarding other ground transportation modes. International arrivals, who enter the arrivals hall at a different location, can clearly see a sign for taxis and elevators affixed to a column (**Photo 9-22**), but are not provided any guidance regarding transit or any other ground transportation modes.

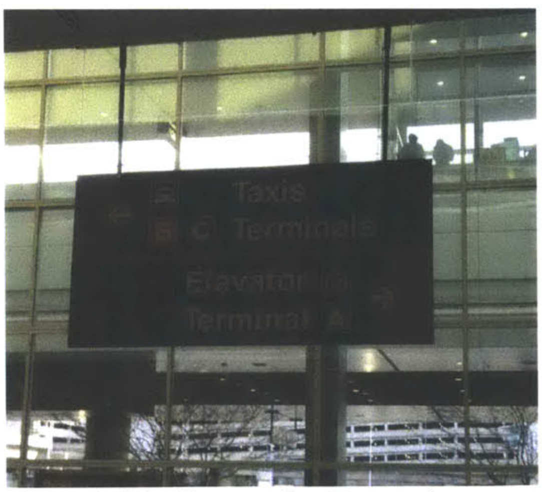


Photo 9-21: Signage for Domestic Arrivals, Terminal E

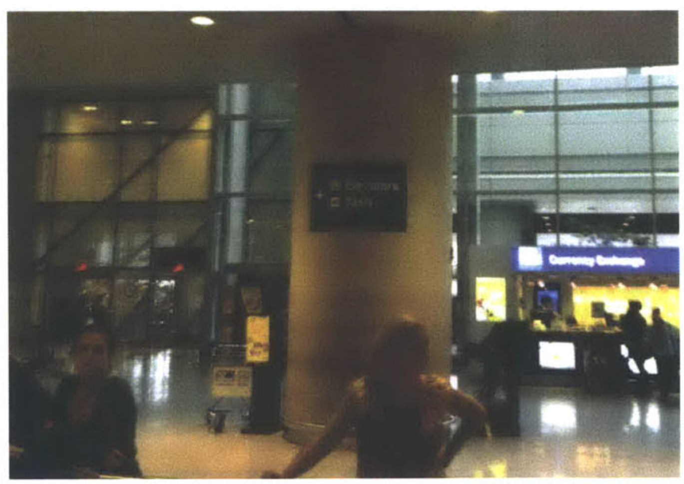


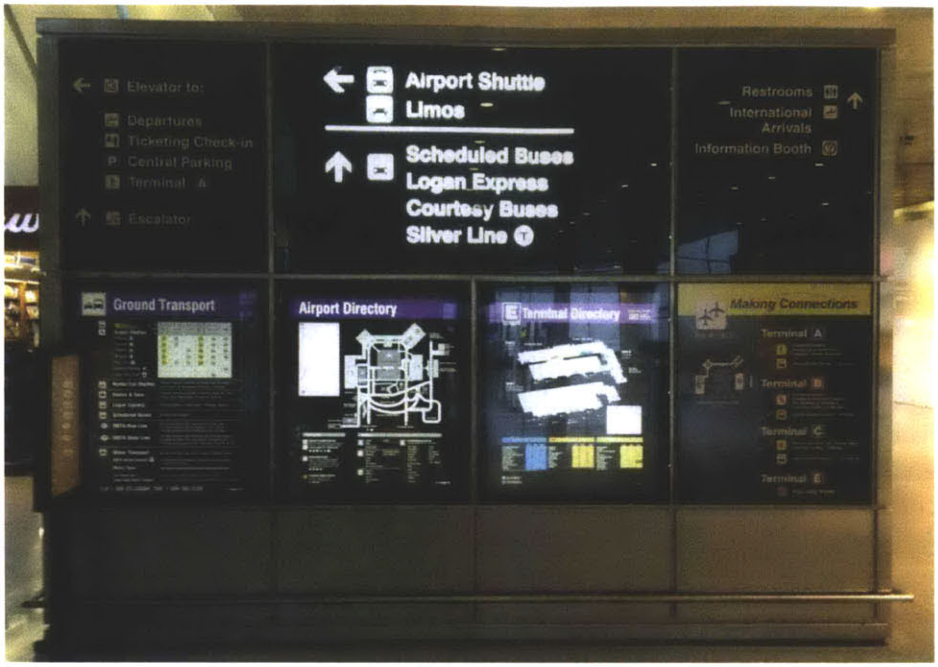
Photo 9-22: Signage for International Arrivals, Terminal E

Terminal E also includes large signs which are situated perpendicular to the curb. These panels consolidate a great deal of useful information, and reduce the risk of information overload by placing the main directional instructions in the top center panel with larger font. However, the options provided on this panel do not clearly present the public transit options available at Terminal E. The shuttles to the Blue Line are denoted by the vague and imprecise label "Airport

Shuttle". It would be difficult for anyone unfamiliar with the system to understand that the "Airport Shuttle" is a free transfer to a heavy rail system that goes directly to downtown Boston.

Further, as a result of the perpendicular placement of the signage, the west-facing panel does not mention the Silver Line because the Silver Line stop is west of the panel itself. The Silver Line is mentioned on the east-facing side of sign, but the west-facing panel is most visible to all incoming international arrivals. Further, while the use of phrase "Silver Line" and the MBTA "T" symbol is recognizable to travelers familiar with the system, this board does not clearly articulate that the Silver Line is a transit service that goes to downtown Boston. This information is available on the "Ground Transport" board, but it would be challenging for a user to find this detail among the large amount of information presented on the panel.

West-Facing Panel of Terminal E Informational Panel



East-Facing Panel of Terminal E Informational Panel
Photo 9-23: Informational Panel in Terminal E, Perpendicular to Curb

Effective signage is provided on the curb of Terminal E (**Photo 9-24**). Color-coded signs delineate the different zones of the curb. Larger overhead signs, which are visible from many locations along the curb, define the main mode while smaller signs with additional details are mounted to the columns.

Photo 9-24: Signage on the Curb, Terminal E

South Station
South Station is a multi-modal hub in downtown Boston that serves the Red Line heavy rail, Silver Line BRT, buses and commuter rail. Users from the street, buses or commuter rail cross through the fare arrays on the concourse level. A large sign points to the stairs for Red Line connections, while a smaller sign points to the stairs to the Silver Line platform.

Wayfinding is important for travelers on the Red Line platforms. If travelers select the central stairs on the platform, they can access the Silver Line platform directly by traveling up one level. If they pick the other stairwells, they need to travel up two levels to the concourse, cross the concourse, and then go down one level to the Silver Line platform. Thus, signage should assist airport travelers to find the most direct transfer to the Silver Line. Presently, the image of an airplane is used on the signage to direct passengers to the airport bus. However, the symbol is rather small and is not visible from all places where a traveler alights from a train.

Once on the Silver Line platform, there are several signs that read "Airport Bus" and point to the designated area of the platform. The signs, which are placed on the fence that separates the inbound and outbound bus lanes, fall directly within natural sightlines.

Airport Station
Signage is provided at Airport Station to help travelers find the shuttles that connect to Logan Airport. Signs are provided at the main exit (**Photo 9-25**) with arrows that unambiguously point to the location on the curb where the shuttles board. It is a very direct transfer to these exits from the outbound trains coming from Boston.

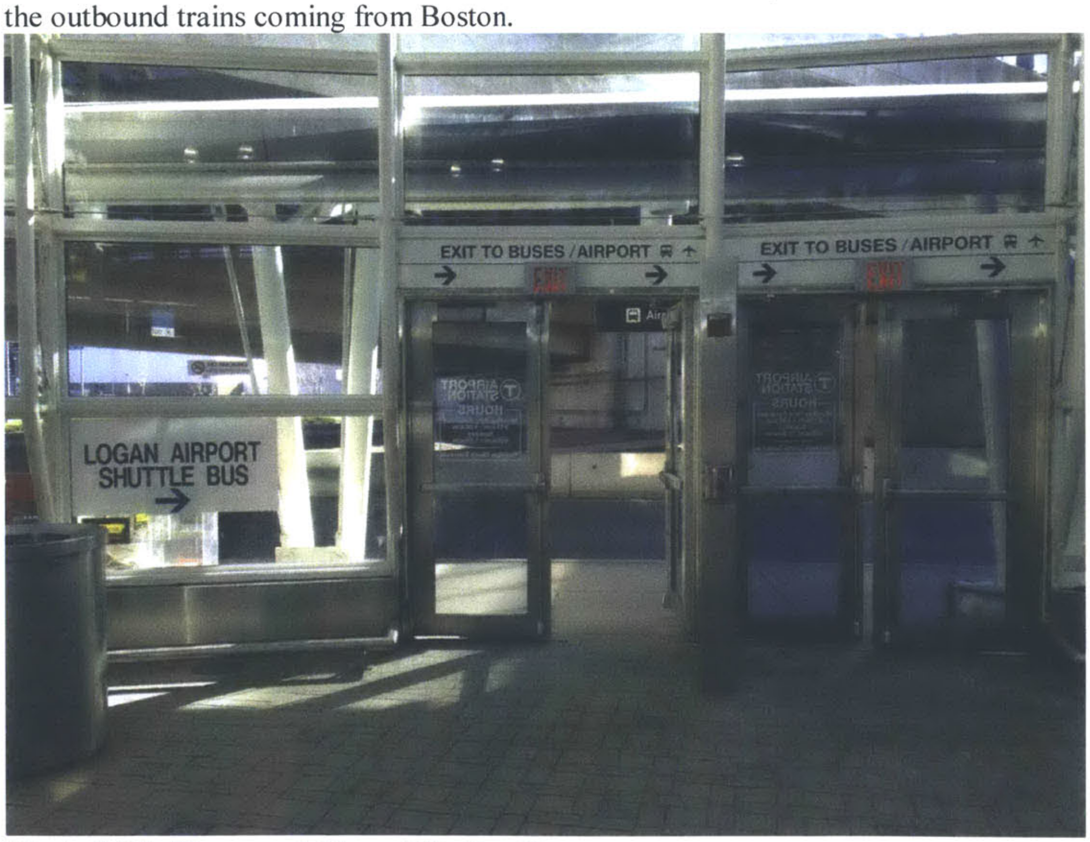


Photo 9-25: Signage at Airport Station Doors

Signage on the curb (**Photo 9-26**) is also provided, in the form of overhead signs that list the route numbers. There are signs for the following routes:

- Shared sign for all courtesy buses (i.e. hotel shuttles, rental car shuttles, etc.)
- Shared sign for Route 44 (to cargo area) and Route 66 (to water transport dock)
- Sign for Route 22 shuttle serving Terminals A and B and Airport Station
- Sign for Route 33 shuttle serving Terminals C and E and Airport Station

Routes 22 and 33 do not run before 11:00 AM or in the late evening because Route 55, which serves all terminals and Airport Station, runs at these times instead. There is no sign or designated stopping location for Route 55, and user confusion was observed when Route 55 approaches the curb. Travelers were observed to wait at a particular sign (for either Route 22 or 33) depending on the terminal to which they were destined, not realizing that Route 55 served all terminals. The shuttle operator would inform travelers that the 55 shuttle served all terminals. Conversely, despite the signage on the curb, user confusion was also observed on the Route 22 and Route 33 branch routes. Travelers would board one bus without realizing that it did not serve their terminal, sometimes completing the circuit all the way back to Airport Station because they had not yet reached their stop. There is also a movable sign that points to the airport buses; however, this sign is actually facing the wrong direction in **Photo 9-27**, suggesting that the airport buses are inside the subway station when they are in fact behind the sign, further down the platform.

Photo 9-26: Signage at the Curb at Airport Station

Photo 9-27: Movable Sign at Airport Station

Shuttles also generally allow passengers to alight closer to the entrance of the station, and then travel down the platform to the boarding area. This also caused confusion in some cases, as passengers tried to board the buses in the area where passengers were alighting.

9.3.3 Directness of Transfer to Service

Terminals

At the Logan Airport terminals, the stops for the Silver Line and Airport Shuttles are on the curb of the lower level, where the baggage claim carousels are located. After collecting their baggage, travelers can proceed directly through the doors to the curb and walk to the bus stops without changing levels. At all terminals, the Silver Line stops are located at the far edge of the terminal curb, furthest from the main doors. The location of the Airport Shuttle stops varies by terminal; the stops are located on the first island for Terminal C and Terminal E, and directly on the curb at Terminals A and B. While the curb layout varies at each terminal, the Silver Line and Airport Shuttle stops are generally situated further from the main terminal doors than are the stops for other ground transportation modes. This reduces the convenience of using the modes, and also subtly implies that they are services of peripheral importance. The curb layout at each terminal is illustrated in the following conceptual figures.

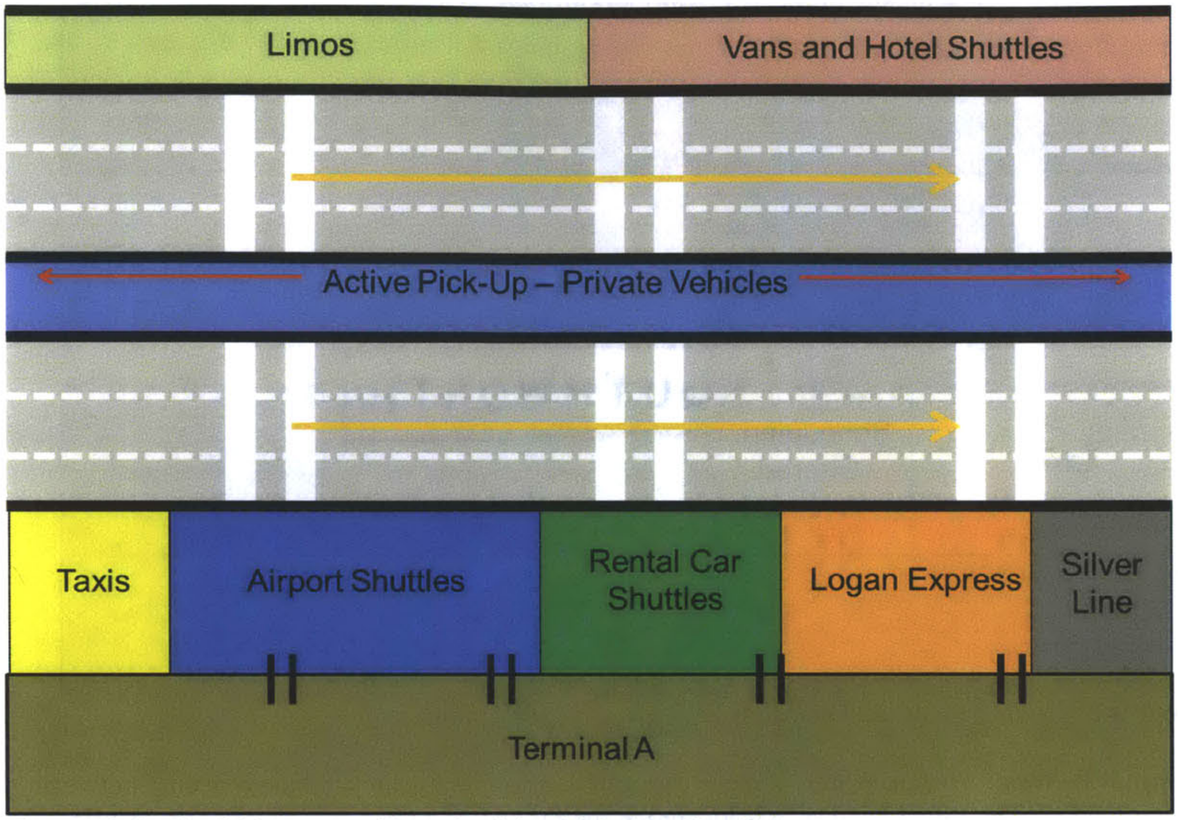


Figure 9-1: Curb Layout at Terminal A – Existing Conditions

Terminal A: Bus modes are located on the curb, while private vehicle pick-up is located on the first island and limos, vans and hotel shuttles are located on the second island. The Silver Line stop is located on the far end of the curb, while the Airport Shuttle is located toward the west side of the curb. Large signage indicates that private vehicles cannot sit and wait at the curb for passengers to arrive.

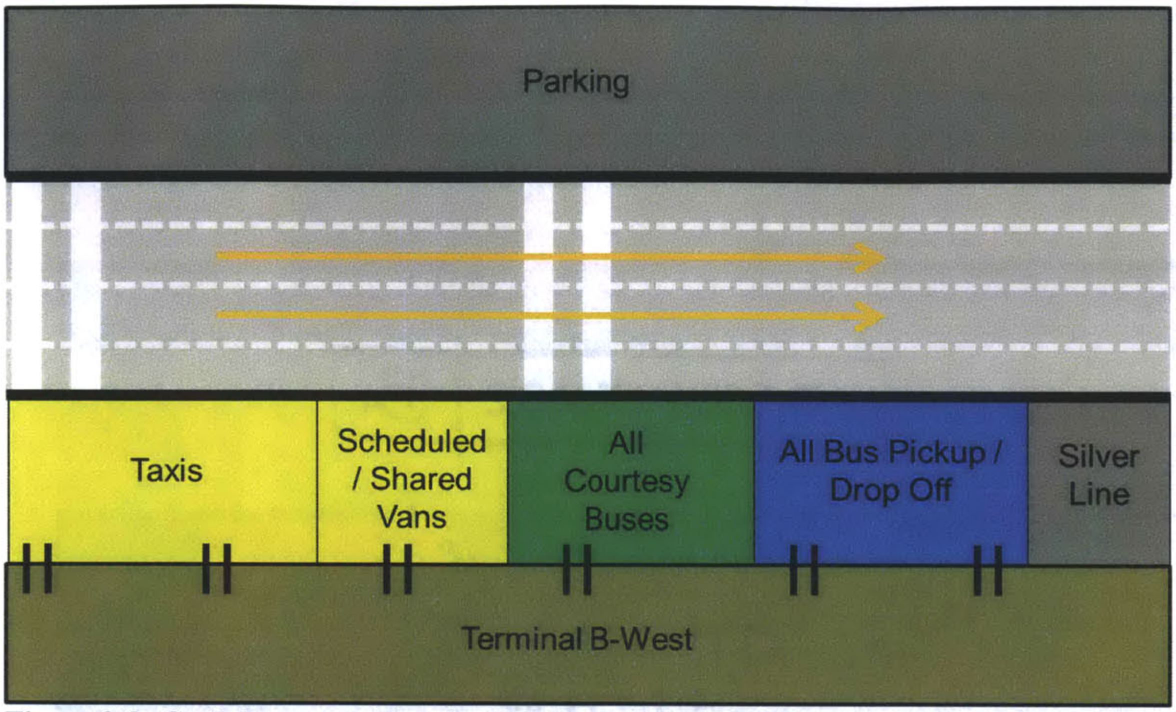


Figure 9-2: Curb Layout at Terminal B-West – Existing Conditions

Terminal B-West: This curb area is more congested, as private vehicle pick-up occurs between stopping buses. The Silver Line stop is located at the far end of curb, while the airport shuttle stops are located closer to the main entrances within the "All Bus Pickup / Drop Off" zone. The first and sometimes second lanes are generally occupied by stopping vehicles while the third and fourth lanes are used for through traffic.

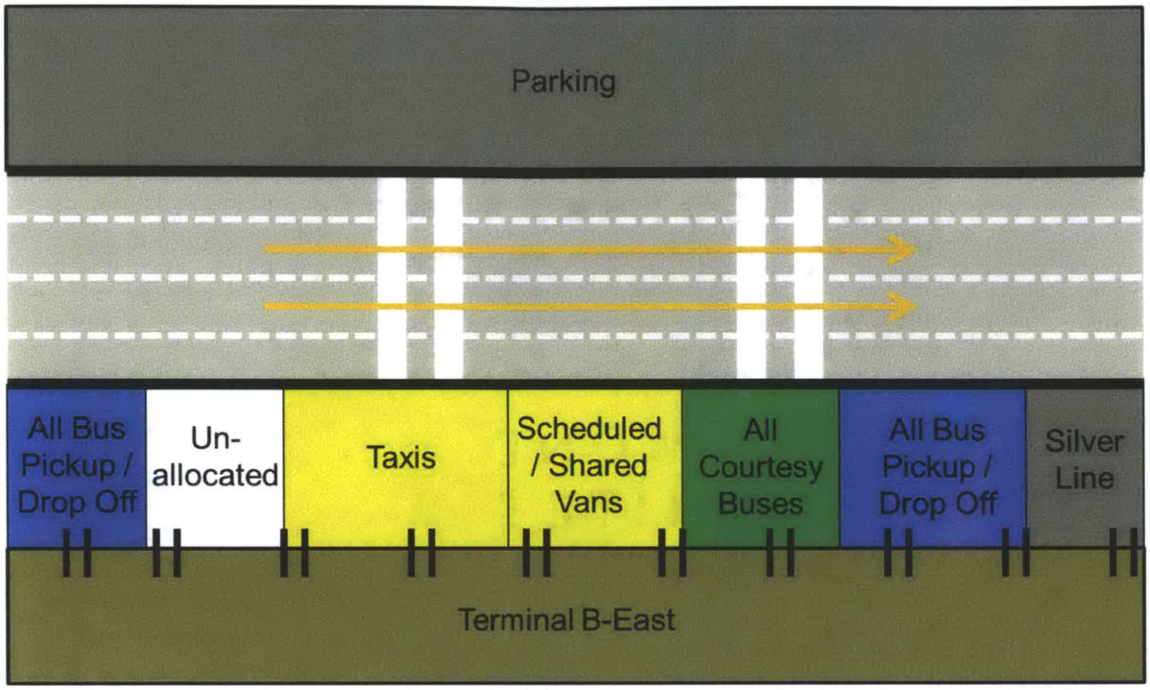


Figure 9-3: Curb Layout at Terminal B-East – Existing Conditions

Terminal B-East: This curb is quite similar to Terminal B-West, in that private vehicle pick-up must occur between the bus stops. Terminal B-East was under construction at the time of the site visit, which is the reason that some of the curb space was unallocated. The Silver Line and shuttles to Airport Station (which stop in the "All Bus Pickup / Drop Off" zone) are located toward the far end of the platform. The first and sometimes second lanes are generally occupied by stopping vehicles while the third and fourth lanes are used for through traffic.

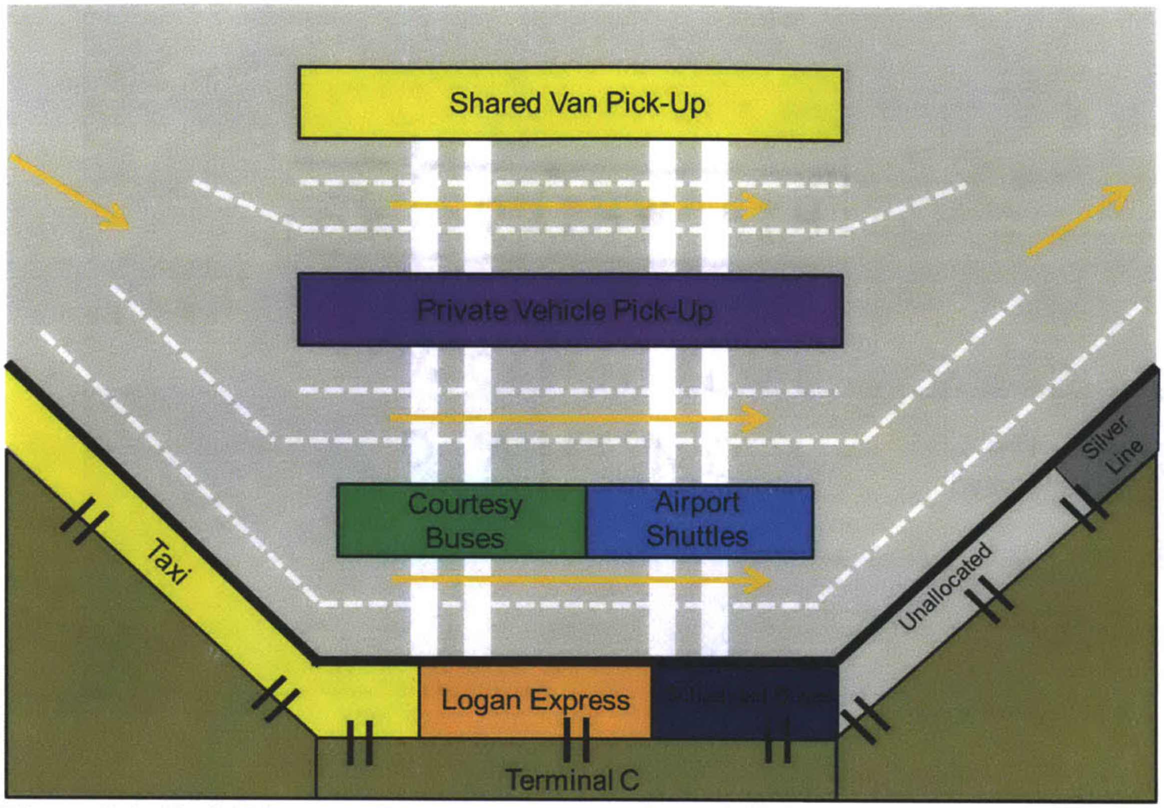


Figure 9-4: Curb Layout at Terminal C – Existing Conditions

Terminal C: Curb operations are more challenging at Terminal C, as the shorter amount of curb length has resulted in a layout without multiple islands. Taxis, the Logan Express and Scheduled Buses occupy the terminal curb. Airport shuttles (including the shuttles to Airport Station) are located on the first island, while private vehicle pick-up is relegated to the second island. Shared van pick-up is located on the furthest island from the main doors. The Silver Line stop is located much further down the terminal curb, spatially separated from all other pick-up and drop-off locations. The lane closest to each curb or island is a stopping lane where vehicles can stop and allow passengers to board and alight, and the second and third lanes are designated as through lanes. The combination of large vehicles, short crosswalk spacing, and multiple merge locations increase operator workload and decrease travel time for through traffic.

