Improving Transportation Access to the South Boston Seaport District

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ABSTRACT

Boston's Seaport District comprises approximately 1,000 acres of mixed-use residential, commercial and industrial space, which fosters innovation, collaboration and entrepreneurship. Development in the area is occurring fast. Projects that have been completed, proposed, or approved by the Boston Redevelopment Authority as of March 2014 add 10 million square feet of development. Long-term forecasts for the area estimate that an additional 21 million square feet of development will be constructed in the Seaport District by 2030.

The overall objective of this thesis is to explore strategies to ensure the Seaport District will have multimodal transportation access to accommodate future economic development. More specific objectives of the thesis are listed as follows:

- Lessen road congestion at specific intersections and major streets.
- Optimize Silver Line operations.
- Improve local bus service.
- Assess and enhance bus-priority and parking policies.

Thus, the main goals in this thesis are to improve the mobility, accessibility and sustainability of the Seaport District by providing more and higher quality public transport and discouraging access by private car.

The evaluation of the public transport and road networks revealed the key weaknesses and issues in the area. The in-depth analyses of the short-term, medium-term, and long-term conditions then illustrated the potential future problems and proposed solutions to address those problems. It was concluded that operational changes in both the transit and road networks can address the issues raised in the short-term. Capital and operational changes are recommended for the medium-term. In the long-term, significant capital improvements and strict parking policies are proposed in order to accommodate the forecast demand.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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1 INTRODUCTION

This 2013-2014 Master of Engineering in Transportation thesis aims to address transportation issues in the Boston Seaport District by examining strategies to improve access through enhancing the public transport and road networks. The thesis begins by presenting background information on the Seaport District, then performing an assessment of the current transportation system and its problems, and finally, evaluating alternative strategies to tackle these issues. It is hoped that this project thesis will thus serve as a contemporary, in-depth review of the area and offer creative suggestions to Massport and the City of Boston for new initiatives.

1.1 AREA OF ANALYSIS

Boston's Seaport District comprises approximately 1,000 acres of mixed-use residential, commercial and industrial space, which fosters innovation, collaboration and entrepreneurship. The Seaport District is located along the South Boston Waterfront (see Figure 1-1), with access to major Interstate highways I-90 and I-93, and is also close to Logan Airport. The area contains a number of public transport routes, including bus services on Summer and Congress Streets as well as the Silver Line BRT service; in addition, the Red Line stop at South Station is within walking distance of the western portion of the District. The foundation for the area's modern development was in fact laid by Massport, which envisioned transforming the once-derelict, industrial land into a vibrant urban neighborhood. This is slowly coming to fruition. For example, since 2010, the District has attracted more than 4,000 new jobs and 200 new companies[1].

In this project, the Seaport District will be defined roughly as the area bounded by 1st Street to the south, the Fort Point Channel to the west, the Design Center to the east, and the harbor to the north. This is because from the fieldwork conducted, we determined that the area south of 1st Street is already developed and has very different characteristics from the Seaport District, so transport analysis would not be easily compatible. Nevertheless, flows to and from our main study area will be carefully considered when formulating strategies. In terms of neighborhood characteristics, the District can be split into three main parts: a cluster of mostly office buildings on the western side and to the north of Summer Street, a more recreational and residential area around the World Trade Center and Boston Convention Center, and largely industrial buildings in other locations.

[1] http://www.Seaportdistrict.org

Figure 1-1: Seaport District

As for the public transport network, there are a number of MBTA routes operating in the area, namely: Route 4, 7, 11 and the Silver Line, as well as express buses 448, 449 and 459 (see Figure 1-2). The Silver Line, abbreviated SL, is the core service running through the District. In addition, there are numerous private shuttle routes (operated by local employers for their employees) serving the District, as will be discussed in Chapter 3. More detailed route descriptions can also be found in Chapter 3.