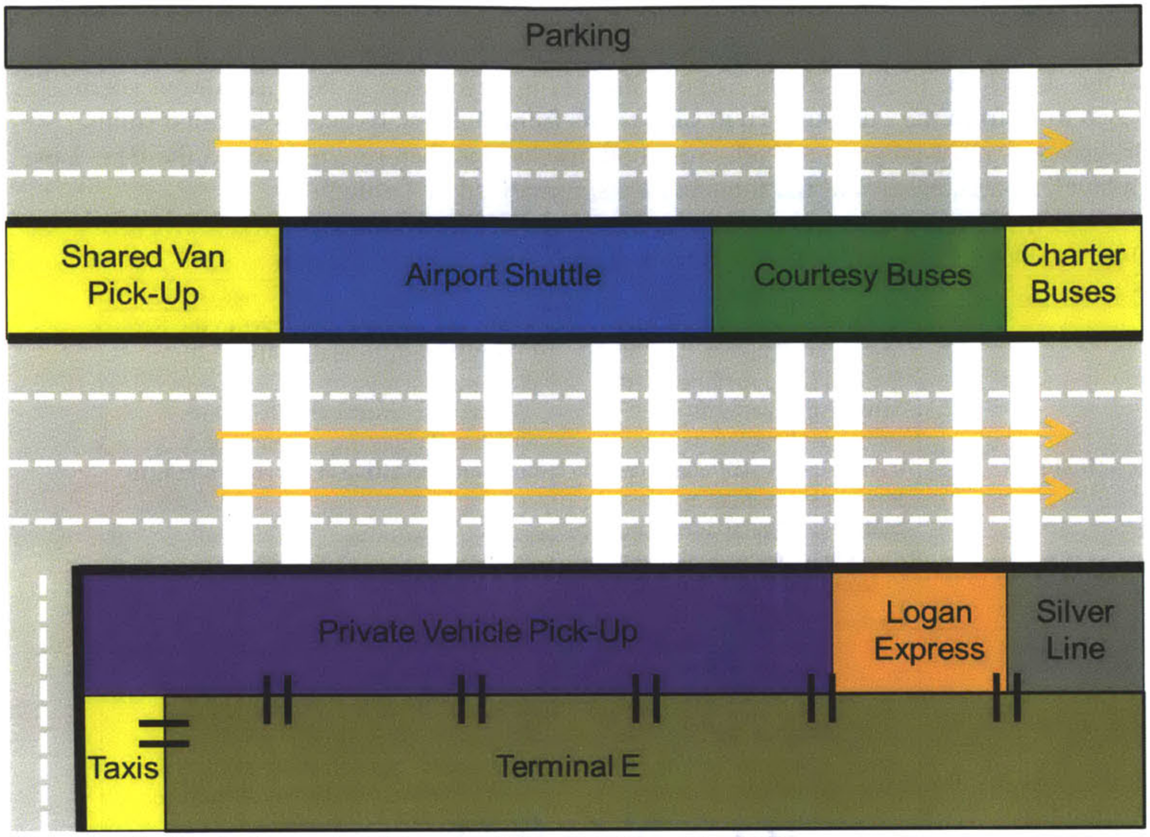


Figure 9-5: Curb Layout at Terminal E – Existing Conditions

Terminal E: In contrast to the other terminals, direct terminal curb space is allocated to private vehicles at Terminal E, while van and bus pick-up occurs on the first island. At Terminal E, Logan Express and the Silver Line are located at the far end of the terminal curb, while the pick-up location for the shuttle to Airport Station is located on the first island ("Airport Shuttle").

Transit Stations

The transfer to the Silver Line at South Station is quite direct for transfers from both the Red Line and the street. The transfer to the Airport Shuttles is quite direct at Airport Station when riders travel to or from the outbound Blue Line trains from Boston. To access inbound trains, however, travelers must go up one level, cross both tracks, and then return down to the Blue Line platform level. Characteristics of the transfers are summarized in **Table 9-4**.

Table 9-4: Transfer Characteristics at South Station and Airport Station

South Station	Inbound to Logan	Outbound from Logan
Transfer to Red Line	-Using the correct staircase, users can climb one level from the Red Line platforms to the Silver Line platform -If users select the wrong staircase they will climb two levels, arrive at the South Station concourse level, cross the concourse level and then descend one level to the Silver Line platform	-Users can descend one level to the Red Line platforms from the Silver Line platform -Users must observe the Red Line directional signs (i.e. inbound or outbound) to arrive at the right platform
Transfer to Street	-Users descend one level from the street to the South Station fare arrays on the concourse level. Once through the fare arrays, users descend one level to the Silver Line platform.	-Users climb one level from the Silver Line platform to the South Station concourse level, and exit through the fare arrays. Once through the fare arrays, users can climb one level to the street or connect to the bus terminal or commuter rail trains
Airport Station	**Inbound to Logan**	**Outbound from Logan**
Transfer to Blue Line	-For outbound Blue Line trains, same level transfer to the Massport shuttles – see **Photo 9-28**. Shuttle boarding location is south of the station exit	-Shuttle let passengers alight near the main entrance. For inbound Blue Line trains to downtown Boston, travelers must go through the fare arrays, go up a level to cross the tracks, and then return down to track level – see **Photo 9-29**.
Transfer to Street	-Path through East Boston Memorial Park leads directly to the boarding location for Massport shuttles. -Users approaching from Bremen Street must enter Airport Station, go up one level to cross the tracks, and then return down to street level	

Photo 9-28: Direct, Same Level Transfers from Outbound Blue Line Platform to Airport Shuttles

Photo 9-29: Users Go Up One Level, Cross the Subway Tracks, and Descend to the Inbound Blue Line Platform

The existing curb layout at Airport Station is shown in **Figure 9-6**. The terminal space for the courtesy buses is closest to the main entrances, while the stops for the airport shuttles 22 and 33 are located further down the platform. No area of the platform is designated for route 55, but this bus stops in the area designated for routes 22 and 33. During the PM Period, route 22 and 33 buses sometimes arrive while the leading buses are already occupying the designated curb area. These buses stop in the "informal drop-off area" to allow passengers to unload, and then proceed forward to the designated stop once the stop has been vacated by the leading bus.

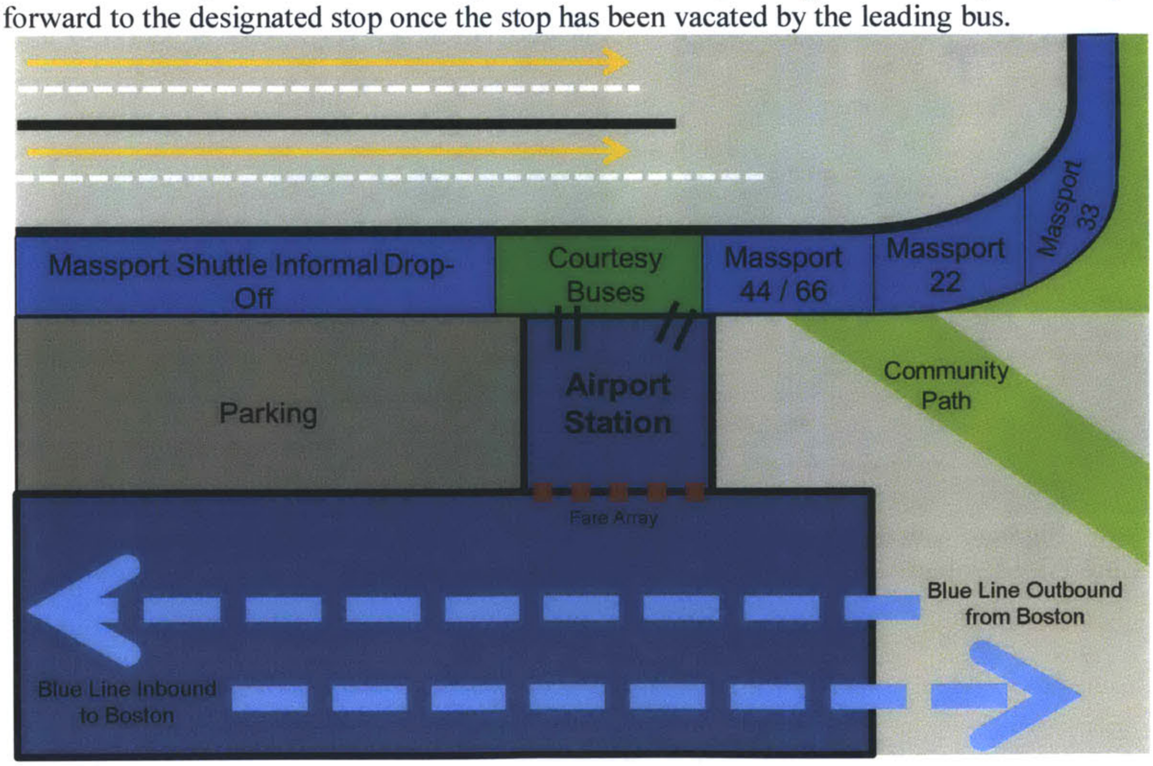


Figure 9-6: Curb Layout at Airport Station – Existing Conditions

9.3.4 Fare Payment

Ease of fare payment is an important element of efficient transfers to the transit mode. Presently, it is free to board both Airport Shuttles to Airport Station and the Silver Line to South Station. Travelers can simply board the buses, using all doors, without obtaining fare media. Travelers on the Silver Line can transfer directly to the Red Line at South Station, whereas travelers on the Airport Shuttle must obtain fare media at Airport Station before accessing the Blue Line. Characteristics of the fare requirements are summarized in **Table 9-5**.

Table 9-5: Fare Requirements for Airport Transit Access

Airport Terminals	▪ Free boardings for Silver Line and airport shuttles facilitates that fare payment process ▪ Large signs alert travelers to the free Silver Line boardings – see **Photo 9-30**
South Station	▪ Fare arrays located on either side of South Station concourse, with 5 fare machines on each side with English and Spanish interface – see **Photo 9-31** ▪ Staff available to assist users ▪ Detailed fare information, with Spanish translation ▪ System map ▪ Queuing observed
Airport Station	▪ Staff available to assist users ▪ 6 fare machines, with English and Spanish interface ▪ System map and informational pamphlets ▪ Detailed fare information, with Spanish translation ▪ Staff report that most frequent issues are confusion about the fare machines and questions about fares (i.e. interest in purchasing a 7-day pass) ▪ Queuing observed – see **Photo 9-32** and **Photo 9-33**

Photo 9-30: Signage Alerting Users to Free Silver Line Pilot Project

Photo 9-31: MBTA Fare Information in English and Spanish

Photo 9-32: Queuing at Fare Machines in Airport Station (1)

Photo 9-33: Queuing at Fare Machines in Airport Station (2)

9.3.5 Comfort of Waiting Area

The waiting areas at Logan Airport and Airport Station are generally barren and devoid of passenger amenities. They are windswept, exposed to the elements and characterized by monolithic concrete structural elements. At Airport Station and some terminals at Logan Airport, travelers are able to wait inside the building and see when the bus arrives through the window. Elements of the waiting area are documented in **Table 9-6**, and photos of typical waiting areas for the Silver Line and airport shuttles are shown in **Photo 9-34**, **Photo 9-36** and **Photo 9-37**.

Table 9-6: Comfort of Waiting Areas for Silver Line and Airport Shuttles

	Silver Line		Airport Shuttles	
	South Station	**Stops at Logan**	**Airport Station**	**Stops at Logan**
Shelter from the Elements	Silver Line platform is enclosed within the station and protected from the elements	Outside and exposed to the elements, although upper deck of terminal provides a roof. At some stops, travelers can wait inside the terminal and see the bus when it arrives	Outside and exposed to the elements, although bus shelter structure provides roof	Generally outside and exposed to the elements, although upper deck of terminal provides a roof. Terminals C and E provide enclosed waiting areas on the curb
Passenger Amenities	Benches	Benches, with concessions available within the airport	Newsboxes and some benches outside, with concessions stand inside the station	Benches, with concessions available within the airport
Real-Time Information	"Next Arrival Time" provided in addition to screens displaying flight arrival and departure times	"Next Arrival Time" provided; however, this information is **sometimes incorrect** and MBTA and Massport should work to fix immediately	-No real-time information about the shuttles -Flight arrival and departure information available within Airport Station	-No real-time information about the shuttles
Transit Schedules / Route Information	MBTA system map	MBTA system map	Overhead signage for the different shuttle routes, but no information about headways or travel times. Information about MBTA services inside station	Overhead signage for shuttle routes at some terminals; no signage beyond "Airport Shuttles" or "Bus Pick-Up" at other terminals

Photo 9-34: Typical Silver Line Stop at Logan Airport

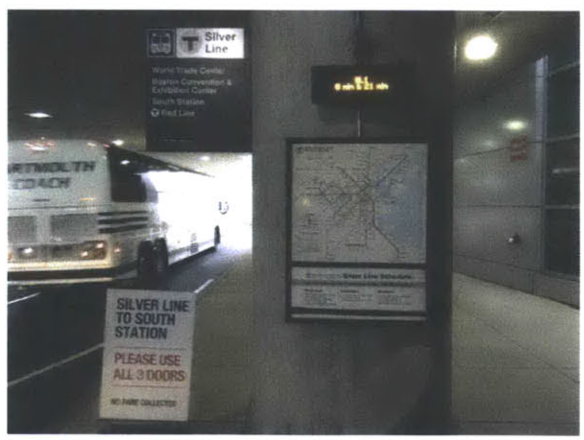


Photo 9-35: Map and Real-Time Information at Silver Line Stop

Photo 9-36: Internal Curb Waiting Area for Airport Shuttle at Terminal E, Logan Airport

Photo 9-37: Waiting Area for Airport Shuttles, Airport Station on the Blue Line

9.3.6 Ease of Using Service

The Airport Shuttles and Silver Line buses include a number of features that increase their ease of use for airport passengers, which are summarized in **Table 9-7** and displayed in **Photo 9-38**, **Photo 9-39** and **Photo 9-40**.

Table 9-7: Ease of Using Massport Shuttles and Silver Line Buses

	Silver Line and Airport Shuttles
Information on Vehicle	Digital display of route name and final destination on front and side of bus
Boarding	Free boarding at all doors
Terminal Information	List of airlines that use each terminal provided within the bus
Auditory Messages	Auditory messages clearly announce the stops
Accommodation for Luggage	Luggage racks provided

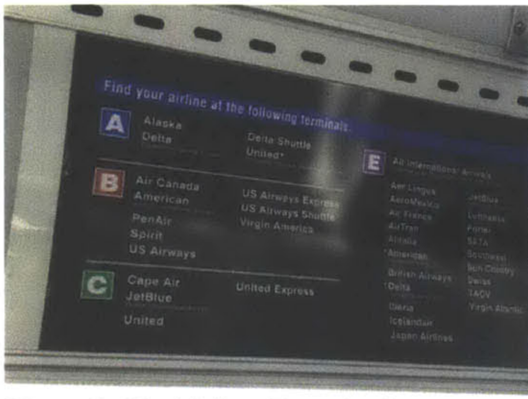


Photo 9-38: Airline Terminal Information in Airport Shuttles

Photo 9-39: Vehicle Information Clearly Displayed on SL1 Bus

Photo 9-40: Luggage Racks in the Airport Shuttles

9.4 Potential Improvements

9.4.1 User Awareness of Services

Marketing and User Information Systems

As discussed, Massport and the MBTA have implemented several measures to increase user awareness of the transit services to the airport. The following measures should be considered to further increase user awareness of transit services:

- Continued emphasis on providing informative staff at terminal Information Desks. Staff should be friendly and personable, and should be able to explain the transit options clearly to travelers. Staff at the Information Desks should be made aware of Massport's sustainability targets and promote HOV modes to travelers
- Press releases of Massport and the MBTA's HOV initiatives (such as the free Silver Line) should be planned to obtain maximum media coverage through newspapers, radio, television and internet. This will help raise awareness and spread word-of-mouth coverage through the Boston area
- Advertising campaigns should continue to be used to inform the public about transportation options to access Logan

- The Silver Line's depiction on the MBTA system map is very clear – unfamiliar users will quickly understand that the Silver Line is a major transit route service to Logan Airport. The Airport Shuttle connection to Airport Station is shown as a small dashed line. The MBTA should consider applying a thicker, solid line on future updates of the system map, as the small dashed line may suggest to users that the route is low-frequency, occasional service, or somehow lower quality than the other, more prominently illustrated services on the map. As key bus routes (such as Route 1 and Route 77) are already illustrated on the MBTA rapid transit map, it is reasonable to classify the Airport shuttles in this way.
- Signage in the arrivals area – such as the existing "Free Silver Line" posters – should be displayed to increase awareness of HOV modes from Logan Airport. The terminology "Public Transportation", "Bus Rapid Transit" and "Subway" should be used more extensively, as these terms are more meaningful to unfamiliar users than are the terms "Silver Line", "Blue Line", "Logan Express" and "Airport Shuttle"
- "Public Transportation" or "Rapid Transit" should be identified as a separate category from "Ground Transportation" on signage within the terminal and on the curb. Airports with subway or rail connections often cite these services directly on their signage, and signage at Logan Airport should explicitly reference the MBTA rapid transit connections to the airport.
- Brand the Airport Shuttle routes that connect to Airport Station as the "Blue Line Connector" or the "Blue Line Express". These shuttles should be branded separately from the other airport shuttles that serve the rental car facilities, terminals, parking lots, etc. The term "Airport Shuttle" is vague, and the service should be marketed more specifically as a high-frequency, high-quality connection to a heavy rail service

Creation of "Public Transportation" or "Rapid Transit" Zone on Terminal Curb

Some airports with high-quality rapid transit connections give a substantial degree of prominence to the service. Residents and visitors alike are aware of the high-quality service; upon arrival at the airport, the signage and wayfinding system promote the service and it is natural, obvious and intuitive for arrivals to find and use the service. The airport design, wayfinding system and communication system are cohesively integrated to emphasize an institutionally-promoted transit connection. Several North American airports and municipalities are investing millions of dollars to extend much-exulted high-quality rail links to airports. Logan Airport is fortunate to be served by a proximal heavy rail service (Airport Station on the Blue Line), a direct Bus Rapid Transit service (the Silver Line) and luxury coaches (Logan Express and other buses). However, in some airport terminals, the transit services are not conspicuous; they can feel like an afterthought.

The creation of a "Public Transportation" or "Rapid Transit" zone on each terminal curb would substantially improve user awareness of transit. Instead of separating the Silver Line and Airport Shuttle stops as is done presently, the stops should be co-located into a dedicated and prominent Rapid Transit Zone on the terminal curb. The Rapid Transit Zone should be well-signed and highly-visible.

The Rapid Transit Zone of the terminal should accommodate the following services:

- MBTA Silver Line Route 1
- Massport shuttle routes 22, 33, 55 and 66, all of which serve Airport Station on the Blue Line

Logan Express services should also be highly visible, and they should be placed adjacent to the Rapid Transit Zone. The zone should include real-time information presenting the next arrival time for both the Airport Shuttle and the Silver Line. MBTA system maps and the "2 Ways to Take the T" signs should be provided in this area. Co-locating the stops will give the users more flexibility in planning their trips: if each route offers an approximately equivalent travel time to a given destination, then the user can take the first bus that arrives.

The concept of a **Rapid Transit Zone** at the Logan Airport terminals will be discussed throughout the remaining sections of this chapter.

9.4.2 Wayfinding to Transit Services

<u>**Logan Airport**</u>
The consolidation of Silver Line and Airport Shuttle stops into a Rapid Transit Zone with adjacent Logan Express services on the terminal curb will improve wayfinding because the zone will be a discrete and prominent location to which all signage refers.

The core pieces of information that must be communicated to new arrivals at Logan Airport can be divided into separate concepts:

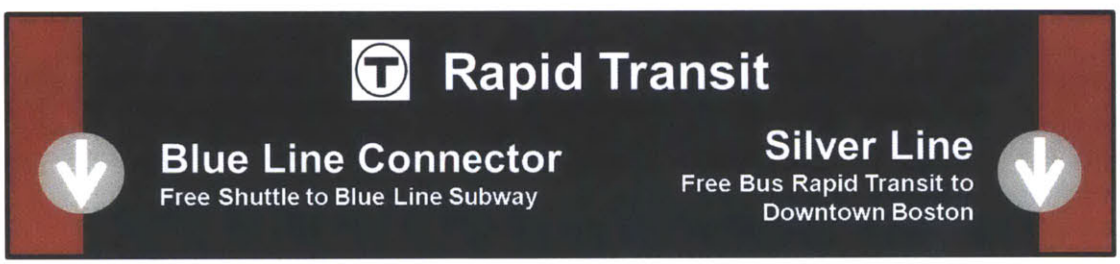
- There are rapid transit public transportation connections to downtown Boston and other regional locations
- These services are called the Silver Line and the Blue Line
- The Silver Line is a free Bus Rapid Transit service; if free entrances to Airport Station are also provided (see **Section 9.4.4**), this information should also be presented
- A free Airport Shuttle provides the connection to Airport Station on the Blue Line subway line
- These are the directions to find the Silver Line and Airport Shuttle stops

A suggested progression of signage that incorporates the wayfinding guidelines with these core pieces of information is presented below.

Primary Signage: The sample Primary Signage, intended for when users first enter the arrivals hall, shows Rapid Transit and Ground Transportation as separate entities. The MBTA "T" logo is placed adjacent to the Rapid Transit to associate the symbol with transit

Secondary Signage: The sample secondary signage, potentially placed above the terminal doors, refers to the rapid transit and ground transportation services specifically.

Tertiary Signage: The sample tertiary signage, to be placed at the terminal curb, provides additional details about the rapid transit modes. The Silver Line is defined as "Free Bus Rapid Transit to Downtown Boston". The Airport Shuttle has been re-named "Blue Line Connector" to increase clarity for users, and the service has been defined as a free shuttle that connects to heavy rail. This signage require co-location of the Silver Line and Airport Shuttle stops



Airport Station

There is clear signage to direct passengers from the Blue Line subway to the station curb where the airport shuttles pick-up passengers. Some signage could be added to the community entrance, although most users at this entrance are likely already familiar with the shuttle location.

The existing curb has signs for Route 22 (serving Terminals A and B) and Route 33 (serving Terminals C and E), but there are no signs for Route 55, which runs in the morning and late evening and serves all terminals. There is an existing sign and curbspace for Routes 44 and 66 which could be converted into a sign for Route 55 and Route 11, another bus which serves all terminals and was observed to stop at Airport Station. Route 44 buses are very infrequent and serve employees who are generally familiar with the route. Route 66 buses have much lower ridership than the other routes and were not observed to stop at this sign. Thus, this space could be re-allocated to Route 55 and Route 11 buses. The times of day when the different routes run could also be added to the signs.

A solution that requires more complex technology is to replace the static signs with two digital signs to display the route number and the terminal destinations for the bus in the adjacent bay. These digital signs would have the flexibility to switch between Routes 11, 22, 33 and 55. Two signs are required in order to accommodate the Route 22 and Route 33 buses simultaneously, as they often dwell at the station at the same time.

<u>South Station</u>
Signage in South Station can be improved to clarify connections to the Silver Line:

- Provide a large sign on the concourse level that points to the Silver Line platform, akin to the existing sign for the Red Line platforms
- Increase visibility of the station name on the Red Line and Silver Line platforms, as they are difficult to read from within the transit vehicles
- Improve signage for the connection to the Silver Line on the Red Line platform. At the stairwells that provide indirect access to the Silver Line platform, provide signage and arrows that point toward the direct stairwell connection

If a future express service to Logan Airport is introduced from an expanded South Station bus terminal, wayfinding and signage will be an important issue, particularly for the transfer from the Red Line.

9.4.3 Directness of Transfer to Service

This section explores strategies to create direct transfers to the public transportation services.

The Rapid Transit Zone on the terminal curb should be located close to the terminal doors in order to give priority to HOV users over travelers who park, take taxis or are dropped off or picked-up. When public transit services are relegated to distant curb or island locations, it implies that the transit modes are unimportant or inferior to other ground transportation services. Placing the transit stops close to the terminal doors increases the visibility of the transportation services and encourages ridership growth by both reducing the access time to the mode from the terminal doors and increasing convenience and user perception of the service quality.

Two alternatives are discussed to implement a "Rapid Transit" zone on the curbs of Logan Airport:

- Alternative 1: Rapid Transit services on lower level of terminals
- Alternative 2: Rapid Transit services on upper level of terminals

Alternative 1: Rapid Transit Services on Lower Level of Terminals
This alternative explores options to reallocate curbspace to give premium locations to a "Rapid Transit" zone and to Logan Express on the lower level of the terminals at Logan Airport. Potential reallocation of curbspace at the Logan Airport terminals is presented in **Figure 9-7**, **Figure 9-8**, **Figure 9-9**, **Figure 9-10** and **Figure 9-11**. An important change in the future layouts is the reduction in the number of rental car buses. Once the new Consolidated Rental Car Facility (CONRAC) is open, all of the rental car buses will be replaced by an airport shuttle operated by Massport that connects to the facility directly. The future curb requirement for rental car shuttles / courtesy shuttles is reduced, and this has been reflected in the recommended layouts.

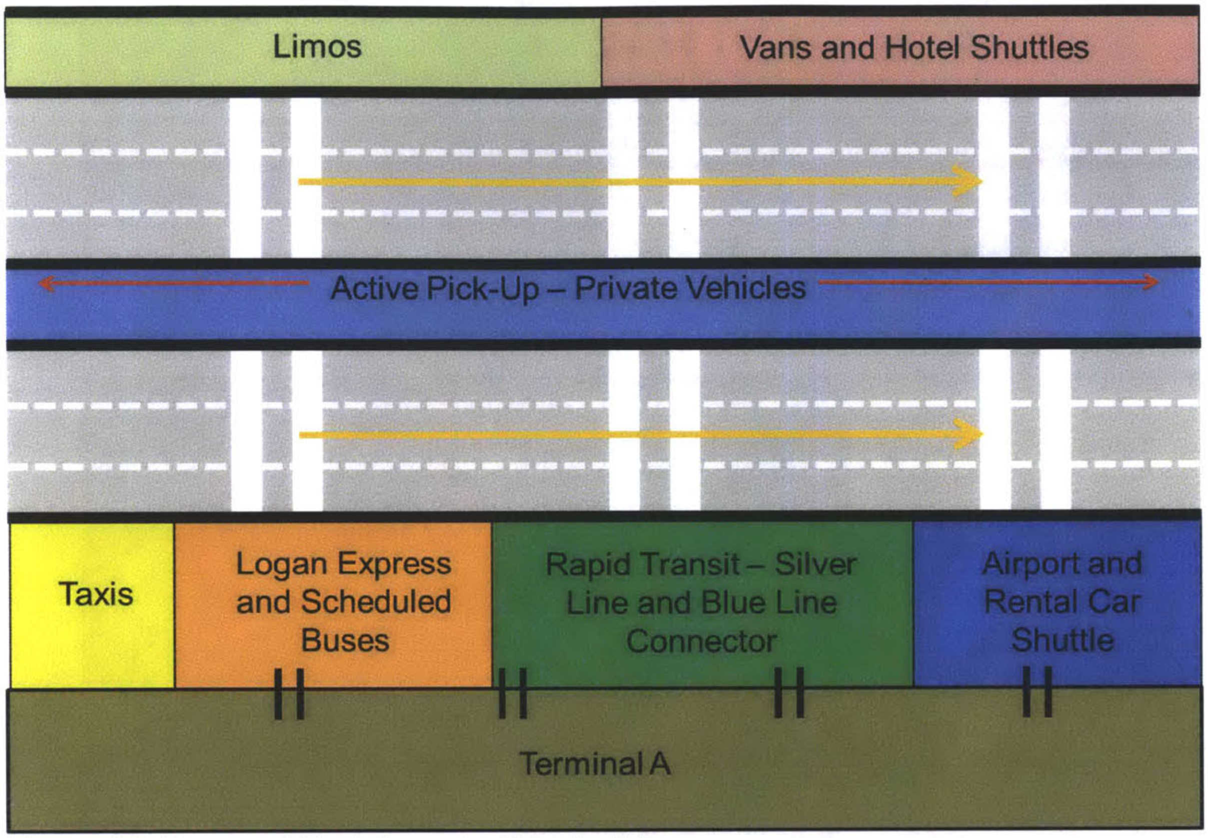


Figure 9-7: Proposed Curb Layout – Terminal A

Terminal A: Several elements of the curb layout at Terminal A are unchanged: active private vehicle pick-up remains at the first island, and limos, vans and hotel shuttles remain at the second island. On the terminal curb, taxis remain at the far left side, but a new rapid transit zone for the Silver Line and Airport Shuttles to the Blue Line has been created in a central location. The zone for Logan Express and other scheduled buses has been located adjacent to the rapid transit zone. As a result of the reduced future need for rental car shuttle curbspace, the remaining Airport Shuttle (for Route 11 which links terminals) and rental car bus have been allocated a smaller amount of space at the edge of the curb. This layout reflects priority for HOV travel from Logan Airport.

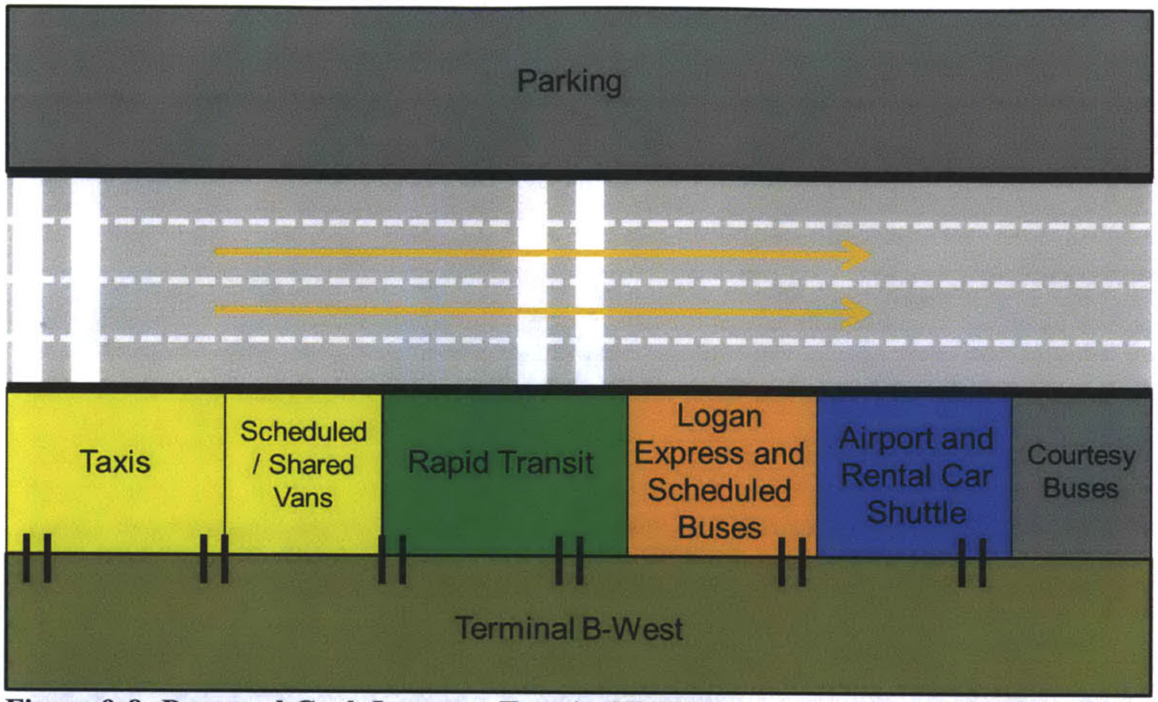


Figure 9-8: Proposed Curb Layout – Terminal B-West

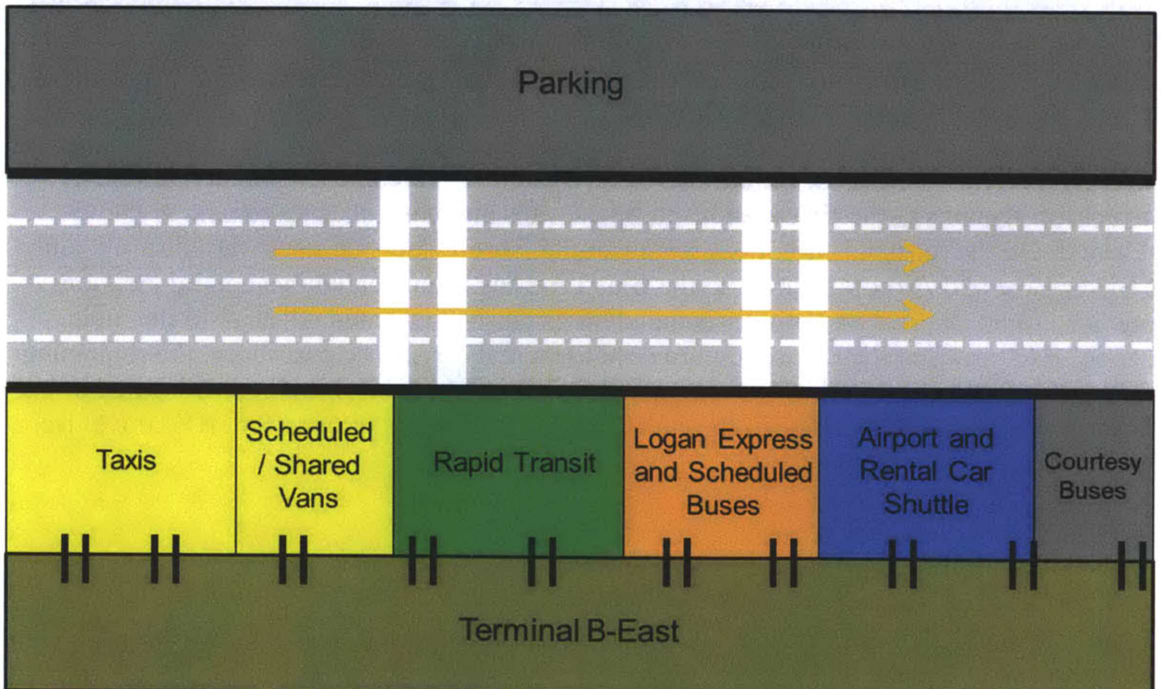


Figure 9-9: Proposed Curb Layout – Terminal B-East

Terminal B-West and Terminal B-East: The curb layouts of Terminal B-West and Terminal B-East have been re-organized to emphasize HOV travel. Taxis, courtesy shuttles to hotels, and the airport and rental car shuttles have been placed toward the edges of the curb, while vans, rapid transit, Logan Express and other scheduled buses have been placed toward the center of the curb.

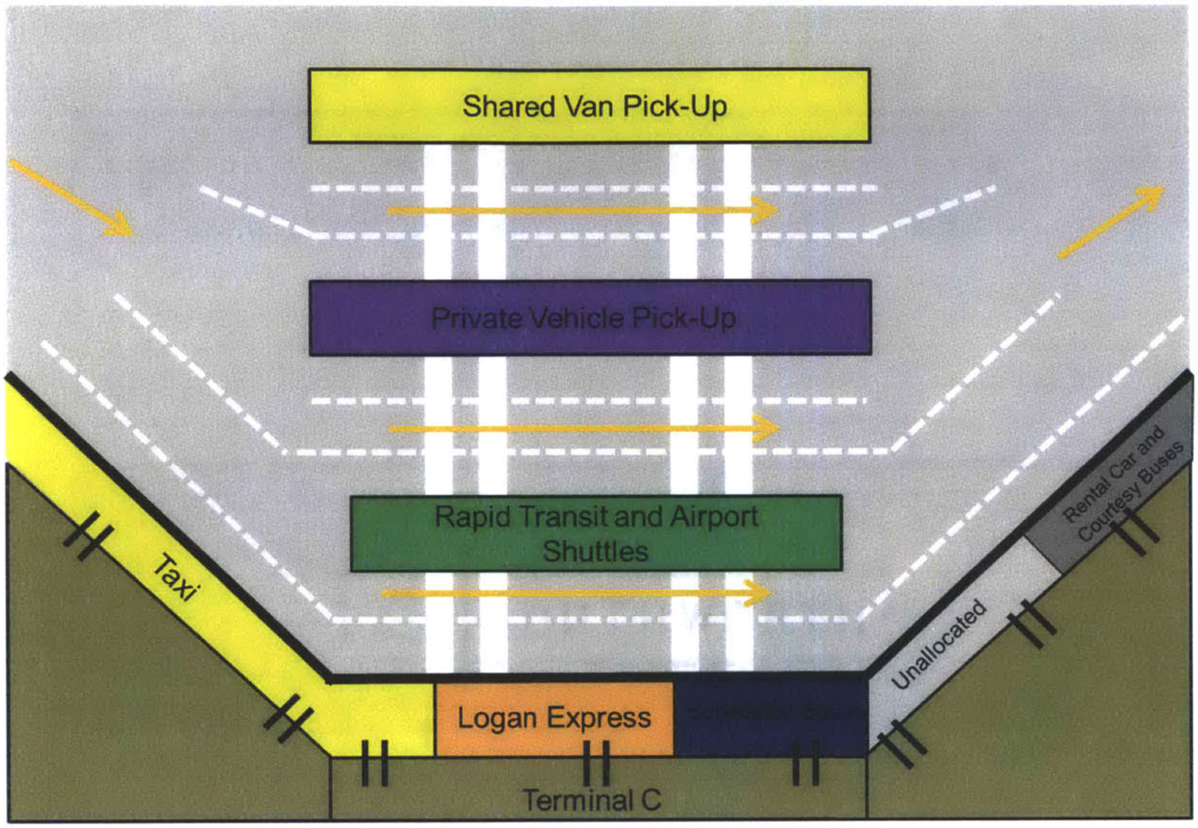


Figure 9-10: Proposed Curb Layout – Terminal C

Terminal C: Terminal C has the most complex layout. As a result of its relatively short terminal curb length, three islands are used to increase space available for pick-ups and drop-offs. The shape of the terminal also results in the half-hexagonal shape of the curb. The proposed layout moves the Silver Line stop to the first island, where a rapid transit zone has been created. The airport shuttle stop is already located on this first island. The rental car bus and courtesy buses for hotels have been moved to the curb further from the terminal doors. The Logan Express and scheduled buses are located at the main curb, where additional curb width is provided. The drivers of these buses load passenger luggage in the storage areas beneath the bus and need sufficient curb width. Further, Silver Line and Airport shuttles can avoid the congested area closest to the terminal doors by stopping at the first island.

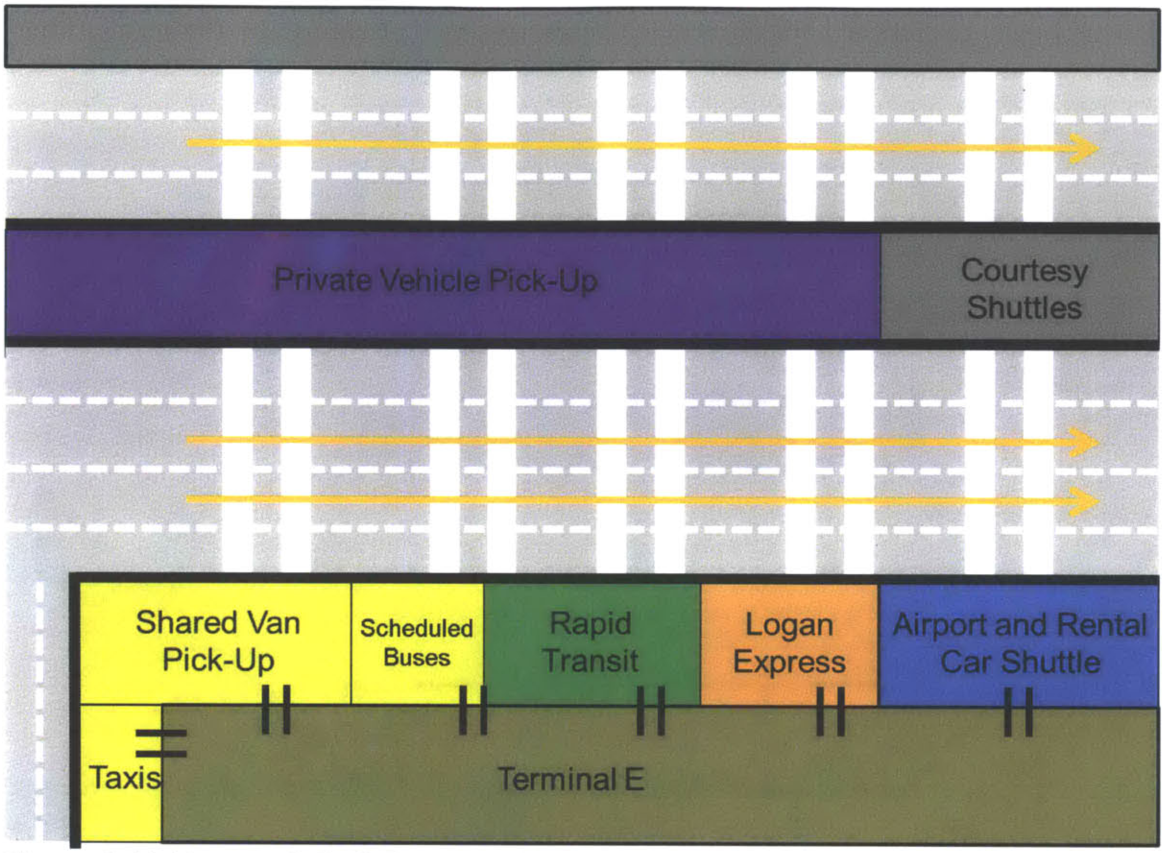


Figure 9-11: Proposed Curb Layout – Terminal E

Terminal E: The major change at Terminal E is the transfer of private vehicle pick-up to the island. Courtesy shuttles, which will only need to serve hotels in the future case, are also located on the island. The rapid transit zone has been located by the central doors of the terminal, which are directly accessible from both arrival areas in the hall. This zone is also close to the main escalators leading to the departures level, which facilitates access for passengers arriving by transit. The curb area dedicated to the Logan Express and scheduled buses are also given a central location. The rental car shuttle and inter-terminal airport shuttle (route 11) is located at the end of the curb, and the location of the taxis has not changed from the existing case.

Alternative 2: Rapid Transit Services on Upper Level of Terminals

A second alternative is to create the Rapid Transit Zone (with the Silver Line and Airport Station shuttle stops) on the upper level of each terminal. Existing Silver Line buses do not fit on the upper level – therefore, this alternative will not be feasible unless and until lower Silver Line buses are procured. See **Chapter 0** for further discussion of the recommended future bus technology for the Silver Line.

Table 9-8: Evaluation of Rapid Transit Zone on Upper Level of Terminals

	Impact
Change of Level	▪ After claiming baggage, passengers would need to go up an escalator with their luggage to reach the stops. Although most airport/rail connections require passengers to change levels, placing the buses on the upper level could dissuade passengers from using transit. ▪ Passengers who do not need to claim any baggage can stay on the same level and proceed directly to the upper level curb ▪ Arriving passengers have a more direct transfer
Access Distance	▪ The lower levels and upper levels are generally well-connected by frequent escalators; Terminals A, B and C each have 4 to 6 escalators ▪ Terminal E only has three escalators; although they are well-placed, this results in slightly longer transfer distance to the upper level
Curb Space	▪ Most of the curb space on the upper levels is unallocated, so premium curb space near the main entrances can be assigned to public transit with significantly less disruption to other modes
Travel Time	▪ More congestion was observed on the lower level roadway than on the upper level roadway; placing the buses on the upper level roadway could result in travel time savings for the buses ▪ Shifting vehicles from the lower level to the upper level could ease congestion for other modes on the lower level
Wayfinding	▪ Spatially separating the public transit modes from the other ground transportation will facilitate wayfinding; signage can clearly indicate that public transit is one level higher, and there will be much less curb confusion if public transit is one of the only major modes using the upper level

The main disadvantage to locating the rapid transit services on the upper level is that users would have to go up one level with their luggage on an escalator. Although arriving passengers on the Silver Line and Airport Station Shuttle must go up one level to the check-in desks, this is less likely to influence their decision to take transit to the airport. As there are several competing modes at the lower level curb for passengers departing from Logan Airport, placing the transit modes on a separate level may disadvantage these modes. This alternative is **not recommended**; rather, Massport should study the relocation of all private vehicles to the upper level, as discussed in **Section 6.10.6**.

Another consideration is to have the Silver Line drop passengers off at the upper level and then deadhead back to the lower level to pick passengers up. While this would improve customer convenience, it would increase running time by 8.5 to 10 minutes by doubling the distance traveled on Logan Airport roadways (see **Table 3-5** for a review of Silver Line average travel times). Therefore, the cost of running the service would increase in order to maintain existing headways. It would also require lower vehicles to travel on the upper level, as discussed in **Chapter 0**.

Airport Station

The curb layout at Airport Station should be modified to facilitate the transfer to the Airport shuttles buses. At present, the highest-volume buses that serve the airport terminals are located down the curb from the door, while the courtesy shuttles which carry significantly lower volumes are able to stop immediately at the main door outside Airport Station. A proposed reallocation of the curb at Airport Station is shown in **Figure 9-12**.

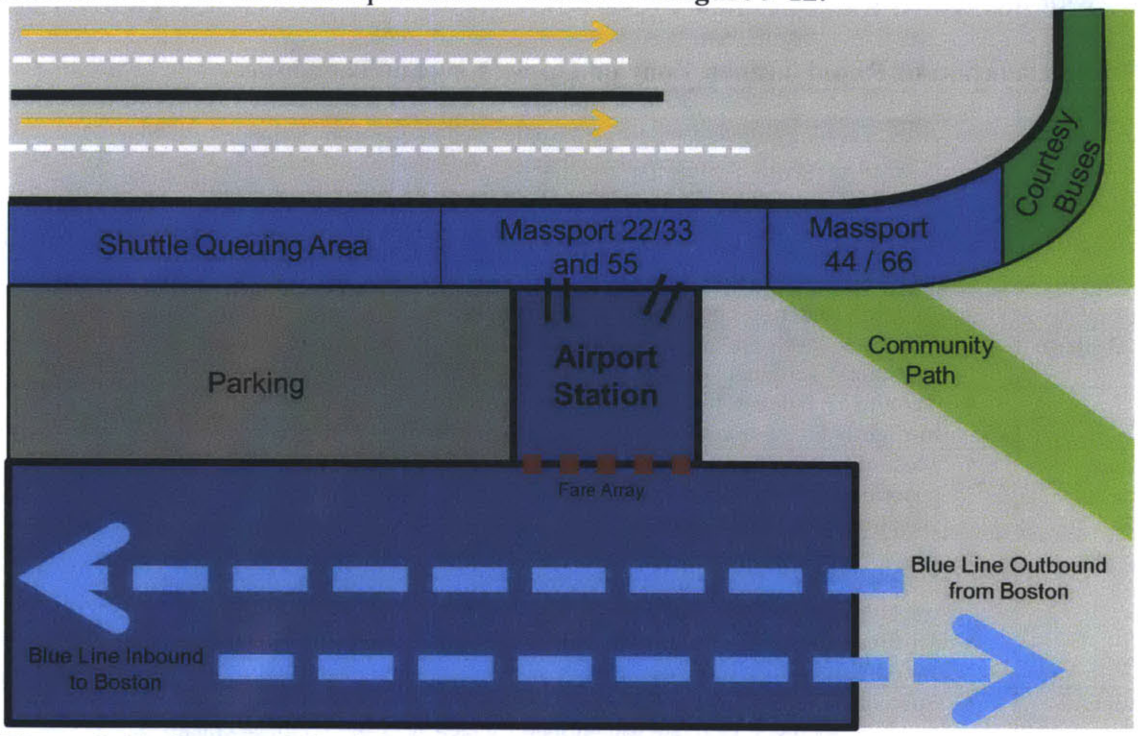


Figure 9-12: Proposed Curb Layout – Airport Station

9.4.4 Fare Payment

The free Silver Line boardings pilot project greatly simplified the fare payment process for this mode by eliminating the need for passengers to obtain fare media and validate it when boarding the bus. Further, free outbound Logan Express trips were recommended in **Section 8.2.4** in order to attract additional ridership. The airport shuttles are also free, although passengers must obtain fare media upon arrival at Airport Station.

An improvement to the existing system would be to provide free entrances to Airport Station on the Blue Line in addition to free boardings on the Silver Line. This would remove the cost imbalance between the two modes and allow users to select the service which is most convenient for them without consideration of the cost. Although this would come at a cost to Massport, providing free boardings to the Blue Line in addition to free boardings to the Silver Line would have the following advantages:

- Free boardings to the Blue Line are expected to result in increased transit usage, supporting Massport's HOV goals. An analysis of the change in Silver Line ridership suggests that ridership has increased, but that some decreases in entrances at Airport Station may have occurred. If both services are free, travelers can select the service which is most convenient, without regard for the cost

- Free boardings to the Blue Line would benefit Logan Airport employees who use the Blue Line to get to Logan Airport. The 2007 Logan Airport Employee Commute survey indicates that a larger proportion of employees earning less than $50,000 use the Blue Line[101]; thus, this measure would disproportionately benefit employees with less disposable income available for transportation. Shifting employees to transit would also help ease parking demand at the employee parking lots
- If the Silver Line, Logan Express and the Blue Line are free for arrivals at the airport, Logan Airport can brand itself as an airport that provides "free public transit". This is a resonant message that will generate interest and attention within the airport, the city and the aviation industry itself
- Providing free Silver Line, free Logan Express and free Blue Line simplifies the decision-making process for transit users. If waiting for transit services in the rapid transit zone, they may be able to use whichever bus arrives first without consideration of the cost difference

Some alternative strategies to provide free access to Airport Station are evaluated in **Table 9-9**.

Based on this analysis, the recommended strategy is to have the shuttle operator provide the transit riders with a Charlieticket with one pre-paid fare. This is the lowest-cost solution to Massport and the MBTA: it requires neither new staff nor modifications to Airport Station, while minimizing the risk of fare evasion. There are some potential disadvantages with this solution, which should be mitigated as follows:

- Driver workload: tickets can be distributed at the front of the bus from a dispensing device, such as how paper transfers are distributed on the buses in some cities.
- Non-authorized users: drivers should distribute tickets at controlled locations where they can verify that tickets are being distributed to authorized shuttle users
- Driver security: as drivers may become targets for theft, they should carry only a minimal number of Charlietickets on each run. Security cameras on the shuttles also help increase driver security
- Dwell time: if users must use the front door to obtain a ticket, this will increase dwell time at the terminal stops. The driver can opt to distribute the tickets as passengers alight at Airport Station, as the buses generally layover at Airport Station; this will reduce the likelihood of ticket distribution lengthening running times.

Table 9-9: Alternative Strategies to Provide Free Access to Airport Station

Technique	Advantages	Disadvantages
Staff at terminal Airport Shuttle stop hand out Charlietickets with one pre-paid fare	-Staff at stop able to help users, answer questions, provide directions, etc. -Introduction of Charlieticket to visitors and tourists may make them more likely to use transit while visiting Boston -Giving a free ticket to people is a tangible, perceptible benefit	-Significant cost required to provide staff at shuttle stops at each terminal at all times of day -Use of fare media somewhat complicated for unfamiliar users -Disposable Charlietickets result in more waste

[101] 2007 Logan Airport Employee Commute Survey, page 11

Technique	Advantages	Disadvantages
Device at terminal Airport Shuttle stop dispenses Charlietickets with one pre-paid fare	-Lower cost to use machine in lieu of staff -Introduction of Charlieticket to visitors and tourists may make them more likely to use transit while visiting Boston -Giving a free ticket to people is a tangible, perceptible benefit	-Challenging to prevent users from taking multiple tickets -Using device increases complexity for users -Ongoing maintenance cost for device -Device malfunction a cause of stress and delay for users
Staff at Logan Airport Information Desks hand out Charlietickets with one pre-paid fare	-Low cost to implement, as Information Desks are already staffed -Introduction of Charlieticket to visitors and tourists may make them more likely to use transit while visiting Boston -Giving a free ticket to people is a tangible, perceptible benefit	-No Charlietickets available when Information Desks are closed -Users must find the Information Desks before finding shuttle stop, which increases complexity -Challenging to design wayfinding if tickets located in separate location from the shuttle stop
Airport shuttle operator gives each passenger a Charlieticket with one pre-paid fare	-Very low cost to implement – requires no new staff and minimal training of existing staff -Introduction of Charlieticket to visitors and tourists may make them more likely to use transit while visiting Boston -Giving a free ticket to people is a tangible, perceptible benefit	-Increase to driver workload -Non-airport users may try to get free ticket from driver -Driver may become a target for theft -May increase bus dwell time at terminal curb or at Airport Station
Reconfigure Airport Station drop-off area so that shuttle passengers alight in a "fare-paid" zone	-Low complexity for transit users – very simple connection -No need for fare media	-Expensive solution -Zone may not be well-controlled; other users to access the zone and evade fare payment -Reduces flexibility of bus boarding and alighting locations at Airport Station -May be a barrier to any through trips along the Airport Station curb
Eliminate fare array on airport side of Airport Station	-Low-cost solution -Low complexity for transit users – very simple connection -No need for fare media	-Sizable number of non-airport related entrances on this side would now be subsidized -Large incentive for users of Bremen Street entrance to use airport side instead for free

The cost to Massport for implementing this initiative has been assessed. The current one-way subway fare using a Charlie Card is $2.00, so Massport would incur an additional cost of approximately $2.1 million (using the outbound ridership from Logan in Table 5.2) for subsidizing these passenger trips. The new amounts that would be spent by Massport in this scenario are summarized in **Table 9-10**, resulting in a $2.00 subsidy per passenger.

Table 9-10: Potential Expenditures by Massport on Blue Line Shuttle Service to Logan Airport with Free Entrances at Airport Station

Description	Amount
Estimated Annual Operating Cost	$2,400,000
Blue Line Subway Fare Subsidy (Outbound from Logan)	$2,100,000
Estimated Annual Ridership	2,250,000
Annual Fare Revenue	$0
Total Annual Cost	$4,500,000
Subsidy/Passenger	$2.00

9.4.5 Comfort of Waiting Area

The waiting areas at Logan Airport and Airport Station are generally uncomfortable. The features of a Ground Transportation Center are instructive in outlining amenities that improve the passenger waiting experience (see **Section 9.2.5**). The broad vision is to provide users with a comfortable, high-quality space that rivals the departure lounges where passengers wait before boarding their flight. Passengers have been observed to wait inside the terminal doors, watching for the buses to arrive. This is an informal place for customers to wait, and it also slightly impedes movement through the doors. It indicates demand for a comfortable waiting area for ground transportation modes.