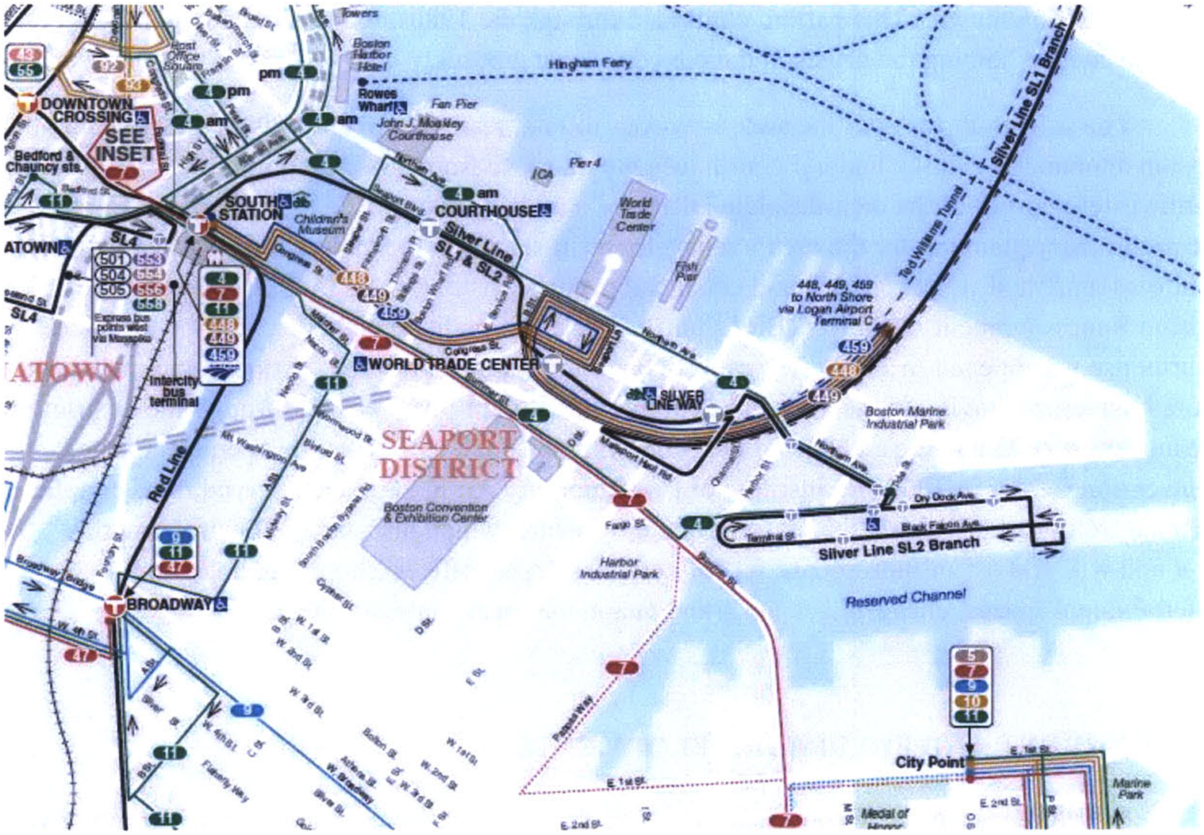

Figure 1-2: District's MBTA routes

1.2 HISTORY

The idea that the Seaport District could be an abandoned no-man's-land might seem absurd to modern eyes, but in fact, until fairly recently, this was actually the case. Although the area was busy during the 1940s and early 1950s, with numerous factories, warehouses and docks, the weaknesses of Boston's traditional economic driver, i.e. heavy industries and manufacturing, were exposed when many plants closed down and moved south to take advantage of cheaper labor. The District was badly affected and although some shipping and port facilities managed to survive, since there was a greatly reduced demand for raw materials, they too struggle. Hence, by the 1960s, what was once a busy, albeit gritty, industrial zone had turned into a decrepit area of abandoned buildings and parking lots (some factories on the western side of the area, closer to downtown, were torn down to make way for commuter parking); even Mayor Kevin White commented that the area was "rotten". In the 1970s, even though the region's economy was slowly improving thanks to the emergence of new high-tech and healthcare-related companies, the area still stagnated with little change. However, at the time, a number of artists and young people began moving into the area close to the Fort Point Channel, attracted by the low rents and proximity to downtown. This pattern continued through the 1980s, with increasing numbers of small businesses joining the artists in the converted warehouses.