The comfort of the waiting area is also a function of the expected wait time. Thus, these waiting areas could serve passengers waiting for the Silver Line (average headway 10 minutes), Logan Express and Scheduled Buses with longer headways.

The recommended curb layout for Terminals A, B and E places the transit modes near the main doors on the first curb. At these locations, consider developing a comfortable waiting area within the lower level of the terminal. The lower level of the terminal is already climate-controlled and there are concessions stands, airport information and restrooms within the vicinity. The waiting area specifically should include the following features:

- Comfortable seats for travelers
- Real-Time information indicating the next arrival time for the Silver Line and the Blue Line connector. This information is important, because if passengers arrive just before the buses arrive they will not have time to sit down.
- "Bus Arriving" flashing light or notification, to encourage travelers to head outside to the boarding area as the bus is arriving. If the bus has to wait for everyone to walk to the boarding area, it may increase the dwell time and consequently increase run times
- Information about MBTA service (i.e. the "2 Ways to take the T" sign)
- Large windows through which users can clearly see the bus when it arrives. Users will feel anxious about missing their connection if they cannot see it arriving.
- Proximity to the main doors, to minimize access time between the waiting area and the boarding area
- Clear signage to indicate that the waiting area is intended for people awaiting particular ground transportation modes
- Art or sculpture to provide visual interest

The recommended layout for Terminal C places the rapid transit modes on the second curb. Thus, a waiting area inside the terminal is not recommended because of the access distance.

Instead, the comfort of the curb area itself can be improved. A sheltered curb waiting area, similar to the one presently installed at Terminal E (**Photo 9-41**), could be provided on the Terminal C second curb. Interior waiting areas within the terminal itself could be provided for Logan Express and Scheduled Bus service.

Photo 9-41: Terminal E Curb Waiting Area

Ground Transportation Center Concept

Some North American airports are introducing Ground Transportation Centers to serve as one-stop locations for all ground access modes. Although these can be very effective at some airports, it would be challenging to implement at Logan Airport as a result of its decentralized terminal layout. Access time and distance to a centralized Ground Transportation Center would be significant, and could discourage transit usage. Further, this would place the transit modes further from the taxi and private vehicle modes using the existing curb space.

Airport Station

The recommended layout for Airport Station relocates the loading and unloading areas for the Massport shuttles closer to the main entrance. Within the station, there is a large space before the fare arrays. This space could be rearranged to provide a comfortable, interior waiting area for the Airport shuttles. Presently, this is an uncomfortable area for travelers to wait because there is poor visibility of the location where the shuttle stops further down the platform. However, if the shuttle stop is relocated to main doors, the buses will be directly visible from the waiting area within the station. This space is also used for passengers to purchase fare media, so any modifications must be planned carefully to avoid congested passenger flows and obstruction of passenger flows into the station.

9.4.6 Ease of Using Service

The existing vehicles and operational procedures contain several design elements that facilitate the ease of using the service for riders. Future vehicle procurement should retain the following existing features:

- Luggage racks
- Terminal information inside the bus
- Auditory messages
- Low-floor boarding
- Clear digital display of route number and destination on the bus
- Climate-controlled vehicles
- Boarding at all doors

To improve the ease of using the buses, the following improvements can be considered:

- Clear announcement of the terminals being served by Airport Shuttle branch routes, to reduce user confusion. The operator should make the announcement to increase user attention
- Louder announcement of the stops on the Silver Line. Unfamiliar riders, often destined to South Station, are unsure of where to alight the Silver Line and sometimes think that airport terminal stops are South Station. When leaving Terminal E, the driver should announce that the terminating stop is South Station. As the bus leaves the airport, this is an ideal time for information about the trip itself and the MBTA system more generally to be announced to passengers. For example, a message can inform passengers that their trip has been paid for courtesy of Massport and can provide them information on where and how they can purchase their return trip to the airport on transit.
- Use the time as the bus leaves Terminal E to provide general announcements about the MBTA, inform unfamiliar users about the system, and encourage them to continue using transit during their trip

9.5 Conclusion

This chapter has discussed several concepts for providing a simple and more intuitive transfer from the airport to public transit modes at the curb. Based on this review, the ideal scenario can be summarized as follows:

- High user awareness of transit services cultivated through advertisements, marketing, transit system maps and signage in the airport
- "Rapid Transit" zone on the curb which serves the co-located stops for the Silver Line and shuttle connection to Airport Station
- Placement of "Rapid Transit" zone in a central and visible location of the terminal curb to enable direct and comfortable transfers for arriving passengers
- Signage that presents the "Rapid Transit" zone as a unique element on the curb and provides unambiguous directions
- Continued free boardings of the Silver Line, introduction of free Logan Express and provision of Charlietickets with one pre-loaded fare on shuttles to Airport Station
- Comfortable waiting areas, potentially within the terminal, with seats, real-time information, public art and direct sight lines to the transit stop
- Vehicles designed with sensitivity to the unique nature of transit travel to and from the airport (i.e. low-floor, luggage racks, clear announcements for unfamiliar users, signs indicating which airlines serve each terminal)

10 Potential Future Transit Services

There are multiple potential future transit services which would increase the accessibility of and therefore improve transit access to Logan Airport:

- A new Logan Express service connecting to Worcester
- A new transit connection to Route 128 near Hanscom Field
- A new Silver Line route connecting to Chelsea, as part of the Urban Ring design or running from South Station
- An express service between South Station and Logan
- The Silver Line Phase III
- The Red Line / Blue Line Connector
- Blue Line extension to Lynn

This chapter focuses primarily on two of these potential new transit services: a Logan Express to Worcester and a Silver Line route to Chelsea from South Station.

10.1 Transit Connections to Worcester

The potential improvements of the transit route connecting Worcester and Logan Airport are discussed and analyzed in this section.

10.1.1 Introduction

Worcester, located in central Massachusetts approximately 40 miles west of Boston, is the second largest city in New England[102]. According to the 2010 Air Passenger Ground Access Survey, there are approximately 300 to 600 average daily ground access trips from Worcester to Logan Airport. Currently commuters have two options to travel between Worcester and Logan Airport by public transit: MBTA service or Peter Pan bus. Both transit services take 2 to 3 hours for a one-way trip. As marked in **Figure 10-1**, Worcester is clearly outside of the Logan Express service catchment areas. As the "Heart of the Commonwealth", the city of Worcester has a high demand for more frequent, direct, and reliable transit service to Logan Airport. It is also notable that Route 128 near Hanscom Field (BED) is a blank spot on the map. This is a potential topic for future study and has not been analyzed in this section.

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[102] 23rd United States Census 2010

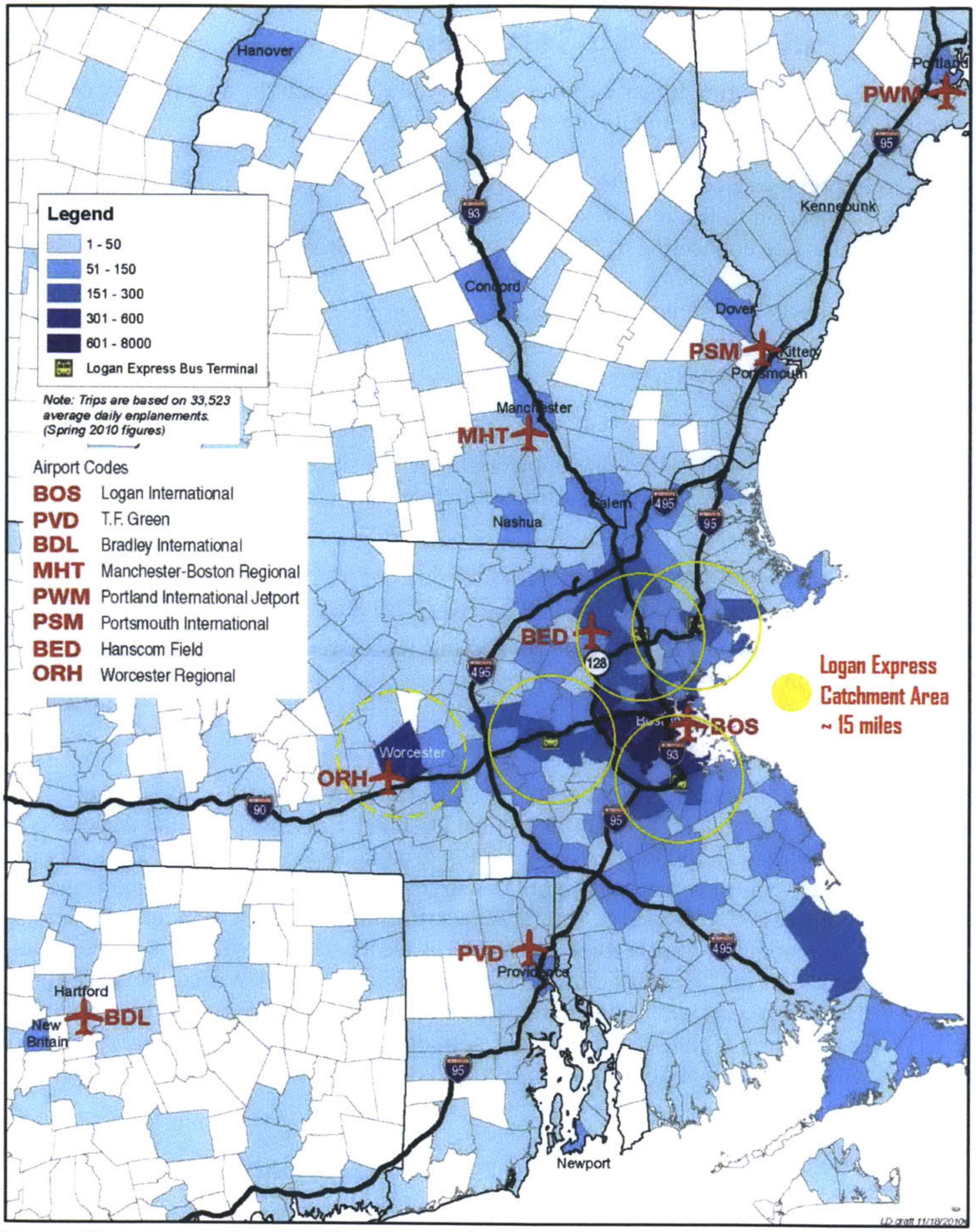

Figure 10-1: Logan Express Catchment Area and Distribution of Average Daily Ground Access Trips to Logan Airport by Municipality[103]

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[103] 2010 EDR Chapter 5, 2010 Air Passenger Ground Access Survey

10.1.2 Existing Conditions

One of the public transit options is to use MBTA services. People traveling from Worcester to Logan Airport could board the Commuter Rail service in the Framingham/Worcester Line from Worcester/Union Station to South Station in Boston, and then transfer to Silver Line #1 to Logan Airport. The trip takes about 2 hours although the MBTA is currently assessing potential improvements to commuter rail, which could improve the existing transit service (see **Figure 10-2**). The regular price is $10 for commuter rail and $2.50 for the rapid transit.

Table 10-1: MBTA Commuter Rail Weekday Schedules[104]

WORCESTER - SOUTH STATION			SOUTH STATION - WORCESTER		
Departs	**Arrives**	**Duration**	**Departs**	**Arrives**	**Duration**
4:45 AM	6:31 AM	1:46	4:05 AM	5:24 AM	1:19
5:15 AM	6:47 AM	1:32	6:50 AM	8:16 AM	1:26
5:55 AM	7:36 AM	1:41	9:05 AM	10:31 AM	1:26
6:20 AM	7:43 AM	1:23	10:30 AM	12:05 PM	1:35
6:35 AM	8:16 AM	1:41	12:22 PM	1:53 PM	1:31
7:00 AM	8:28 AM	1:28	1:15 PM	2:48 PM	1:33
7:30 AM	9:03 AM	1:33	2:45 PM	4:18 PM	1:33
8:30 AM	10:00 AM	1:30	4:05 PM	5:24 PM	1:19
10:50 AM	12:25 PM	1:35	5:00 PM	6:23 PM	1:23
12:20 PM	1:55 PM	1:35	5:35 PM	6:43 PM	1:08
2:10 PM	3:45 PM	1:35	5:40 PM	7:04 PM	1:24
3:25 PM	5:00 PM	1:35	5:55 PM	7:36 PM	1:41
4:55 PM	6:31 PM	1:36	7:18 PM	8:55 PM	1:37
6:12 PM	7:53 PM	1:41	8:35 PM	10:11 PM	1:36
7:55 PM	9:11 PM	1:16	10:20 PM	11:56 PM	1:36
9:30 PM	11:00 PM	1:30	11:25 PM	1:01 AM	1:36
12:10 AM	1:30 AM	1:20			

The trip between Worcester and Logan Airport by MBTA services consists of a long in-vehicle travel time and a transfer at South Station. The MBTA Worcester Line has a headway that ranges from 30 minutes to two hour during weekdays, with 17 inbound and 16 outbound scheduled trips per weekday. It takes about 90 minutes each way between Worcester / Union Station and South Station in Boston, and another 20 minutes on SL1 between South Station and Logan Airport.

[104] http://www.mbta.com/schedules_and_maps/rail/lines/?route=WORCSTER&direction=O&timing=W&Redisplay Time=Redisplay+Time

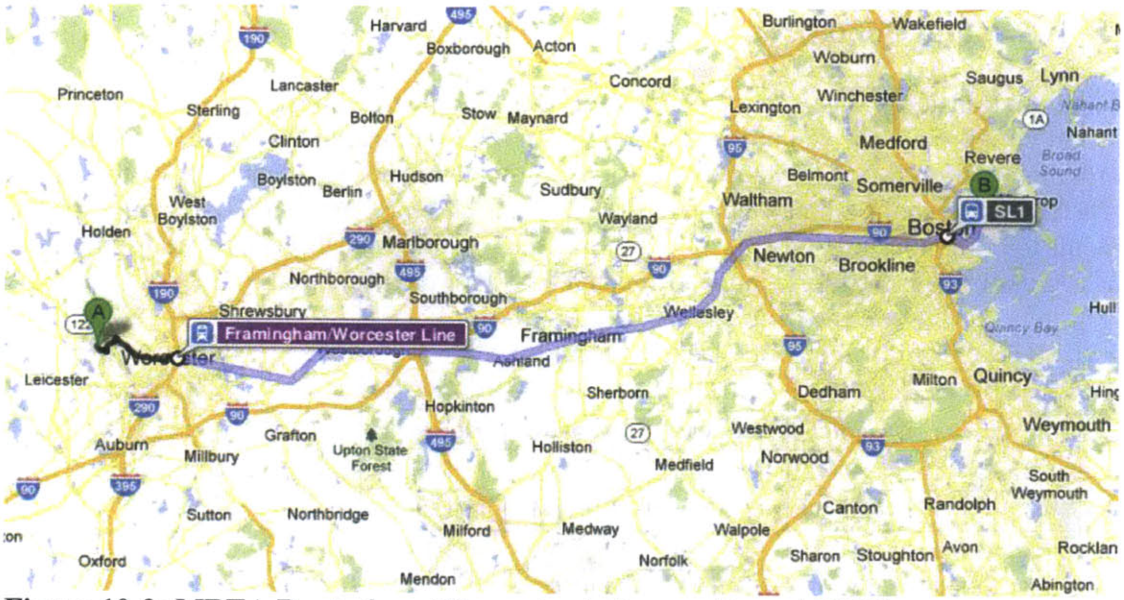

Figure 10-2: MBTA Route from Worcester to Logan Airport (BOS)

The second option is to take Peter Pan Bus Lines. The bus schedules between Worcester and Logan Airport are shown in **Table 10-2**. The Peter Pan services between Worcester and Logan Airport are operated at a one-way fare of $17.50. Most of the scheduled Peter Pan trip lengths are between 2 and 3 hours, similar to the trip lengths for using MBTA services. However, they have a higher one-way ticket cost. These trips are long because they make multiple stops between Worcester and Logan Airport.

Table 10-2: Peter Pan Bus Schedules[105]

WORCESTER - LOGAN			LOGAN - WORCESTER		
Departs	**Arrives**	**Duration**	**Departs**	**Arrives**	**Duration**
5:55 AM	8:10 AM	2:15	8:00 AM	10:30 AM	2:30
7:15 AM	9:00 AM	1:45	10:00 AM	12:25 PM	2:25
10:35 AM	12:30 PM	1:55	11:20 AM	2:10 PM	2:50
11:25 AM	1:55 PM	2:30	12:01 PM	2:30 PM	2:29
2:35 PM	4:15 PM	1:40	1:20 PM	4:10 PM	2:50
5:30 PM	6:55 PM	1:25	2:00 PM	4:10 PM	2:10
7:35 PM	9:40 PM	2:05	3:20 PM	6:00 PM	2:40
			5:30 PM	8:40 PM	3:10
			6:30 PM	9:10 PM	2:40

The driving time between downtown Worcester and Boston Logan Airport is approximately 50 minutes each way without congestion. An express transit service between Worcester and Logan Airport might be of interest to Massport, as it would result in significantly improved travel times between Logan Airport and Worcester compared to the existing services.

105 http://secure4.gatewayticketing.com/PeterPanBus/Transportation/ETickets.aspx

10.1.3 Parking for Worcester Logan Express

One major factor in planning a new Worcester Logan Express service is the location of the park and ride facility. There are three locations Massport could consider (see **Figure 10-3**):

- Worcester Regional Airport Garage
- Union Station Hub Press Center
- Highway Interchange Parking Facility (I-90 @ I-495 or I-290 or Hwy 146)

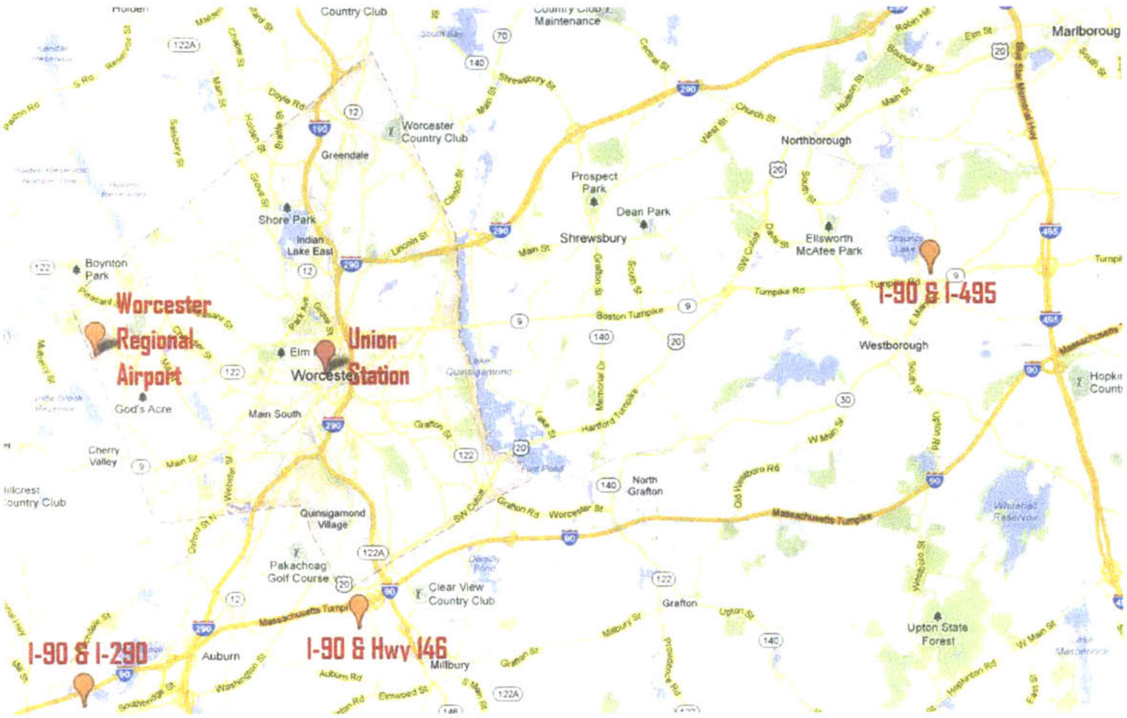

Figure 10-3: Potential Park & Ride Facility Locations near Worcester

Worcester Regional Airport

Worcester Regional Airport (ORH) is a small public airport which has been owned and operated by Massport since June 2010[106]. The Worcester Airport had 47,911 total air operations in 12 months to May 31, 2012, more than 95% of which were general aviation[107]. Direct Air was the only commercial airline flying out of Worcester when Massport acquired the airport. However Direct Air canceled all their flights and later declared bankruptcy in April 2012[108]. In order to attract more commercial flights to the airport, Massport is currently planning to spend $32 million to upgrade its landing system[109]. This effort could potentially bring JetBlue Airways to Worcester.

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[106] http://transportation.blog.state.ma.us/blog/2010/06/massport-worcester-airport-deal-completed.html

[107] http://www.gcr1.com/5010web/airport.cfm?Site=ORH&AptSecNum=2

[108] http://pressrepublican.com/0100_news/x1968911547/Direct-Air-bankruptcy-goes-to-Chapter-7

[109] http://www.telegram.com/article/20130310/NEWS/103109754/1116/mobile&TEMPLATE=MOBILE

As Massport already owns the airport, the under-used parking lots could serve as a park and ride facility for transit service to Logan Airport. The advantage of using this parking lot is that it could be used with little additional cost to Massport. However, since Worcester Airport is located in a relatively remote area and lacks freeway and public transit connections, it is unlikely to attract travelers to use the service.

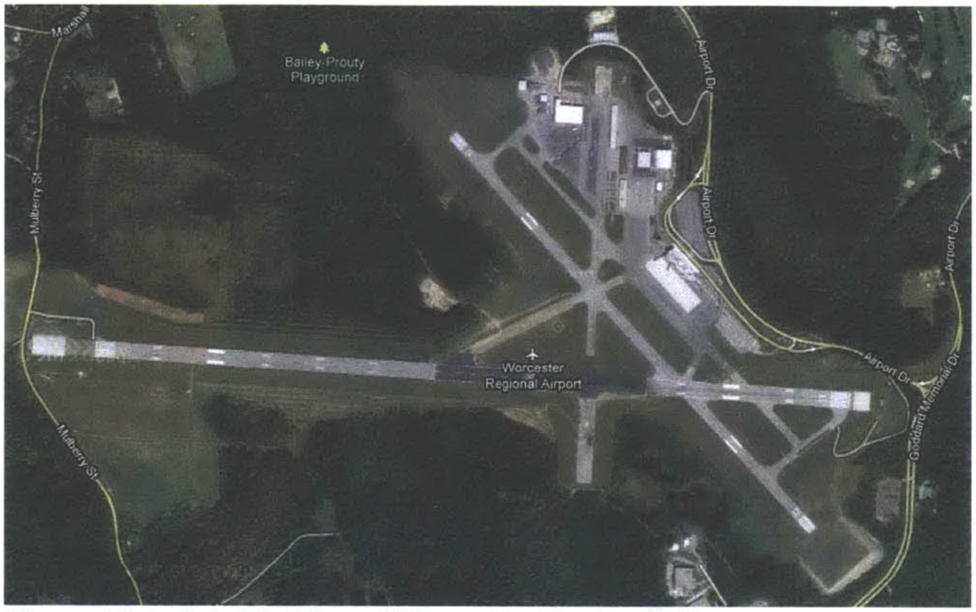

Figure 10-4: Satellite View of Worcester Regional Airport

Union Station

Union Station is the transportation hub in downtown Worcester, which provides access to MBTA Commuter Rail, Amtrak Inter-City Rail, Peter Pan bus services, Greyhound bus services, most local Worcester bus routes and taxis. Union Station was renovated in 2000, and is owned by the Worcester Redevelopment Authority[110]. As an inter-modal hub, this is another potential location for pick-up and drop-off in Worcester.

A 500-space public parking garage was constructed next to Union Station in July 2008 to provide convenient access for visitors and commuters[111]. However the new garage has a low rate of usage. A new transportation hub adjacent to Union Station named Hub Press Center has been under construction since April 2012[112]. The new facility will be the new WRTA administrative offices, customer service center, and the bus transportation hub in downtown Worcester. The project costs approximately $14 million, and was fully funded by Federal Transit Administration and the State[113]. The facility is scheduled to open on June 1, 2013[114].

[110] http://www.worcesterma.gov/development/business-assistance/union-station
[111] http://www.worcesterma.gov/development/business-assistance/union-station
[112] http://www.therta.com/about/hub-press-center/
[113] http://www.worcesterma.gov/announcements/groundbreaking-ceremony-for-wrta-transportation-hub
[114] http://www.therta.com/news/2013/04/new-union-station-hub-opening-soon/

Figure 10-5: Planned Worcester Union Station Hub Press Center[115]

Given its central location and the opportunity to provide direct transfers to other transit modes, Massport could also consider utilizing Union Station garage for a Logan Express service to Worcester. Connecting Logan Express to Worcester/Union Station would provide extra services for airport employees and attract new transit users. However, Massport would also be competing with service provided by the Peter Pan Bus Company.

Highway Interchange Parking Facility
Massport could acquire a new parking facility along the Mass Turnpike near Hwy 146, I-290, or I-495 (see **Figure 10-3**). These locations are highly accessible by automobile. Massport should co-ordinate with MassDOT to determine if there are any unused parcels which could easily be converted into a parking facility.

While the Union Station option provides inter-modal connectivity, the acquisition of a new park and ride facility near the highway junction area could improve automobile accessibility while effectively avoiding competition with Peter Pan. Thus, this location is recommended. Massport should perform further study to determine the optimal location for parking facilities.

10.1.4 Potential New Services

To implement a Logan Express service to Worcester, there are two main approaches Massport could take:

- An extension of the Framingham Logan Express service to Worcester (**Figure 10-6**)
- A new Logan Express route to Worcester (**Figure 10-7**)

[115] http://www.therta.com/about/hub-press-center/

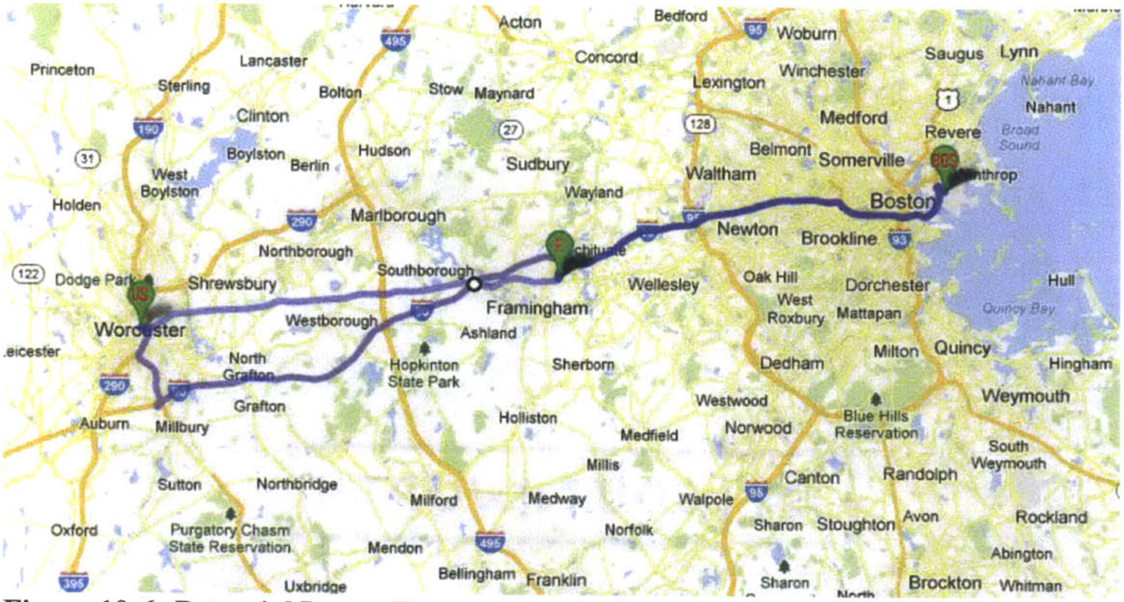

Figure 10-6: Potential Logan Express Framingham Route Extension to Worcester

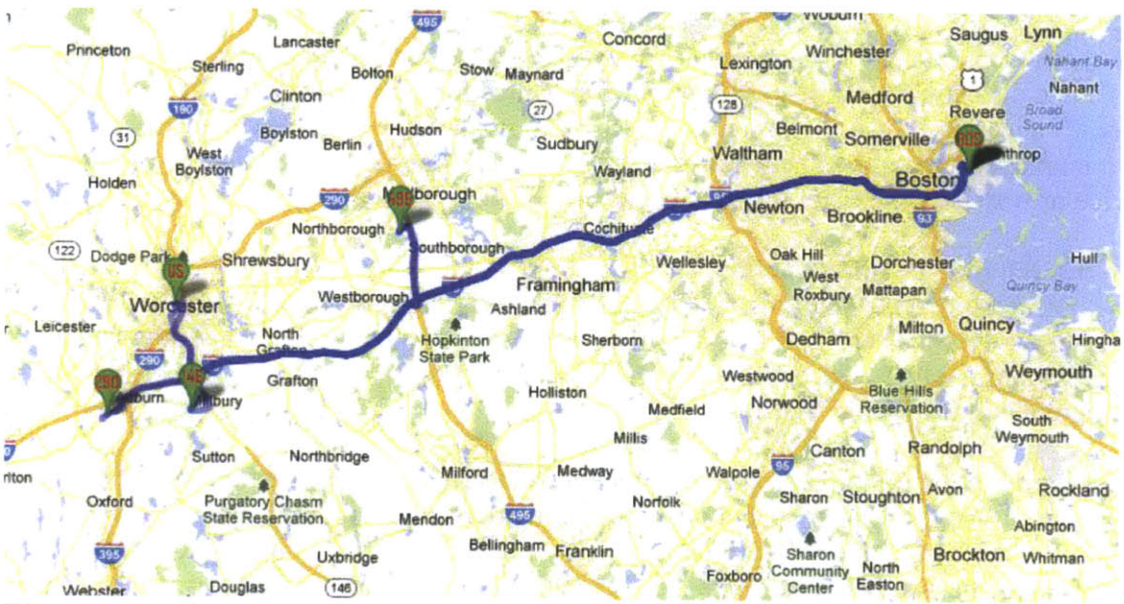

Figure 10-7: Potential New Logan Express Alternatives to Worcester

The new Logan Express route has the advantage of being a non-stop connection between Worcester and Logan Airport. However, the extension of the Framingham route to Worcester could reduce the required fleet size and decrease the initial investment required. Massport should consider extend some of the existing Logan Express trips on the Framingham route to test the demand before making a decision on implementing a full new service.

10.1.5 Recommendations / Summary

It is recommended that Massport initially extend some buses on the Framingham route to a highway interchange parking facility near the Massachusetts Turnpike to test the transit demand. Initially, hourly buses could be run. As ridership increases, an exclusive Worcester Logan Express service could be introduced, with a potential extension to Union Station to attract more transit users. Massport should also monitor whether the extension to Worcester results in new riders, or if people currently boarding at Framingham simply switch to Worcester.

In order to improve the transit access between Worcester and Logan Airport, Massport should also work actively with both Worcester Regional Transit Authority and Peter Pan Bus Company to plan potential express service between Worcester and Logan Airport.

10.2 Transit Connections to Chelsea

10.2.1 Introduction

Chelsea has the third highest population density and the lowest vehicle ownership in Massachusetts. Existing transit access to Logan Airport relies on local buses and shuttles which are often subject to traffic congestion. The city of Chelsea deserves reliable rapid transit connections to Logan Airport.

Currently MassDOT is conducting an Alternatives Analysis for Silver Line to Chelsea, also known as Silver Line Gateway or SL6. This section has also been identified as one of the most cost effective segments with the highest ridership of the Urban Ring plan. MassDOT has listed four main tasks in their scope: Civic Engagement, Refinement of Alternatives, Alternatives Analysis and Environmental Notification Form (ENF)[116]. The alternatives analysis is expected to be completed in September 2013[117].

All Silver Line extension alternatives include a route through South Station, the Ted Williams Tunnel, Airport Station (bypassing airport terminals), East Boston-Chelsea Bypass, Chelsea Street Bridge, and downtown Chelsea. The new Silver Line routes could utilize either the South Boston Silver Line Transitway, or follow the South Station – Logan Express Service route on I-90 as described in **Section 6.11**. Another possibility would be to run the Silver Line 6 service from Broadway station (following the alignment outlined in the Urban Ring, as shown in **Figure 10-8**).

In parallel with MassDOT's research, this section will primarily focus on the critical gap between East Boston and Chelsea. Citilabs Cube modeling software will be used to investigate the potential ridership of different alignments in Chelsea.

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[116] MassDOT, Silver Line To Chelsea Scope of Service, November 2012

[117] Silver Line Gateway Alternatives Analysis Public Meeting, March 13, 2013

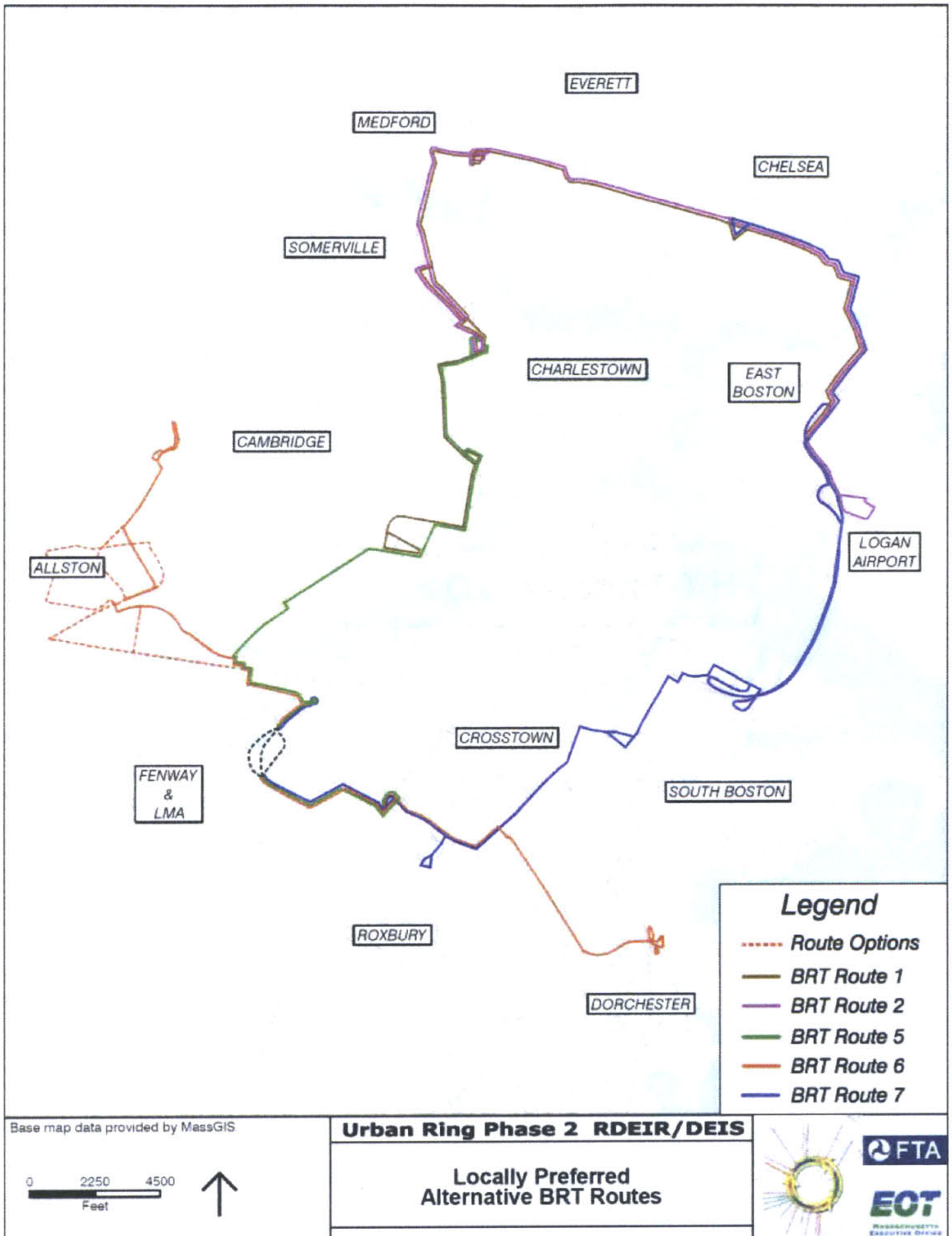

Figure 10-8: Urban Ring Phase 2 Locally Preferred Alternative BRT Routes[118]

[118] Urban Ring Phase 2 RDEIR/DEIS Executive Summary, November 2008

10.2.2 Existing Conditions

One of the Grand Junction Railroad segments connecting East Boston and Chelsea constructed in 19th century was abandoned after only a short period of operation[119] (red route in **Figure 10-10**). In 1930s, a drawbridge was built over the Chelsea Creek. However the bridge was later found to be "structurally deficient" and "high risk" for modern fuel tankers to pass under[120]. After years of planning, MassDOT replaced the 73-year bridge with a permanent lift bridge in 2011. The approximate construction cost was $125 million. The new bridge, now called Chelsea Street Bridge, was opened to traffic on May 12, 2012[121].

The Coughlin East Boston-Chelsea Bypass route, a two-lane roadway utilizing the abandoned East Boston railway was constructed for airport-related commercial traffic only. Massport contributed approximately $23.5 million toward the cost of this infrastructure, which opened in 2012[122]. The new route reduced bus and truck traffic through adjacent residential areas, and provided a convenient corridor between Logan Airport and Chelsea.

The existing transit services connecting Chelsea and downtown Boston include long walking distances and multiple transfers. The Seaport District is even harder to reach from Chelsea (see **Figure 10-9**). Currently people from Chelsea could take Commuter Rail to North Station, Route 111 to Haymarket, or Route 114/116/117 to Blue Line Airport Station[123]. The transit travel time to the area surrounding Chelsea is usually more than 30 minutes, further limiting transit access to Logan Airport. A more frequent rapid transit service is required to improve transit access and mobility for Chelsea residents.

The socioeconomic distributions of Chelsea are shown in **Figure 10-11** and **Figure 10-12**, which have been generated in TransCAD using the Census Transport Planning Package (CTPP) 2000 data. This data shows that several residents in Chelsea have medium-low income and that the public transit mode share is relatively high compared to adjacent cities (aside from Boston and Cambridge.)

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[119] Early Chelsea Transportation, http://www.olgp.net/chs/d2/trans.htm

[120] http://www.bostonglobe.com/metro/2012/05/14/new-million-chelsea-street-bridge-opens/qmA5SQaCv5TXxk1LvmJisO/story.html

[121] http://transportation.blog.state.ma.us/blog/2012/05/chelsea-street-bridge-opens.html

[122] http://www.eastietimes.com/2012/11/30/bypass-road-officially-opens/

[123] Silver Line Gateway Alternatives Analysis Public Meeting, March 13, 2013

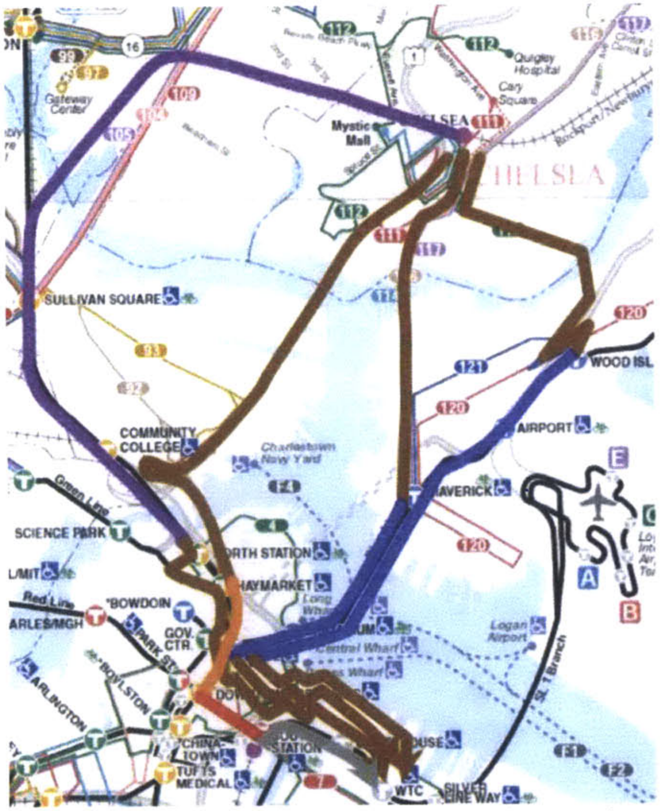

Figure 10-9: Existing Transit Routes Connecting Chelsea and Downtown/Seaport District[124]

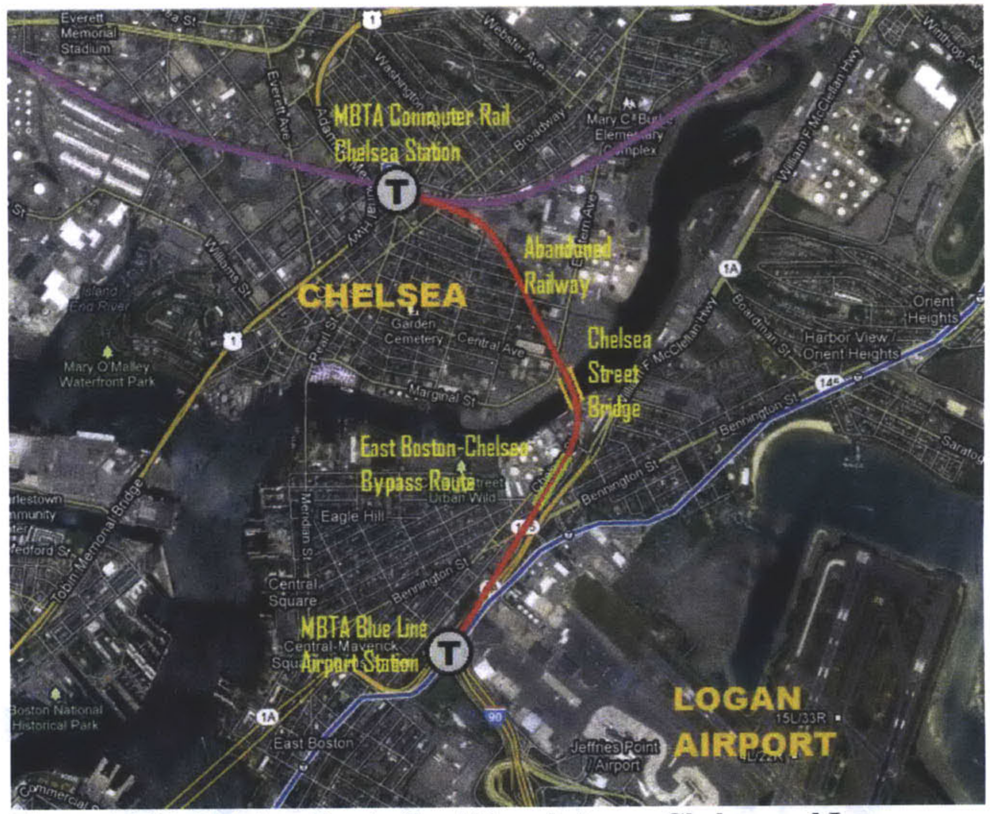

Figure 10-10: Existing Route Conditions between Chelsea and Logan Airport

[124] Silver Line Gateway Alternatives Analysis Public Meeting, March 13, 2013

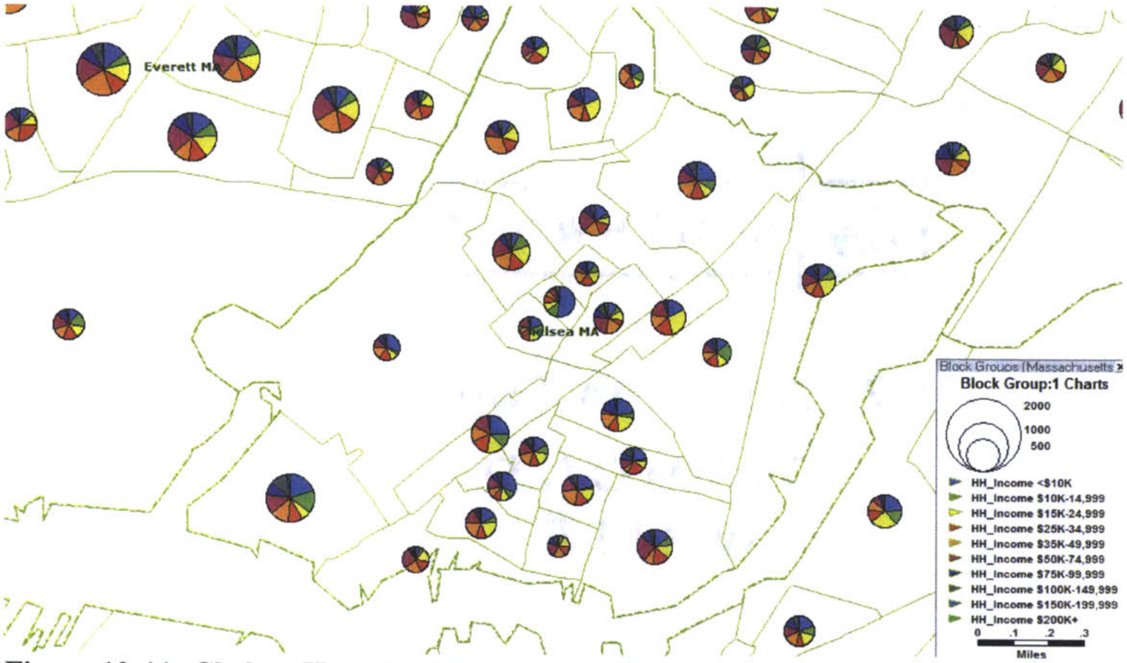

Figure 10-11: Chelsea Household Income Distribution Chart

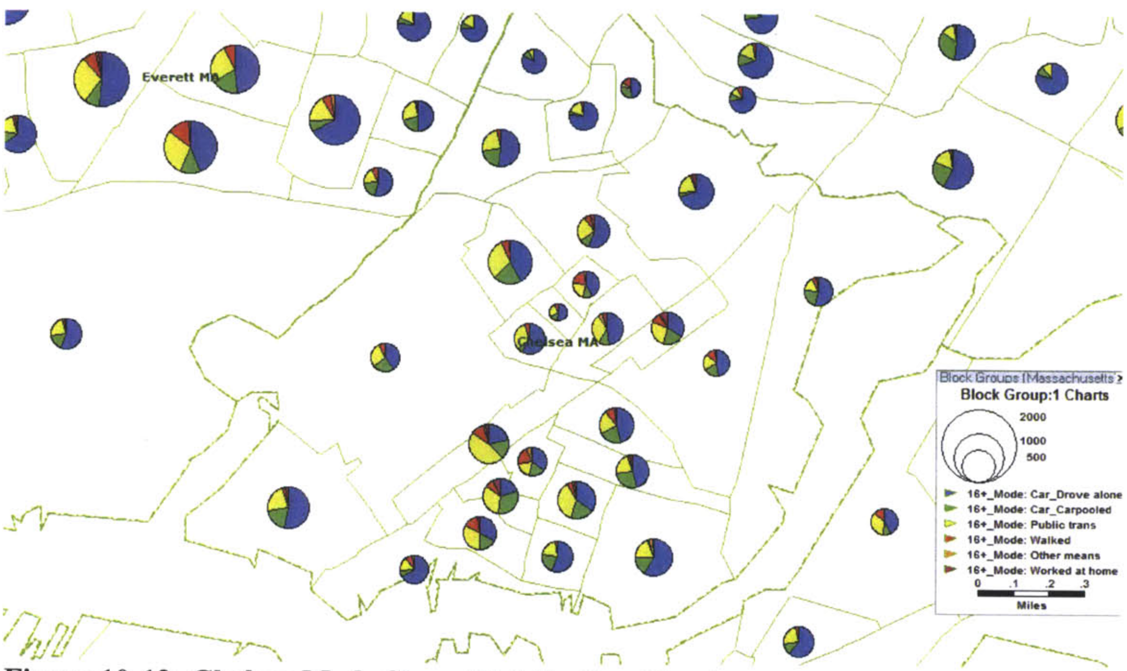

Figure 10-12: Chelsea Mode Share Distribution Chart

10.2.3 Potential Alternative Routes

This section describes the potential Silver Line 6 route and station locations in Chelsea. The new transit service will provide a more frequent service for Logan Airport employees. Bellingham Square station is the transit hub located in downtown Chelsea, which generates higher transit demand than Everett Ave and Spruce Street. However, the preferred connection to Bellingham Square can only be reached by using congested local routes from Eastern or Everett Ave, since Broadway and Washington Ave are grade separated over the Grand Junction. As shown in **Figure 10-15**, three different route options are analyzed in Chelsea[125]. All alignments connect to the Logan Airport Chelsea Employee Parking Garage which is currently served by employee shuttles. An overview of the primary advantages and disadvantages of the three routes is provided in **Table 10-3**.

Alternative #0: 2000/2030 Base Case Scenario
The base case represents the transit conditions in both 2000 and 2030 on the existing infrastructure without any new transit routes.

Alternative #1: Local Routes to Bellingham Square
SL6 will utilize local streets with limited stops, with a final stop at Bellingham Square.

Alternative #2: Urban Ring Phase 2 LPA
SL6 will follow Urban Ring Phase 2 Locally Preferred Alternative BRT Route 7 with partial utilization of the abandoned railway corridor. Buses will stop under Broadway Bridge, then at Chelsea Commuter Rail station, with a final stop on Everett Ave at Spruce St.

Alternative #3: Full Grand Junction Right of Way
The new transit route will fully utilize the abandoned railway corridor in Chelsea between Eastern Ave and Washington Ave, return to surface streets at Spruce Street, with a final stop at Bellingham Square (accessed via local streets).