The shift in fortunes of the area, however, did not really begin until 1991 when the city of Boston announced that the Federal courthouse would move from downtown into the northwestern corner of the then-desolate District – a move that surprised many people. In fact, the preliminary planning for the area's redevelopment started in the 1970's during Mayor White's tenure and was expanded and enhanced over the ensuing years by Massport and the Boston Redevelopment Authority (BRA) until it became a reality much later. By the time the courthouse was opened in 1999, the Seaport District had a much brighter outlook, with more and more businesses moving to the area. The completion of the I-90 extension through the District to the airport in 2003 and the creation of the Silver Line in 2004, as well as the openings of the Convention Center in 2004 and Institute of Contemporary Art in 2006 only served to hasten the area's development. Indeed, the massive Seaport Square, which just started construction this year and will add 6.5 million square feet of new residences, offices, shopping, hotel and entertainment spaces, encapsulates the grand vision that many have for the area.

1.3 CURRENT AND FUTURE DEVELOPMENTS

Development in the Seaport District is occurring fast. Projects that have been completed, proposed, or approved by the Boston Redevelopment Authority as of March 2014 add around 10 million square feet of development, of which approximately 40% is office and retail, 20% is hotel, 30% is residential, and 10% is industrial. The description and phase of these projects are shown in Table 1-1 and Table 1-2.

	Existing Projects	Phase
1	124,000 square feet of office and 16,000 retail use	Construction Complete
2	257,000 square feet of residential use (corresponding to roughly 202 dwelling units)	Construction Complete
3	43,700 square feet of residential use (corresponding to roughly 88 dwelling units)	Construction Complete
4	98,000 square feet of light industrial use	Construction Complete
5	1,100,000 square feet of office use	Construction Complete
6	525,000 square feet of office use	Construction Complete
7	300,000 square feet of residential and 72,000 retail use (corresponding to roughly 235 dwelling units)	Construction Complete

Table 1-1: Existing projects

	Future Projects	Phase
1	201,000 square feet of residential use (corresponding to roughly 200 dwelling units)	Under Construction
2	525,000 square feet of residential use, 314,700 square feet of hotel use and 62,000 square feet of retail use	Under Construction
3	85,900 square feet of hotel use	Under Construction
4	455,000 square feet of office use	Under Construction
5	193,400 square feet of residential use (corresponding to roughly 200 dwelling units)	Under Construction
6	310,900 square feet of hotel use and 26,300 square feet of retail use	Under Construction
7	23,000 square feet of residential use and 2,900 square feet of retail use	Board Approved
8	377,300 square feet of residential use (corresponding to roughly 400 dwelling units)	Board Approved
9	510,500 square feet of industrial use	Board Approved
10	2,900,000 square feet of mix uses (including residential, office, hotel, retail and cultural)	Board Approved
11	355,000 square feet of light industrial use	Board Approved
12	300,000 square feet of residential use (corresponding to roughly 300 dwelling units), 150,000 square feet of hotel use, 25,000 square feet of retail use and 16,000 square feet of office use	Under Review

Table 1-2: Future projects

The locations of the future projects are shown in Figure 1-3. As can be seen, these projects are focused mostly in the northwestern part of the District. After their construction, limited space for future development will be available on this side of the Seaport District.

Long-term forecasts of the future development in the area were developed by ABC[2] in 2008. According to those estimates, an additional 21 million square feet of development will be constructed in the Seaport District by the year 2030. This development will be accompanied by a significant increase in population (300%), and in the number of jobs (more than 100%). Figure 1-4 provides ABC's estimate regarding land-use development and job growth in the area. Note that the aforementioned projects in Table 1-1 and Table 1-2 constitute most of the 2015 growth shown in Figure 1-4 and about 50% of the incremental growth shown for 2030.