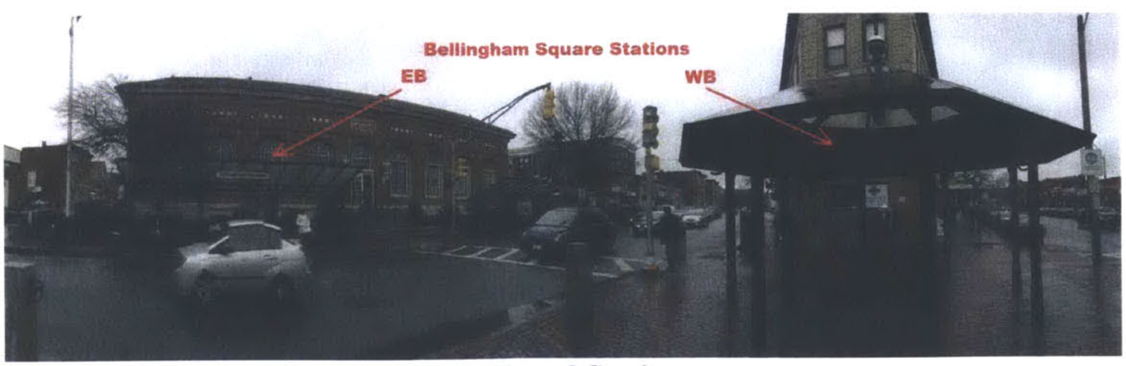

Figure 10-13: Bellingham Square Sheltered Stations

[125] MassDOT 2012, Silver Line to Chelsea – Alternatives Analysis

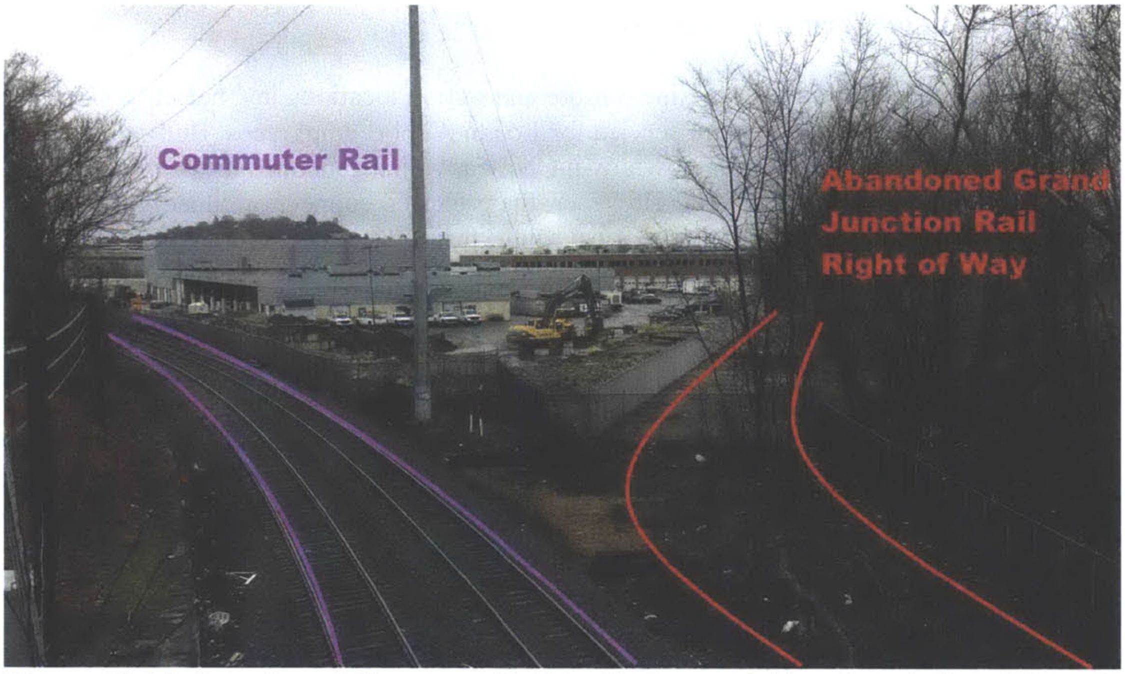

Figure 10-14: Junction of Commuter Rail in Chelsea and Abandoned Grand Junction Right of Way. Photo taken on Broadway Bridge looking East, 04/12/2013

Table 10-3: Overview of Potential Silver Line 6 Alignments

Alternatives	#1	#2	#3
Advantages	▪ Low-complexity design and implementation ▪ Minimal investment ▪ Travels directly through populated areas	▪ Provide partial two-way exclusive bus lane ▪ Less disturbance to communities ▪ Minimum distance with short cycle time	▪ Provide a two-way exclusive bus lane ▪ Least disturbance to communities ▪ Service connected to downtown Chelsea
Disadvantages	▪ Increased noise, vibration, and pollution within the residential area ▪ Potential congestion in local streets could increase running time and cause delay ▪ No recovery time at end station	▪ Requires moderate investment ▪ Lack of connection to high transit demand area and connection to other buses (Bellingham Square)	▪ Requires high investment ▪ Possible congestion on Washington, Broadway, and Everett Ave to access Bellingham Square ▪ Requires acquisition of land

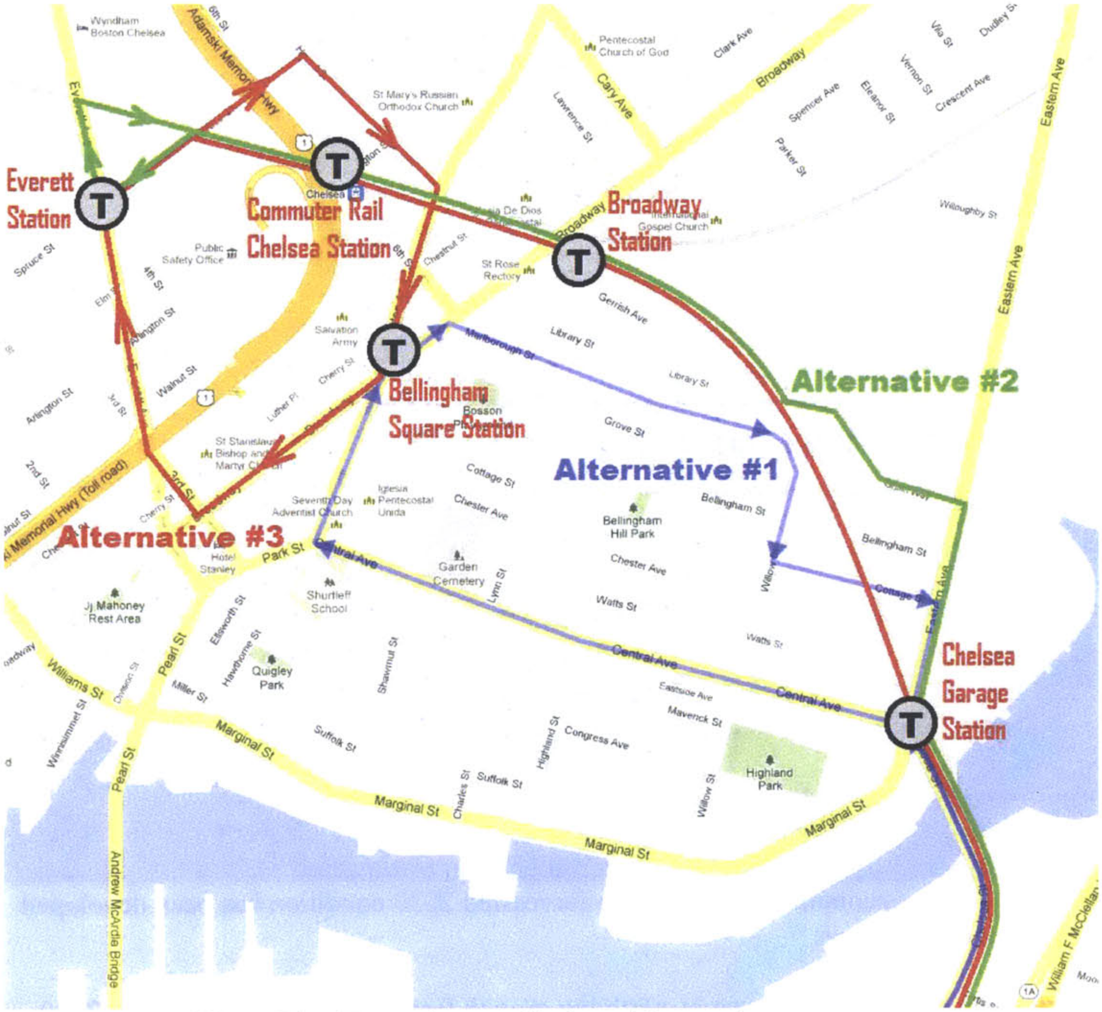

Figure 10-15: Silver Line Extension to Chelsea Alternatives

10.2.4 Transportation Modeling

This section describes the models used to forecast the ridership for each of the three SL6 route alternatives.

The transportation modeling software Cube[126], which performs traffic and transit assignment on a network representing the Greater Boston Area, was used for the transportation modeling. The model follows the conventional 4-step trip-based demand model to forecast ridership under different scenarios. The four steps include Trip Generation, Trip Distribution, Modal Split and Trip Assignment.

The modeling software contains three primary building blocks: the Travel Network, Socioeconomic Data, and the Behavioral Pattern of travelers. The most recent blocks used in Cube are the 2010 Greater Boston infrastructure network and the 2000 Census Transport Planning Package (CTPP 2000) socioeconomic data as the 2010 census data is not yet available. The behavioral pattern of travelers is coded into the script of the model, and has remained unchanged in the future scenarios.

Each alternative was coded into the Greater Boston 2010 infrastructure network as an individual scenario, and all scenarios were executed based on both Census Transport Planning Package (CTPP) 2000 socioeconomic data and the forecasted 2030 socioeconomic data. A detailed analysis of each result is provided in the following section.

The intent of this analysis is to compare the ridership of each route alignment. Ridership forecasts are provided for both 2000 and 2030 (based on socioeconomic data from 2000 and forecast socioeconomic data for 2030), but the evaluation of each alternative is primarily based on the existing 2000 socioeconomic data since the forecasted 2030 condition has been developed based upon several assumptions.

The 2030 socioeconomic data is forecast by applying growth factors to the existing CTPP 2000 data. The CTPS smart growth data was used to project the population, household, and employment growth rates in all the Traffic Analysis Zones (TAZs) in the Greater Boston model from 2000 to 2030. As shown in **Figure 10-16**, MassDOT also projected population and employment growth in the South Boston – Chelsea corridor for 2035. By comparing both analyses, the team used the CTPS smart growth data with 50% increased growth factors in the Seaport District area. The sample growth factors the team used to predict the 2030 condition for the study area are listed in **Table 10-4**.

[126] Cube transportation modeling software by Citilabs

Table 10-4: Growth Factors Used to Predict 2030 Socioeconomic Data[127]

Study Area	Growth Factors		
	Population	Household	Employment
East Boston	1.06	1.07	1.07
Seaport District	1.56	1.57	1.57
Chelsea	1.11	1.07	1.02

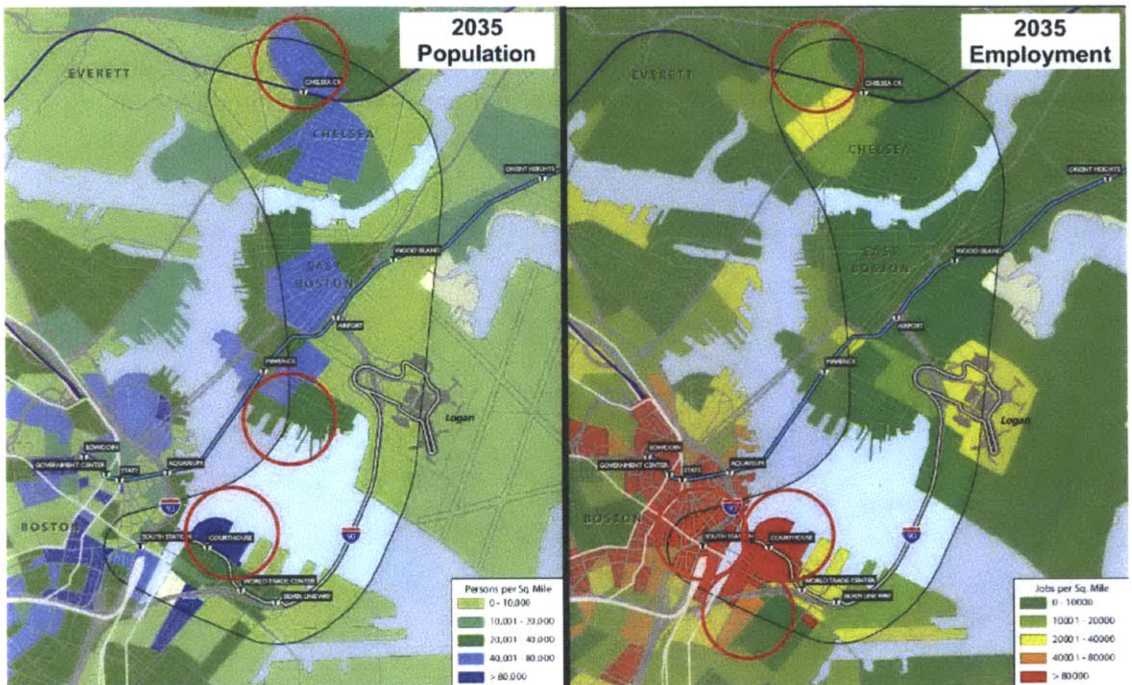

Figure 10-16: Projected Population and Employment Growth for 2035[128]

The following characteristics have been coded for the new SL6 route:

- The SL6 vehicles share properties with the existing SL1 and SL2 vehicles
- Travel through South Boston Transitway
- Have a direct connection from Silver Line Way to Ted Williams Tunnel
- Travel on I-90
- Travel on local routes instead of Coughlin Bypass Route in East Boston
- Travel through the Grand Junction corridor in Chelsea

[127] CTPS TAZ Population Employment Smart Growth Data

[128] Silver Line Gateway Alternatives Analysis Public Meeting, March 13, 2013

10.2.5 Analysis and Evaluation

After coding the new transit route into the model, the software generates and distributes trips in the modeled network based on the socioeconomic data and transportation network. The detailed descriptions and statistics of each new SL6 route alternative are provided in the following pages. The inbound and outbound load profile comparisons among the three alternatives are provided in **Figure 10-20** and **Figure 10-21**.

Silver Line Alternative Route #1

The model was constructed without new infrastructure, and executed based on both 2000 and 2030 socioeconomic data. The new Airport Station on SL6 routes were connected by walking links to local streets. The new transit route operates on the existing local roads. The modeled ridership of the SL6 is shown in **Table 10-5**.

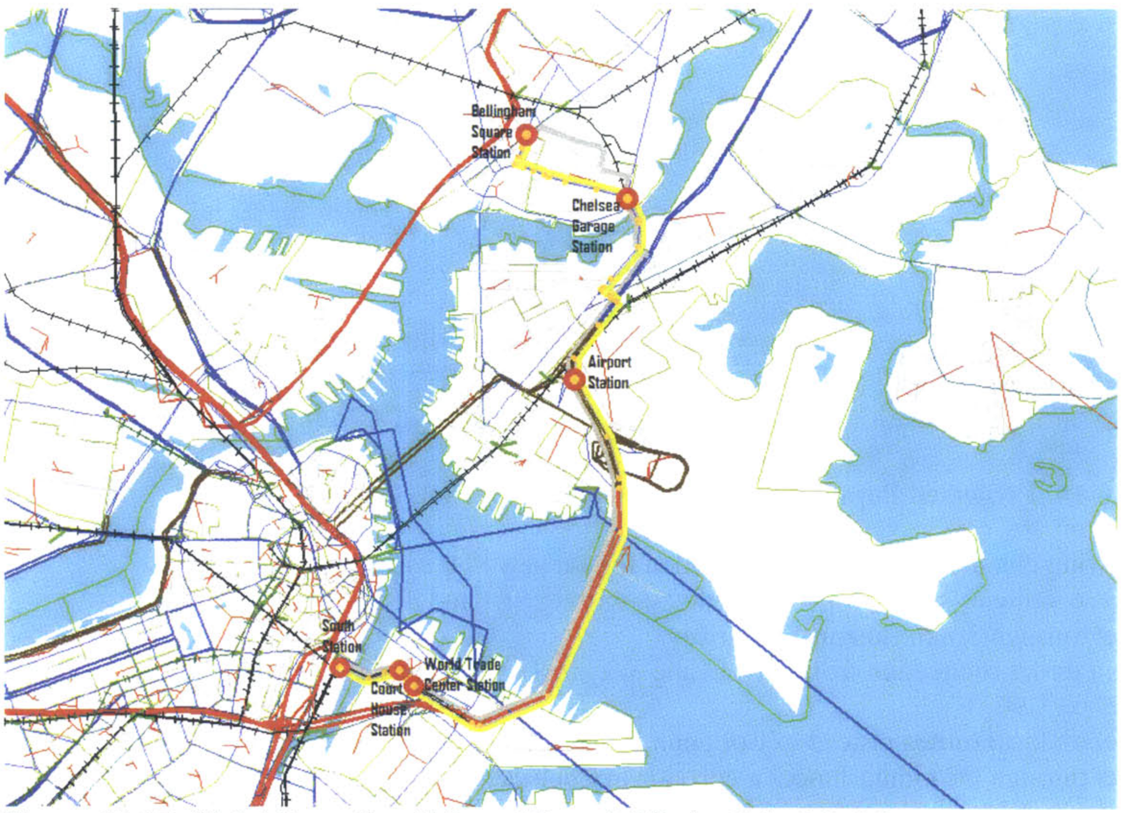

Figure 10-17: SL6 Alternative #1 Input Transit File in Cube Model

Table 10-5: Model Results for SL6 Alternative #1

Name	Mode	Direction	Number of Stops	Distance	Year	Daily Passengers	Passenger Miles	Passenger Hours
SL6	BRT	Inbound	6	5.24	2000	5,728	13,968	697
					2030	6,512	15,550	779
		Outbound	6	5.24	2000	5,260	14,410	699
					2030	6,113	16,590	811

Silver Line Alternative Route #2

Partial Grand Junction corridor and partial private road were coded into the infrastructure based on the existing local road properties. Since Broadway Station is expected to be under the Broadway Bridge, walking links were created to the proposed station. The transit assignment was executed based on both 2000 and 2030 socioeconomic data. The modeled ridership of the SL6 is shown in **Table 10-6**.

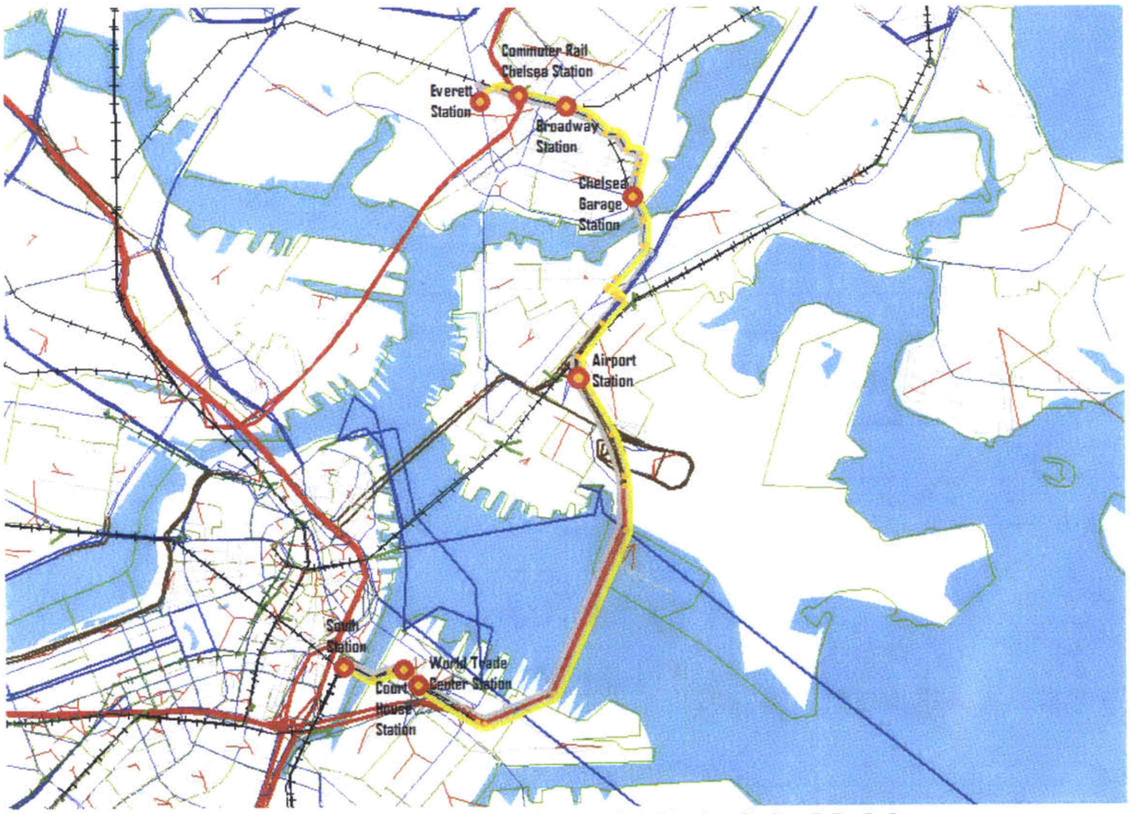

Figure 10-18: SL6 Alternative #2 Input Transit File in Cube Model

Table 10-6: Statistics for SL6 Alternative #2

Name	Mode	Direction	Number of Stops	Distance	Year	Daily Passengers	Passenger Miles	Passenger Hours
SL6	BRT	Inbound	8	5.74	2000	8,317	20,870	954
					2030	9,668	24,265	1,115
		Outbound	8	5.67	2000	8,612	25,201	1,175
					2030	10,111	29,259	1,381

Silver Line Alternative Route #3

The Grand Junction corridor was coded into the model for use by the SL6. SL6 vehicles connect to the surface street at Spruce Street, travel on local streets to reach Bellingham Square, and then return to the Grand Junction right of way at Everett. The transit assignment was executed based on both 2000 and 2030 socioeconomic data. The modeled ridership of the SL6 is shown in **Table 10-7.**

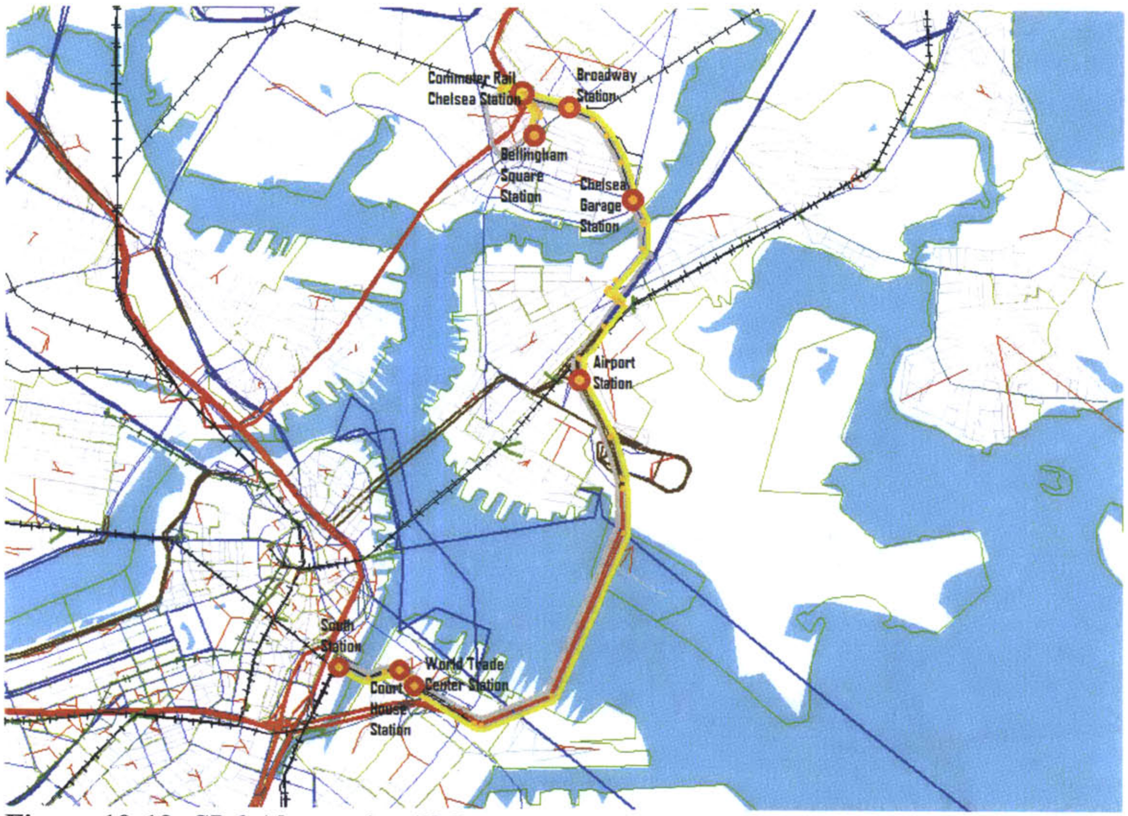

Figure 10-19: SL6 Alternative #3 Input Transit File in Cube Model

Table 10-7: Statistics for SL6 Alternative #3

Name	Mode	Direction	Number of Stops	Distance	Year	Daily Passengers	Passenger Miles	Passenger Hours
SL6	BRT	Inbound	8	6.07	2000	8,841	24,015	1,025
					2030	10,140	26,931	1,155
		Outbound	8	5.87	2000	8,733	25,999	1,118
					2030	10,306	30,299	1,318

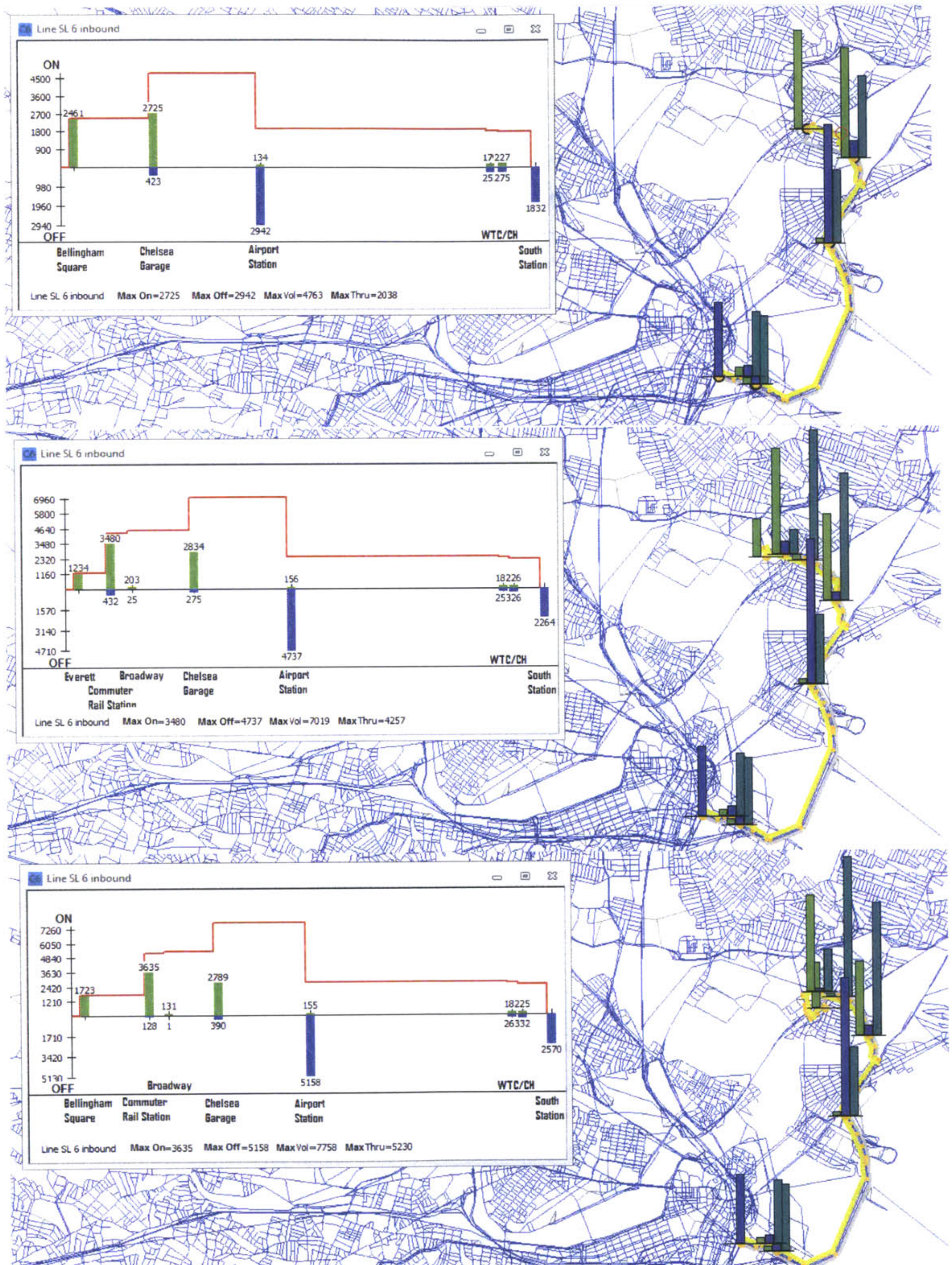

Figure 10-20: SL6 Inbound Load Profile, Public Transit 24 Hours Assignment, Alternative #1 (Upper), #2 (Middle), #3 (Lower)

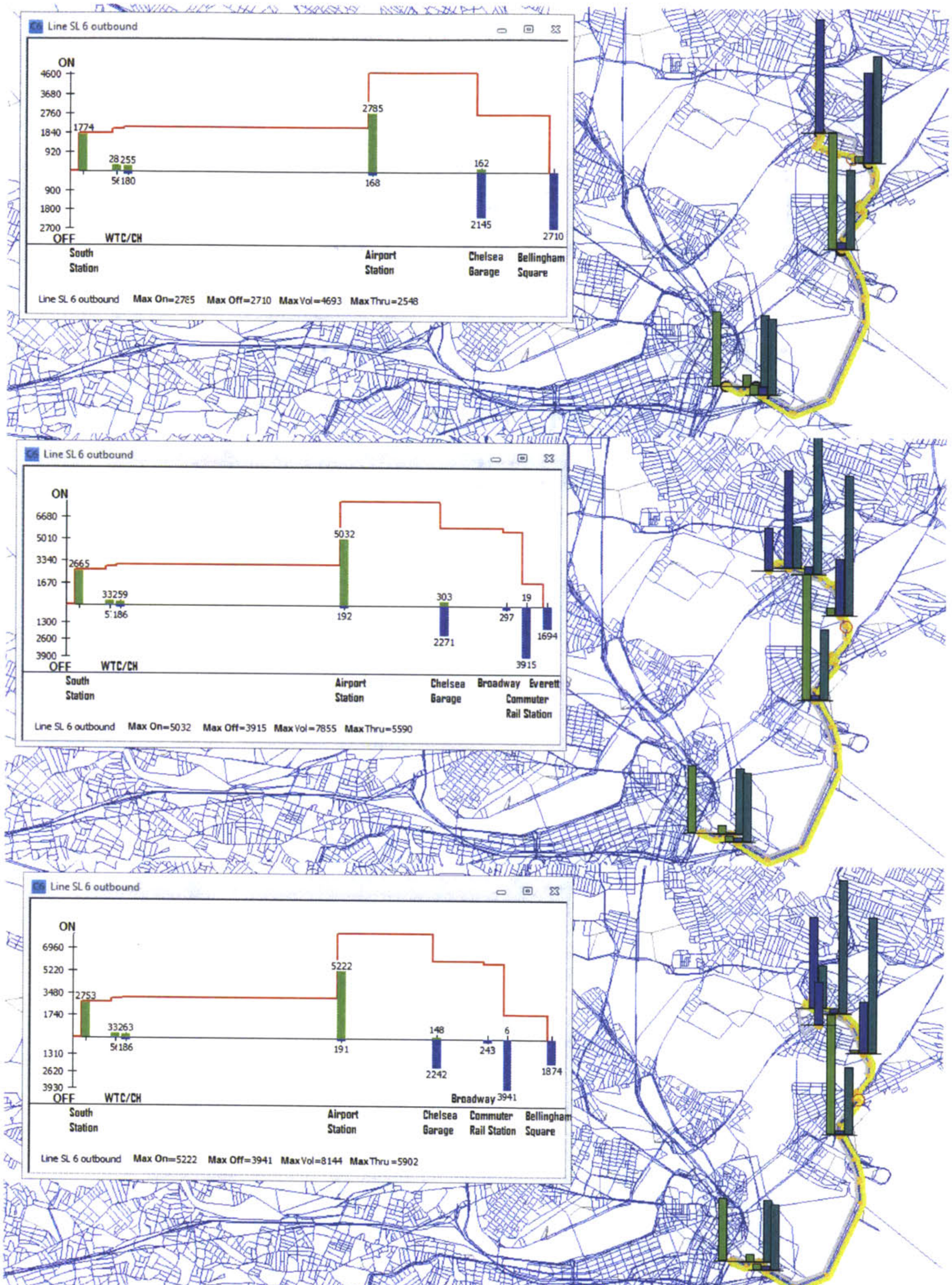

Figure 10-21: SL6 Outbound Load Profile, Public Transit 24 Hours Assignment, Alternative #1 (Upper) #2 (Middle) #3 (Lower)

The preliminary model results are summarized in **Table 10-8**. These results suggest that the potential Silver Line 6 Alternative #3 – full Grand Junction right of way with local routes to Bellingham Square – is expected to have the highest ridership, since the new transit route serves both the downtown transit hub Bellingham Square and the Commuter Rail station. Notably, the model shows that very few people would alight at Airport Station to board the Silver Line 6 to travel to the South Boston Waterfront and South Station. While this is based on socioeconomic data from year 2000, more ridership between these stations is expected and the model results should be reviewed and critically assessed as part of a more rigorous study before any decisions are made about the SL6 route.

Table 10-8: Summary of Load Profiles

SL6 Alternatives		2000 Scenario					2030 Scenario
		Max On	Max Off	Max Volume	Max Thru	Passenger (24hr)	
Inbound	#1	2725	2942	4763	2038	5,728	6,512
	#2	3480	4737	7019	4257	8,317	9,668
	#3	**3635**	**5158**	**7758**	**5230**	**8,841**	**10,140**
Outbound	#1	2785	2710	4693	2548	5,260	6,113
	#2	5032	3915	7855	5590	8,612	10,111
	#3	**5222**	**3941**	**8144**	**5902**	**8,733**	**10,306**

Figure 10-22 shows the multi-modal summary of the downtown Chelsea and Logan Airport areas. Green lines are routes with more than 1,000 walk trips, blue and red lines represents the routes with more than 10,000 transit and auto trips. The contribution of the Silver Line 6 to transit connectivity in the area is visible in this figure.

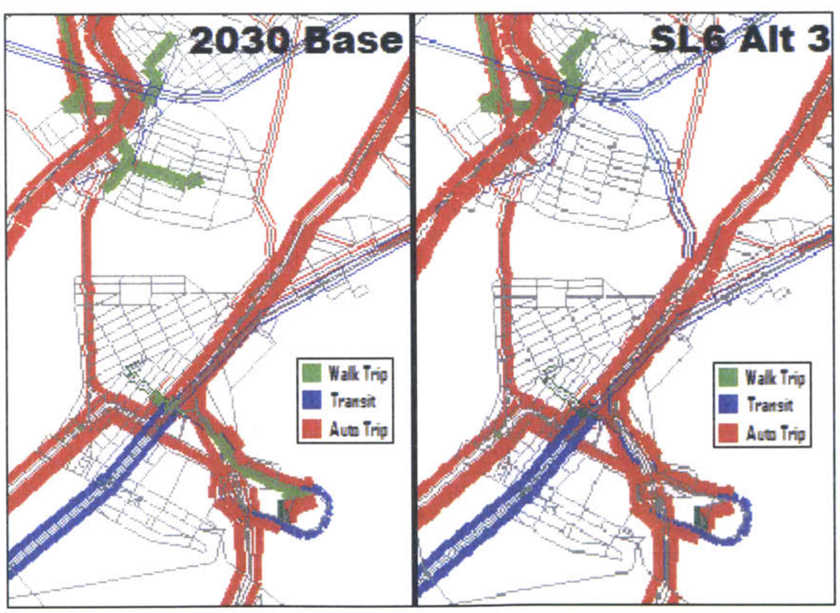

Figure 10-22: Multi-Modal Summary

A significant increase in transfers at Airport Station is clearly shown in **Figure 10-23**, which also indicates the effectiveness of SL6 route. All links with transfer volume larger than 100 are shown in the blue bars. Higher bars represent larger transfer volume within stations.

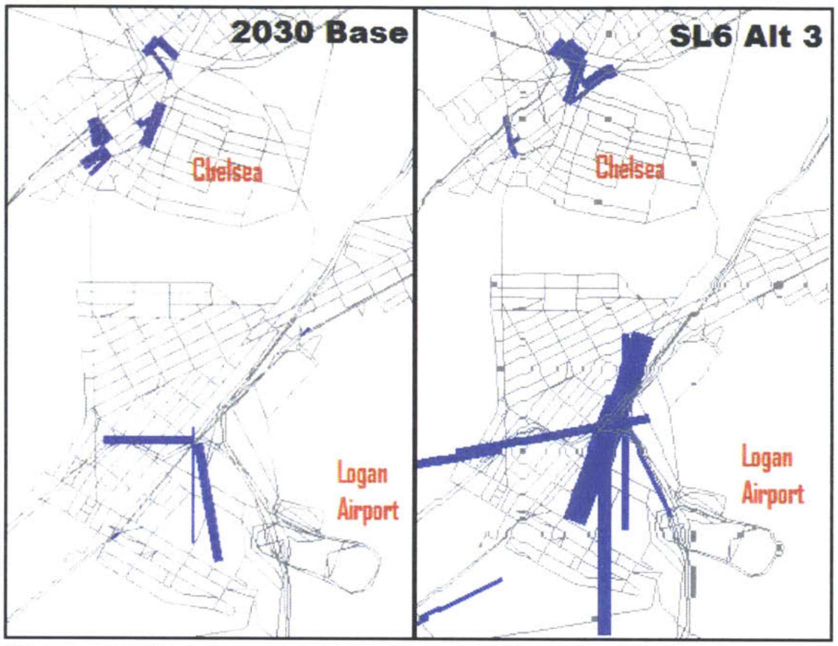

Figure 10-23: Transfer Walk Access Flows in Chelsea and at Airport Station

Another direct effect of implementing SL6 is the ridership impact on adjacent transit routes, which is observed in **Table 10-9**. There is a moderate increase on Blue Line ridership and a significant increase on the Airport Shuttle.

Table 10-9: Statistics for Loaded Blue Line & Airport Shuttle

Name	Stops	Distance	Time	Scenarios	Passenger (24 hours)	% Increase
Blue Line EB To Wonderland	12	6.02	20.72	2000 Base	37,169	
				2030 Base	42,166	
				SL6 Alt #1	46,409	10.1%
				SL6 Alt #2	44,808	6.26%
				SL6 Alt #3	44,908	6.50%
Blue Line WB To Bowdoin	12	5.99	20.70	2000 Base	36,137	
				2030 Base	40,873	
				SL6 Alt #1	47,018	15.0%
				SL6 Alt #2	45,036	10.2%
				SL6 Alt #3	45,309	10.9%

All above preliminary modeling results indicates the significant positive influences of implementing SL6.

10.2.6 Conclusions

The load profiles indicate high demand between the Chelsea Commuter Rail Station, Bellingham Square, Chelsea Garage and Airport Station. Yet Broadway Station in Chelsea generates very limited trips, possibly because the area has low population density and the station is more difficult to access (it is located beneath the Broadway bridge). Therefore, it is recommended that the new SL6 transit route bypass Broadway Station. Courthouse Station and World Trade Center Station also generate a small number of trips, but both stations cannot be skipped due to the route being shared with SL1, SL2 and SLW Shuttles. The load profile diagrams also show that the section between Chelsea and Airport Station is the maximum load section of the route. There is less ridership on the portion between South Station and Airport Station.

While this modeling should be confirmed and validated by the study being undertaken by MassDOT, the results suggest that there is demand for increased transit services to Chelsea and that an alignment that connects both to the commuter rail station and Bellingham Square will result in the greatest ridership.

Figure 10-24 illustrates the improvement in accessibility offered by the SL6. It shows the traffic analysis zones transit users could reach within 60 minutes from downtown Chelsea (maked in black) with or without the new SL6 route in 2030. The SL6 increases transit accessibility in Chelsea and also further improves transit access to Logan Airport.

As the preliminary modeling has shown the ridership potential of routes using the Grand Junction corridor, MassDOT should ensure that it protects this corridor. The corridor should not be encroached upon by any new infrastructure or bridge reconstruction (such as the Washington Avenue Bridge) which could limit the clearance or right-of-way that may be required for BRT.

MassDOT has owned the Chelsea Grand Junction right of way since 2009. Massport should co-ordinate with MassDOT and invest in the new service, since this alignment provides direct benefit to Massport by improving accessibility for passengers and employees to Logan Airport. Paul Revere shuttles are also providing service to Chelsea Parking Garage, which could potentially be extended to Bellingham Square without significant added vehicles as well to increase the service accessibility and attract more transit users.

As an alternate alignment, an express bus from the South Station bus terminal to Airport Station via the I-90 would provide a direct route and effectively avoid any capacity constraints in the SLW tunnel, but may experience congestion due to future development. It also requires users to transfer to the bus terminal at South Station instead of using the Silver Line platform directly above the Red Line.

The future SL6 could also be extended north to Everett or even further to Sullivan Square, and south to Broadway Station and Ruggles Street to continue implementing the Urban Ring phase II configuration.

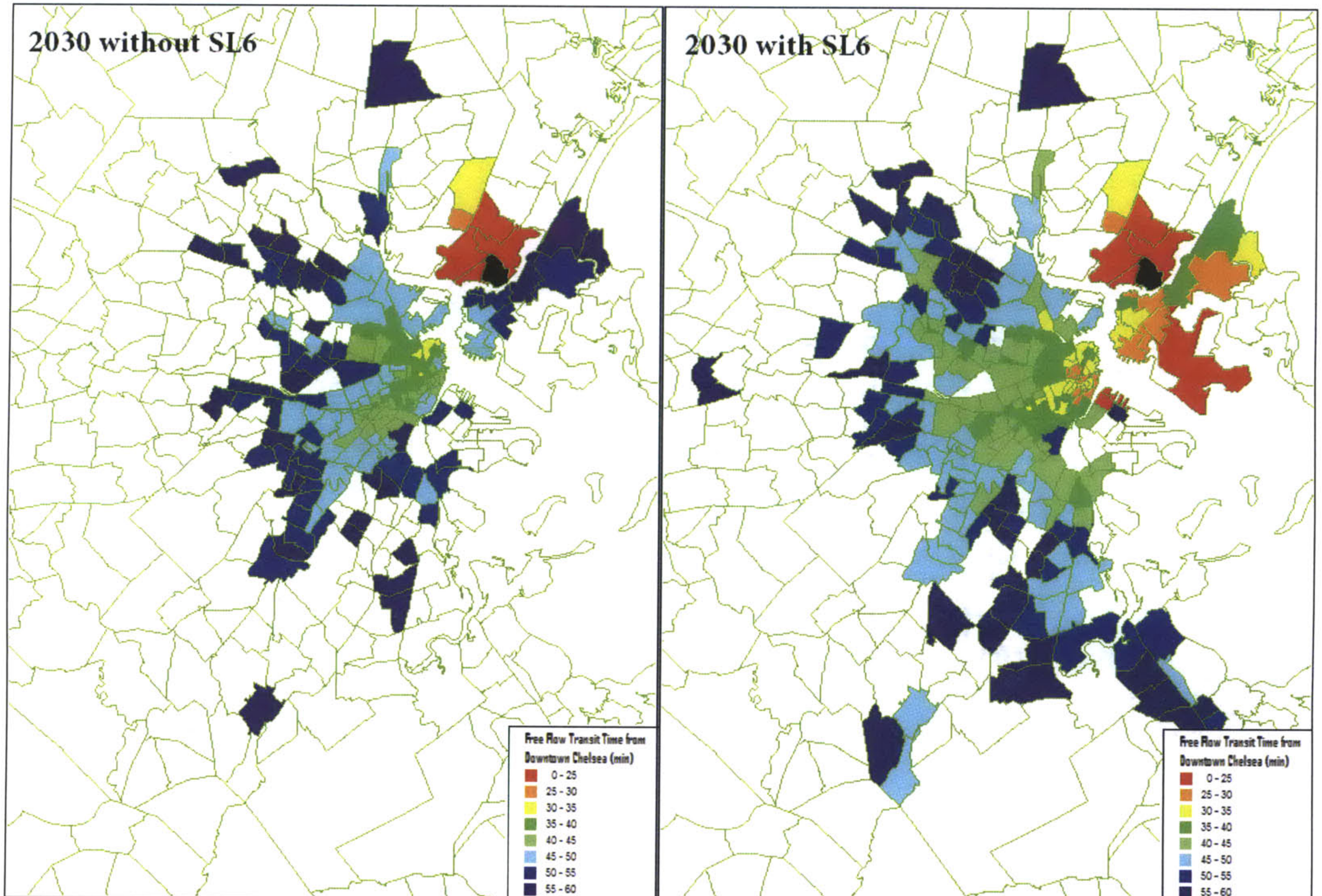

Figure 10-24: Transit Isochrones Comparison between 2030 Base Case Scenario and Silver Line 6 Alternative 3

11 Recommendations and Topics for Future Study

11.1 Final Recommendations

This study has shown that effective public transportation services are critical to Logan Airport's functioning, and will become only more important as ground transportation demand increases. The main areas where Massport, MassDOT and the MBTA should invest their resources in the short-term to improve public transportation to Logan Airport are:

- Decreasing the running time of the Silver Line through operational improvements and infrastructure upgrades at D Street and the Transitway
- Providing free outbound trips for the Silver Line, Blue Line and Logan Express
- Improving the ease of transferring to transit at Logan Airport
- Introducing new transit services to Chelsea

More detailed recommendations and conclusions are discussed by topic.

Existing Access Patterns

- Improved public transportation to Logan Airport is necessary as a result of the limited roadway capacity and limited parking capacity; without improved transit services to the airport for air passengers and employees, it will become increasingly challenging to manage ground transportation
- As passenger and employee trip origins are distributed throughout the region, an integrated system of complementary transit services that can serve both local and regional trips is necessary
- Employees at Logan are a sizable market segment and transit services should be planned with consideration of their travel patterns
- The travel time comparison between Silver and Blue Line routes indicates travel time dominance of the Blue Line and highlights the need to maintain and increase usage of the Blue Line and improve travel time on the Silver Line

Massport Data Collection

- Install Automatic Passenger Counters (APC) on Silver Line buses in order to collect ridership data more effectively
- The Logan Airport employee survey is critical, and should be completed every 2 years instead of every 5 years; the methodology should be improved to ensure that employees are not surveyed in a way which is modally biased (i.e. handing out surveys asking about mode choice on the Logan Express).
- The employee survey should be extended so that employers are also surveyed, in order to provide Massport with a more complete understanding of subsidies for employee parking, transit, etc.
- Consider a web-based survey accessed through individual email links for employees and employers
- The Ground Transportation survey of passengers should include questions about how passengers would respond to changes in the ground transportation system, such as:
    - If the price of parking increased by $5 per day, how would you travel to Logan Airport on your next trip?

- For Massport's future Environmental Data Reports, entrances at Airport Station should be sub-divided by fare array. The existing EDR reports total entrances, which counts the substantial number of community-side entrances in addition to airport-related entrances

Support for Employee Transit Use

- Fully subsidized transit passes should be provided for Massport employees, to match the free parking provision
- Massport should strongly encourage other airport employers to provide transit incentives to their employees
- Massport should investigate whether it is feasible to convert additional on-airport employee parking spaces to commercial parking spaces

Ease of Transferring to Transit

- A "Rapid Transit Zone" for the Silver Line and Airport Shuttles should be created in a central location on the curb at each terminal. Logan Express services should be adjacent to this zone.
- Improve signage at Logan Airport and Airport Station, using terminology "Rapid Transit Zone"
- Improve comfort of waiting areas
- Provide free ticket to enter Airport Station on the airport shuttles
- Continue building awareness of airport transit services through advertisements, marketing, transit system maps and signage in the airport

Airport Shuttles

- The airport shuttles should not be combined with services to Conrac; rather, **separate services** should be run for Conrac and the Airport Station connection

Logan Express

- The price of using Logan Express compared to driving or taking a taxi to the airport is the likely cause of the declining passenger share
- Outbound Logan Express services should be made free, to improve simplicity of using the service and attract new riders

Future Silver Line Vehicle Technology

- The MBTA and Massport should proceed with the mid-life re-build of the existing dual-mode vehicles
- Massport should purchase and test some battery-electric vehicles for future procurement options
- Further research on the feasibility of a hybrid bus with extended range capability and pure electric operation in the tunnel should be undertaken

Silver Line Improvements

<u>Shorter-Term</u>

- Study and implement Transit Signal Priority (TSP) to reduce Silver Line delay at the intersection of D Street and the Transitway. TSP will not be a viable long-term solution, however, as a result of growing congestion in the surrounding roadway network. As congestion increases, queues on Congress Street will increase the travel time for the Silver Line return trip from Logan Airport as it travels through this corridor

- Initiate planning and design of grade separation of the South Boston Transitway at D Street
- Allow Silver Line buses to use the South Boston Emergency Access Ramp on the trip from South Station to Logan Airport, after making necessary adjustments to the ramp and I-90 to ensure safe merging conditions, adequate sight distance, etc.
- Continue the fare-free boardings of the Silver Line at all Logan Airport terminals, as the program has reduced dwell times and resulted in a ridership increase
- Decrease headways to 8 minutes immediately in order to reduce crowding under existing conditions
- Consider further decreasing headways to 5 minutes and launching an aggressive marketing campaign to attract new riders to the service. If there are not enough buses available, consider reallocating buses from the SL2 and short-turn shuttle route to the SL1 until more buses are available
- Run additional Silver Line buses during the Government Center closure to serve passengers who would transfer from the Green Line to the Blue Line at Government Center under regular circumstances. Consider also running buses via the Sumner and Callahan Tunnels between Logan Airport and Haymarket Station, which is accessible to both Orange Line and Green Line passengers
- Instruct SL1 operators to only stop once for the technology transition at Silver Line Way (instead of stopping once underneath the John Hancock building and then again at Silver Line Way) in order to reduce the number of stops for passengers
- Re-configure the platform at South Station so that the SL1 bus only stops at the first stop and leaves without excessive dwell on the platform. Platooning of SL1 and SL2 buses can be introduced to limit boarding and alighting time of non-Airport passengers on the SL1
- Fix the real-time "next bus arrival time" displays for the Silver Line at Logan Airport, which have been observed to malfunction

Recommendations Contingent upon the Availability of a Suitable Vehicle Technology

- Use a new vehicle technology which does not require a technology transition between the Transitway and surface streets to reduce passenger delay
- Eliminate Silver Line Way stop for Silver Line 1 (in the meantime, buses must stop at Silver Line Way for the technology transition so passenger boarding and alighting should continue)

Longer Term:

- Transit Signal Priority and/or having buses make right-turns at D Street and the Transitway are infeasible in the long-term
- Grade separate D Street and the South Boston Transitway
- Consider a tunnel connection that directly links the westbound I-90 with the Transitway so that buses returning from Logan Airport do not need to use surface streets

Potential Future Transit Services

- Worcester is a major population center in Massachusetts with fairly inconvenient existing transit connections to Logan Airport. To better serve this market, consider extending some Framingham Logan Express buses to Worcester to test the demand. At first, buses could be run hourly. Monitor whether new riders use the service, or whether passengers presently boarding at Framingham simply shift to Worcester. If a significant level of new demand is attracted to the service, Massport can consider introducing a new Logan Express route that serves Worcester exclusively.
- MassDOT is presently studying a Silver Line 6 service to Chelsea. Some preliminary modeling suggests that an alignment connecting South Station, Airport Station, the Chelsea Commuter Rail station (via the Grand Junction corridor) and Bellingham Square would result in 8,700-8,800 passengers per day. MassDOT should ensure that this corridor is preserved for the implementation of BRT and not encroached upon by the construction of bridges or other new infrastructure.

11.2 Topics for Future Study

The following topics are related to transit access to Logan Airport and are recommended for future study:

- The restructuring of the Logan Airport taxi service in order to reduce empty taxi trips to and from the Airport and excessive taxi queues
- The impacts and benefits of shifting all private vehicle travel to the upper level of the Logan Airport terminals so that the lower level can be used exclusively by commercial and transit vehicles
- The implementation of tolls on airport roadways or on highways leading to Logan Airport to discourage private vehicle travel and finance public transportation improvements
- Opportunities to include an express service to Logan Airport in the plans for the South Station Bus Terminal Expansion
- The use of an Urban Ring type alignment for Silver Line 6 from Sullivan Square across Everett and Chelsea to Airport Station and then connecting to Broadway and Ruggles Station (instead of using South Station and the South Boston Transitway)
- The possibility of reducing demand for ground access to Logan Airport by attracting air passengers taking short-haul flights to high-speed rail, coach buses or other regional airports.
- The possibility of further enhancing Silver Line and Blue Line access to Logan by considering:
    - Silver Line Phase III: the extension of the Silver Line tunnel from South Station to Chinatown and Boylston Street Station
    - Blue Line extension from Government Center to Charles Street Station (Blue Line / Red Line connector) and from Wonderland to Lynn
- The possibility of attracting more passengers to use the Logan Express by developing new locations at Route 128 and Route 495 and introducing amenities at Logan Express sites to attract non-Boston air travellers to the service, such as car rental and motel services.

Appendix A – Resource Provision and Fees for Ground Transportation to Logan

In alignment with its goal of promoting HOV ground access mode share, Massport provides resources for the various public transportation services to Logan Airport. These include the Silver Line BRT service that connects passengers from the MBTA's South Station to the airport, the Logan Express bus services between various suburban locations and the airport, and the provision of complementary shuttle bus services connecting the MBTA's Blue Line Airport Station and water shuttle routes from the ferry dock to the airport terminal area.

Massport also provides round-the-clock shuttle bus service from the employee parking garage in Chelsea to the terminals and other airport employment areas. In August 2007, the Sunrise Shuttle was launched to provide early morning shuttle service for airport employees. This shuttle operates between East Boston, where a large concentration of airport employees lives, and the airport terminal areas, and is funded by Massport.

Additionally, Massport offers additional discounts/incentives to its own employees to encourage public transportation use, including commuter pass discounts and reduced remote parking fees.

This section examines Massport's provision of resources and fees for Ground Transportation to Logan Airport, with the objective of comparing the costs and effectiveness of various alternatives and developing options for new initiatives. It is organized as follows:

- Section A.1: Silver Line BRT
- Section A.2: Blue Line Shuttles
- Section A.3: Logan Express
- Section A.4: Sunrise Shuttle
- Section A.5: Water Shuttle Bus Service
- Section A.6: Chelsea Garage Shuttle
- Section A.7: Parking and Other Employee Subsidies
- Section A.8: Typical Costs of Commuting and Travelling to Logan Airport
- Section A.9: Conclusion

A.1 Silver Line

As described more completely in **Chapter 3**, the Silver Line Route 1 (SL1) provides a direct connection between South Station and all the terminals at Logan Airport, with similar hours of operation as the subway system and scheduled headways between 8 and 12 minutes.

Massport purchased the buses serving this route at a total cost of $12.8 million ($1.6 million each), for eight 60' articulated Neoplan dual mode buses. The MBTA covered the tunnel construction costs, and operates the service with an annual operating subsidy of $2 million from Massport (before free boardings at Logan Airport)[129].

[129] ACRP 36

Annual Logan boardings on the SL1 service have been steadily increasing, and were estimated at 1.2 million in 2011. The annual alightings at Logan Airport are estimated at 960,000, resulting in a total ridership of about 2.2 million (see **Table 3-9** in **Chapter** 3).

With the introduction of free boardings in June 2012, Massport now pays a total annual subsidy of $3.5 million to the MBTA for the SL1 service to the Airport. The subsidy per passenger with free boardings at Logan is therefore estimated at $1.60/passenger (Annual Massport subsidy divided by the total ridership), as shown in **Table A-1**.

Table A-1: Amounts Spent by Massport on SL1 Service to Logan Airport

Description	Amount
Total Bus Purchase Cost	$12,800,000
Annual Amount Paid by Massport Before Free Boardings	$2,000,000
Annual Amount Paid by Massport After Free Boardings	$3,500,000
Annual Ridership	2,200,000
Massport's Subsidy/Passenger with Free Boardings	$1.60

A.2 Blue Line Shuttles

As described more completely in **Chapter 3**, MBTA's Blue Line Airport station is located on airport property, about three-quarters of a mile from the airport terminal area. This provides a rapid transit line connection to downtown Boston and communities north of Logan Airport. Massport provides a complementary shuttle bus service between Airport station and the airport terminals.

Massport recently purchased eighteen 40ft CNG buses and thirty-two 60ft articulated diesel-electric hybrid buses, some of which are being used for the Blue Line shuttle bus services. The annual operating cost for the shuttle services is $2.4 million[130].

Annual ridership on the Blue Line shuttles is summarized in **Table A-2** (See **Table 3-20**, **Chapter 3**).

Table A-2: Blue Line Shuttle Ridership

	Inbound to Logan	Outbound from Logan
Tuesday	3,322	2,783
Friday	3,983	3,326
Sunday	2,558	2,525
Average Daily Ridership	3,288	2,878
Average Annual Ridership	1,200,000	1,050,000

The Blue Line shuttle bus service is free for all riders, meaning that Massport fully subsidizes each trip. The subsidy per passenger can be estimated by dividing the annual operating cost by the total annual ridership, resulting in about $1.10/passenger subsidy, as shown in **Table A-3**.

[130] ACRP 36

Table A-3: Amounts Spent by Massport on Blue Line Shuttle Service to Logan Airport

Description	Amount
Estimated Annual Operating Cost	$2,400,000
Estimated Annual Ridership	2,250,000
Annual Fare Revenue	$0
Net Annual Operating Cost	$2,400,000
Subsidy/Passenger	$1.10

A.3 Logan Express

As described more completely in **Chapter 3**, Massport operates 4 express bus services between the airport terminals and park-and-ride facilities in Peabody, Framingham, Braintree and Woburn. Three of the 4 routes provide service for approximately 20 hours a day, generally every half hour. The Peabody route provides half as many trips as the other 3 routes, and provides service every 60-90 minutes.

Annual ridership data on each of the Logan Express routes in 2010 is summarized in **Table A-4.**[131]

Table A-4: Annual Logan Express Ridership

	Peabody	Framingham	Braintree	Woburn
Air Passengers	25,500	272,000	231,500	115,000
Airport Employees	26,000	62,000	251,500	127,000
Total Riders	51,500	334,000	483,000	242,000

Annual operating costs and fare revenues for each of the four Logan Express routes are summarized in **Table A-5**. These amounts are used to estimate the annual net subsidies for each route (operating costs less fare revenues), as summarized in **Table A-6**. The subsidy amount per rider is then estimated using the total ridership figures in **Table A-4** for each route.

The results show that the Braintree service almost breaks even, while all other trips are subsidized. The Peabody route is the most heavily subsidized due to low ridership on this route.

Table A-5: Logan Express Annual Operating Costs and Fare Revenues

	Peabody	Framingham	Braintree	Woburn
Annual Operating Costs	$1,168,000	$3,500,000	$2,920,000	$3,500,000
Annual Fare Revenues	$290,000	$2,720,000	$2,650,000	$1,320,000

Table A-6: Subsidies for Logan Express Services

	Peabody	Framingham	Braintree	Woburn
Annual Net Subsidy	$878,000	$780,000	$270,000	$2,180,000
Subsidy/Rider	$17.00	$2.30	$0.60	$9.00

[131] Massport's 2010 EDR– Appendix G

A.4 Sunrise Shuttle

As more completely described in **Chapter 3**, the Sunrise Shuttle was launched in August 2007 to provide a low cost transportation alternative for Airport employees residing in East Boston. The shuttle operates every half-hour between 3 and 6am to provide access to Logan before MBTA service begins. Massport funds the shuttle, and a private contractor operates the services and provides the vehicles.

The Sunrise Shuttle costs approximately $59,000 per year to operate.[132] Shuttle ridership has grown to 1,040 riders per month (on the southern route)[133], yielding an annual ridership of 12,500. Employees pay $1 for a ride on the shuttle, with the annual fare revenues estimated at $12,500.

The net annual operating cost for this route is therefore approximately $46,500, and the subsidy per passenger is about $3.70, as shown in **Table A-7**.

Table A-7: Amounts Spent by Massport on the Sunrise Shuttle – Southern Route

Description	Amount
Annual Operating Cost	$59,000
Annual Ridership	12,500
Annual Fare Revenue	$12,500
Net Annual Operating Cost	$46,500
Subsidy/Passenger	$3.70

A second shuttle route – the Northern Route - was launched in October 2011 to provide early morning services to another part of East Boston and the adjacent town of Winthrop. Ridership on this route is approximated at 260 riders per month[134], with an annual fare revenue of $3,100.

The total projected cost for the new route was approximated at $200,000 over 3 years.[135] Massport and Logan TMA received some funding for the project in the form of an FTA Job Access Reverse Commute (JARC) grant of $93,000, which will subsidize the new service on a sliding scale over the 3-year period. The total cost covered by Massport per year in operating this shuttle route is $36,000.

The annual net cost of this route (less fare revenues) is therefore approximately $33,000, and the subsidy per passenger is about $10.60, as shown in **Table A-8**. The subsidy per passenger is still relatively high despite the JARC grant due to the low ridership on the route, as the service is still new.

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[132] ACRP 36

[133] L. Dantas – Personal Communication, November 20, 2012

[134] L. Dantas – Personal Communication, November 20, 2012

[135] ACRP 36

Table A-8: Amounts Spent by Massport on the Sunrise Shuttle – Northern Route

Description	Amount
Annual Operating Cost	$67,000
Massport's Annual Cost (less JARC Grant)	$36,000
Annual Ridership	3,100
Annual Fare Revenue	$3,100
Annual Net Cost	$33,000
Subsidy/Passenger	$10.60

A.5 Water Shuttle Bus Service

Several companies provide water transportation access to Logan Airport, including City Water Taxi, Rowes Wharf Water Shuttle, Boston Harbor Water Taxi, and the MBTA Harbor Express. Each of these services stops at the Logan Airport dock on Harborside Dr. Massport provides a complimentary shuttle bus service that connects the Airport terminal area to the ferry dock.

Annual ridership on the water transportation shuttle is summarized in **Table A-9**[136].

Table A-9: Water Shuttle Ridership

2007	101,000
2008	96,600
2009	88,600
2010	89,200

The operating cost for this service once available should be used to estimate the subsidy per passenger provided by Massport.

A.6 Chelsea Garage Shuttle

Massport operates an off-airport employee parking garage in Chelsea, which is served by a round-the-clock Massport shuttle that travels between the garage and the Airport terminal area, as well as other airport employment areas.

Approximately 3,600 to 3,800 employees per month sign up to use this parking garage.[137]

The annual ridership and operating cost for this service, once available, should be used to estimate the subsidy provided by Massport per passenger.

A.7 Parking and Other Employee Subsidies

Massport manages on-Airport parking supply with the goal of promoting long-term parking, hence reducing the number of trips to the Airport, in compliance with the provisions of the Logan Airport Parking Freeze. Additionally, Massport provides parking at the four Logan Express terminals, and operates an off-Airport employee parking garage at Chelsea.

[136] Massport's 2010 EDR

[137] M. Deangelis - Personal communication, January 18, 2013

Massport pays a significant amount of rent for the Chelsea parking garage, and although parking revenues cover the employee shuttle operating costs, the garage is operating at a net loss.[138] On the other hand, by transferring 1550 parking spaces out of Logan, this service provides a potential revenue stream of at least $15million/year (assuming one occupancy per day for each space at a rate of $27), demonstrating that it is financially prudent. This strategy may also have secondary benefits of encouraging employee mode shift to transit.

In Fiscal Year (FY) 2011, Massport reported $116.5 million in Logan Airport parking revenue, including revenue from public parking at the Airport, tenant employee parking at the Airport, and public off-Airport parking, including Logan Express. This was an 8% increase over the parking revenue reported in FY 2010.[139]

Massport employees get free parking in all Massport's parking facilities, while other Airport employees get discounted parking. As of 2012, 2,673 on-Airport parking spaces are allocated for employees (see **Chapter 2**). Each of these employee spaces is associated with an opportunity cost, since the spaces could be converted into higher revenue public parking spaces if some employees shift to public transportation.

On-Airport parking costs $140 per month[140] for (non-Massport) Airport employees or $7/day using 20 workdays per month. In comparison, the daily parking rate for non-employees is $27 at the Central Parking, Terminal B Garage, and Terminal E Lots 1 and 2, and $18 at the Economy Parking.[141]

At the Logan Express terminals, Airport employees pay $40 per month or $2 per day using 20 workdays, while air passengers pay $7 per day for parking. Other off-Airport parking providers charged between $13.50 and $18.50 per day and between $81 and $105 per week for parking in 2010.[142]

Parking at the employee parking garage in Chelsea is free for Massport employees, but costs $100 per month for other airport employees[143].

Table A-10 summarizes monthly employee parking rates for accessing the Airport.

Table A-10: Monthly Parking Rates for accessing Logan Airport

	Logan Express Terminals	Chelsea Garage	On-Airport Parking
Massport Employees	$0.00	$0.00	$0.00
Other Airport Employees	$40.00*	$100.00	$140.00

*ACRP

138 ACRP 36
139 Massport's Comprehensive Annual Financial Report - 2011
140 ACRP 36
141 Massport's 2010 EDR
142 Massport's 2010 EDR
143 ACRP 36

Massport offers discounts and other incentives to its employees to encourage commuting alternatives to the drive-alone commute, including transit pass subsidies and parking discounts. Massport offers its own employees up to $100 per month to subsidize up to 50% of their cost to commute by HOV. Employees can pay their portion of the commuter pass costs using their pre-tax earnings. In FY2011, Massport spent about $90,000 on commuter pass discounts to its employees for use of the MBTA, Logan Express and other scheduled HOVs. Approximately 170 Massport employees participated that year in the commuter pass discount program[144].

Massport also encourages private transportation providers to offer fare discounts to Airport employees for scheduled bus and van routes, and encourages other Airport employers to offer incentives to their employees for public transportation use. The TSA and Signature Flight Support are among the Airport employers offering subsidized transit passes to their employees, but the exact details and extent of the subsidies are unknown[145].

A.8 Typical Costs of Commuting and Travelling to Logan Airport

Excluding tolls and other car ownership costs, it is generally cheaper for an air passenger to use public transportation to access the Airport, as opposed to driving to the Airport. A 5-day trip from Logan Airport, for example, would cost only $2 for ground transportation access by the Silver Line, since passengers only pay one way (Massport fully subsidizes the return trip). The Blue Line alternative would cost $4 round trip (using a Charlie Card). A 5-mile drive to Logan Express and using the express bus service would cost about $59 (($35 for 5-days parking, $22 round trip bus fare, and $2 both ways for gas, assuming $0.20/mile).

Driving to the airport would cost $141 if On-Airport parking is used ($135 for 5-day parking plus $6 round trip for gas for the 30-mile round trip from Braintree to Logan Airport) or $98.50 if Off-Airport parking is used (($92.50 for 5-day parking plus $6 round trip for gas). These costs are summarized in **Table A-11**.

Table A-11: Round Trip Cost of Ground Transportation Access to Logan for a 5-day Trip for Air Passengers

	Silver Line*	Blue Line**	Logan Express	Drive + Off-Airport Parking	Drive + On-Airport Parking
Air passenger	$2.00	$4.00	$59.00	$98.50***	$141.00****

*One-way subway fare using a Charlie Card
**Round trip subway fare using a Charlie Card
***$18.50 off-Airport parking rate per day
****$27 on-Airport parking rate per day

The cost of commuting by public transportation is also less than driving costs for Massport and other Airport employees living 15 miles from the Airport (see **Table A-12**).

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Table A-12: Round Trip Monthly Cost of Ground Transportation Access to Logan for Airport Employees

	Silver Line*	Blue Line*	Logan Express**	Drive + Chelsea Parking***	Drive + On-Airport Parking****
Massport Employees	$35.00	$35.00	$80	$120	$120
Airport Employees	$70.00	$70.00	$140	$220	$260

*$70 for an unlimited monthly T-pass. Massport subsidizes 50% of T pass costs for its employees

**$40 monthly pass and free parking for MP employees, $100 monthly pass for bus fare and parking for Airport employees, $40 gas cost per month assuming 20 working days for a 10-mile round trip drive to the Braintree Logan Express terminal

***30-mile round trip from Braintree to the Airport for 20 days at gas cost of $0.20/mile. Free parking for MP employees, $100/month parking for other Airport employees

***30-mile round trip from Braintree to the Airport for 20 days at gas cost of $0.20/mile. Free parking for MP employees, $140/month parking for other Airport employees

A.9 Conclusion

Massport spends a significant amount on funding public transportation services to Logan Airport. Estimated yearly costs for each service are summarized in **Figure A-1**, with the 4 Logan Express routes having the highest combined cost ($11.1 million), followed by the Silver Line then the Blue Line ($3.5 and $2.4 million, respectively).

The operating costs are partially or fully offset by fare revenues, resulting in the net subsidies illustrated in **Figure A-2**. The four Logan Express routes combined receive the highest subsidy ($4.11million).

Figure A-3 shows annual ridership on the various public transportation routes. The annual ridership has been used to determine the subsidy per rider (**Figure A-4**).

At $17/rider, the Peabody route is the most heavily subsidized, followed by the Sunrise shuttles, due to the low ridership levels on these routes. Woburn trips are also highly subsidized (at $9/rider).

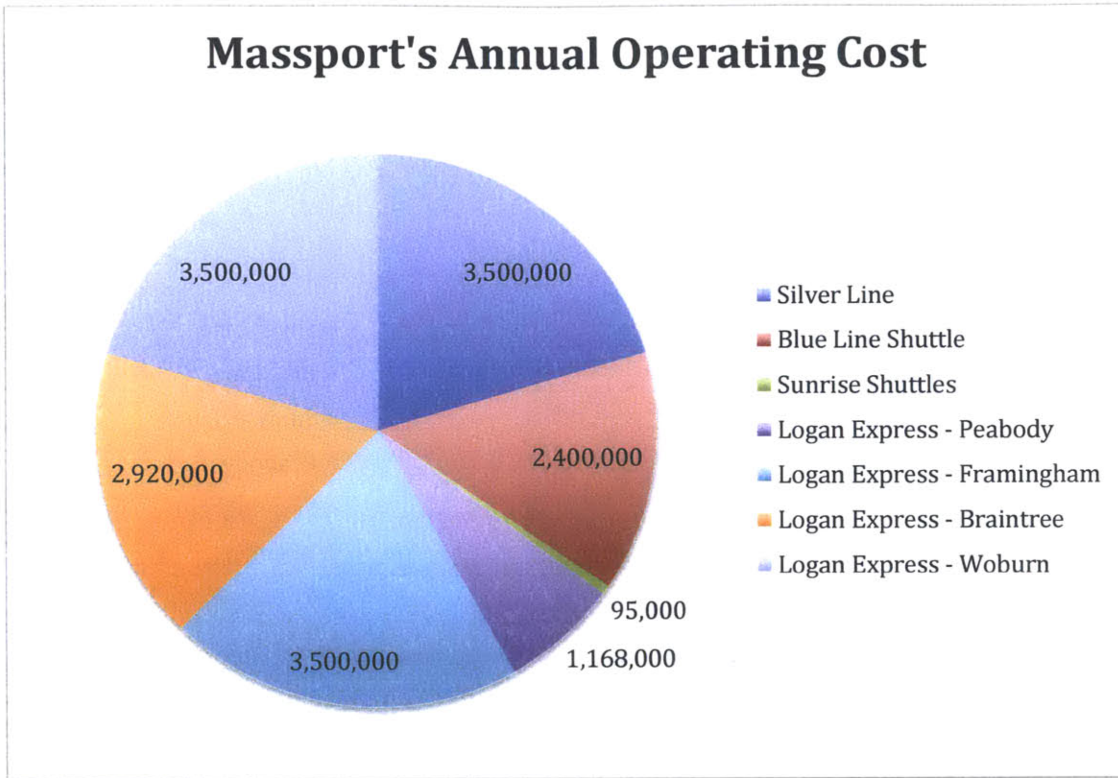

Figure A-1: Massport's Annual Operating Costs for Public Transportation Access

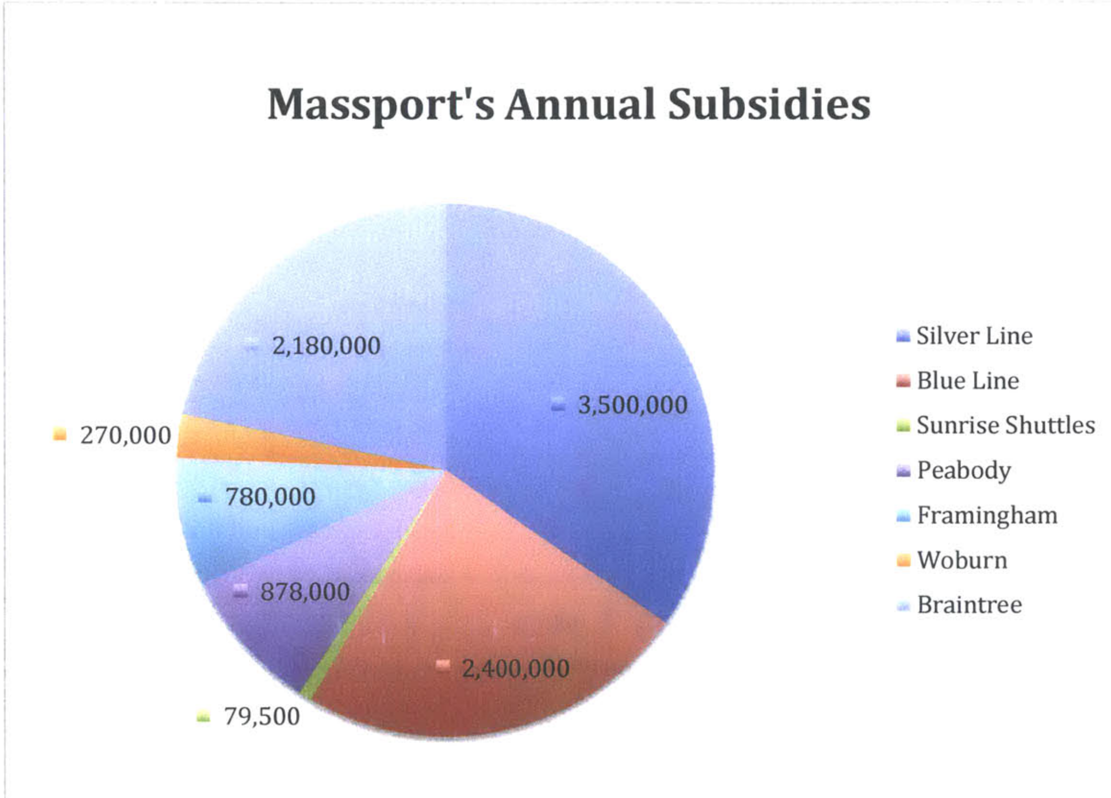

Figure A-2: Massport's Annual Subsidies for Public Transportation Access

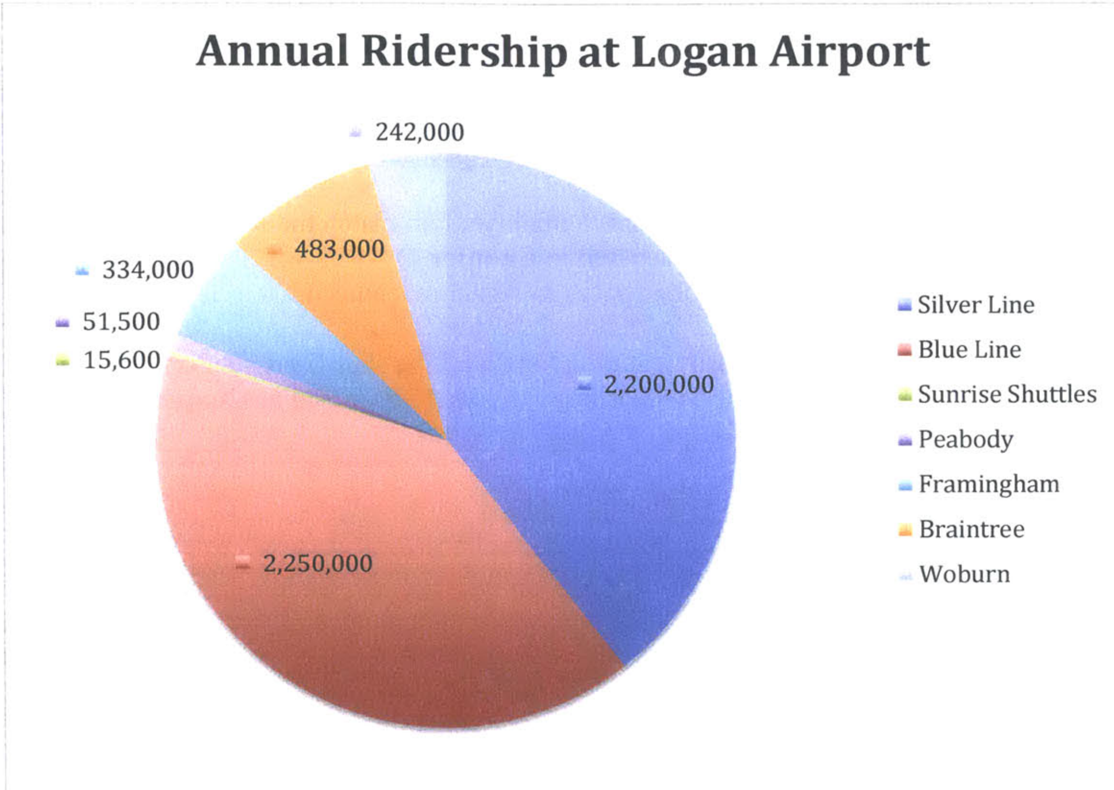

Figure A-3: Annual Ridership to Logan Airport by Massport-funded Public Transportation

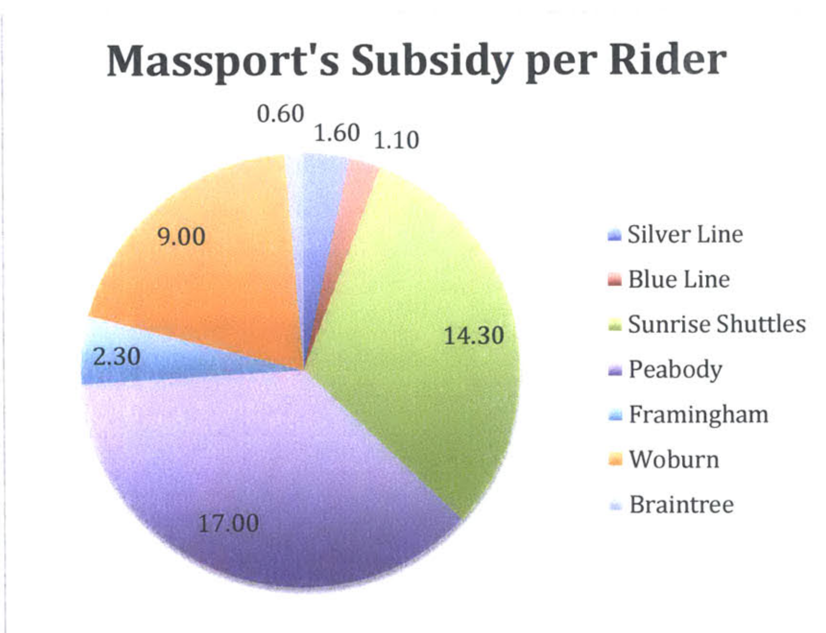

Figure A-4: Subsidy per Rider covered by Massport for Public Transportation Access to Logan

Massport spends over $10.1 million annually in subsidizing the various public transportation services to Logan Airport. A total of $116.5 million is collected in parking revenues each year.

The following new initiatives arose from the analysis of Massport's operating costs and revenues for Ground Transportation access to Logan Airport, and are discussed in other chapters in the main body of this report:

- 100% subsidized transit passes for Massport employees, to match the free parking provided for Massport employees (discussed in **Chapter 2**)
- Conversion of some employee parking spaces to higher revenue commercial spaces (discussed in **Chapter 2**)
- Free transfers to the Blue Line Airport station for Blue Line shuttle passengers from the Airport, to match the free Silver Line boardings at Logan (discussed in **Chapter 9**)

Appendix B – Airport Shuttle Weekly Vehicle Hours

A summary of the weekly vehicle hours for Massport's shuttles is shown in **Table B-1**.

Table B-1: Headways, Travel Times and Vehicle Hours for Airport Shuttles

Route 22				
Average Round-Trip Travel Time: 10:44				
	Saturday	**Sunday**	**Monday - Wednesday**	**Thursday - Friday**
Time Period	11:00 AM - 8:00 PM	11:00 AM - 10:00 PM	11:00 AM - 10:00 PM	11:00 AM - Noon; 6:00 PM - 10:00 PM
Number of Hours	9	11	11	5
Number of Buses	2	2	2	2
Headway	6 minutes	6 minutes	6 minutes	6 minutes
Vehicle Hours	18	22	22	10
Time Period				Noon - 6:00 PM
Number of Hours				6
Number of Buses				3
Headway				6 minutes
Vehicle Hours				18
Total Weekly Hours	**90**			
Route 33				
Average Round-Trip Travel Time: 9:29				
	Saturday	**Sunday**	**Monday - Wednesday**	**Thursday - Friday**
Time Period	11:00 AM - 8:00 PM	11:00 AM - 10:00 PM	11:00 AM - 10:00 PM	11:00 AM - 10:00 PM
Number of Hours	9	11	11	11
Number of Buses	2	2	2	2
Headway	6 minutes	6 minutes	6 minutes	6 minutes
Vehicle Hours	18	22	22	22
Total Weekly Hours	**84**			

Route 55				
Average Round-Trip Travel Time: 12:54				
	Saturday	Sunday	Monday - Wednesday	Thursday - Friday
Time Period	4:00 AM - 5:00 AM	4:00 AM - 5:00 AM	4:00 AM - 5:00 AM	4:00 AM - 5:00 AM
Number of Hours	1	1	1	1
Number of Buses	2	2	2	2
Headway	6 minutes	6 minutes	6 minutes	6 minutes
Vehicle Hours	2	2	2	2
Time Period	5:00 AM - 11:00 AM	5:00 AM - 11:00 AM	5:00 AM - 11:00 AM	5:00 AM - 11:00 AM
Number of Hours	6	6	6	6
Number of Buses	3	3	4	4
Headway	5 minutes	5 minutes	4 minutes	4 minutes
Vehicle Hours	18	18	24	24
Time Period	8:00 PM - 10:00 PM	10:00 PM - 1:00 AM	10:00 PM - Midnight	10:00 PM - Midnight
Number of Hours	2	3	2	2
Number of Buses	4	4	4	4
Headway	4 minutes	5 minutes	4 minutes	4 minutes
Vehicle Hours	8	12	8	8
Time Period	10:00 PM - 1:00 AM		Midnight - 1:00 AM	Midnight - 1:00 AM
Number of Hours	3		1	1
Number of Buses	3		3	3
Headway	5 minutes		5 minutes	5 minutes
Vehicle Hours	9		3	3
Total Weekly Vehicle Hours	**143**			
TOTAL WEEKLY VEHICLE HOURS FOR ALL ROUTES	**317**			