[2] Available online at http://www.abettercity.org/docs/land_sbw_fs_landuse.pdf & http://www.abettercity.org/docs/land_sbw_fs_employment.pdf (last visit 04/22/2014)

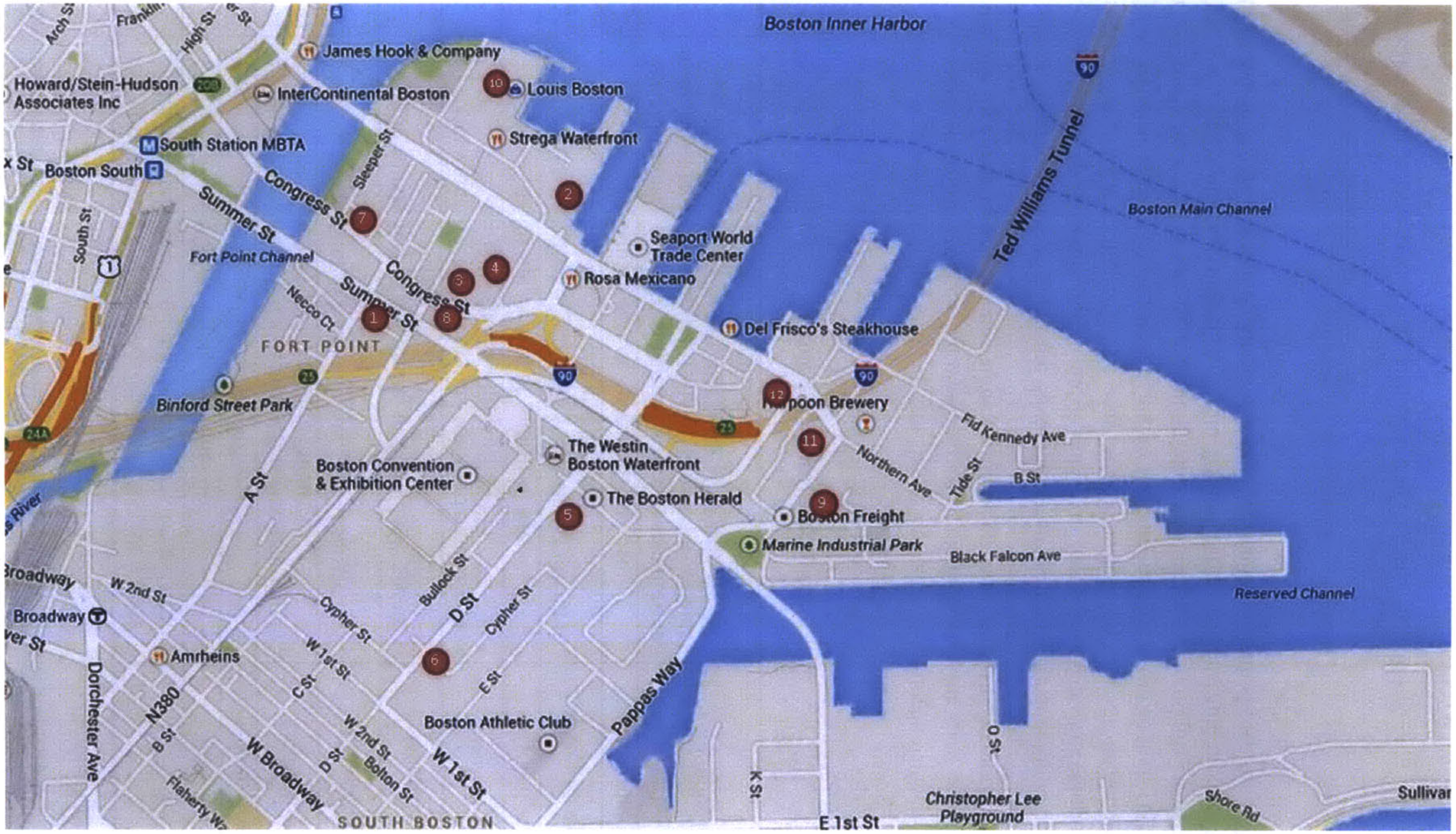

Figure 1-3: Locations of future projects

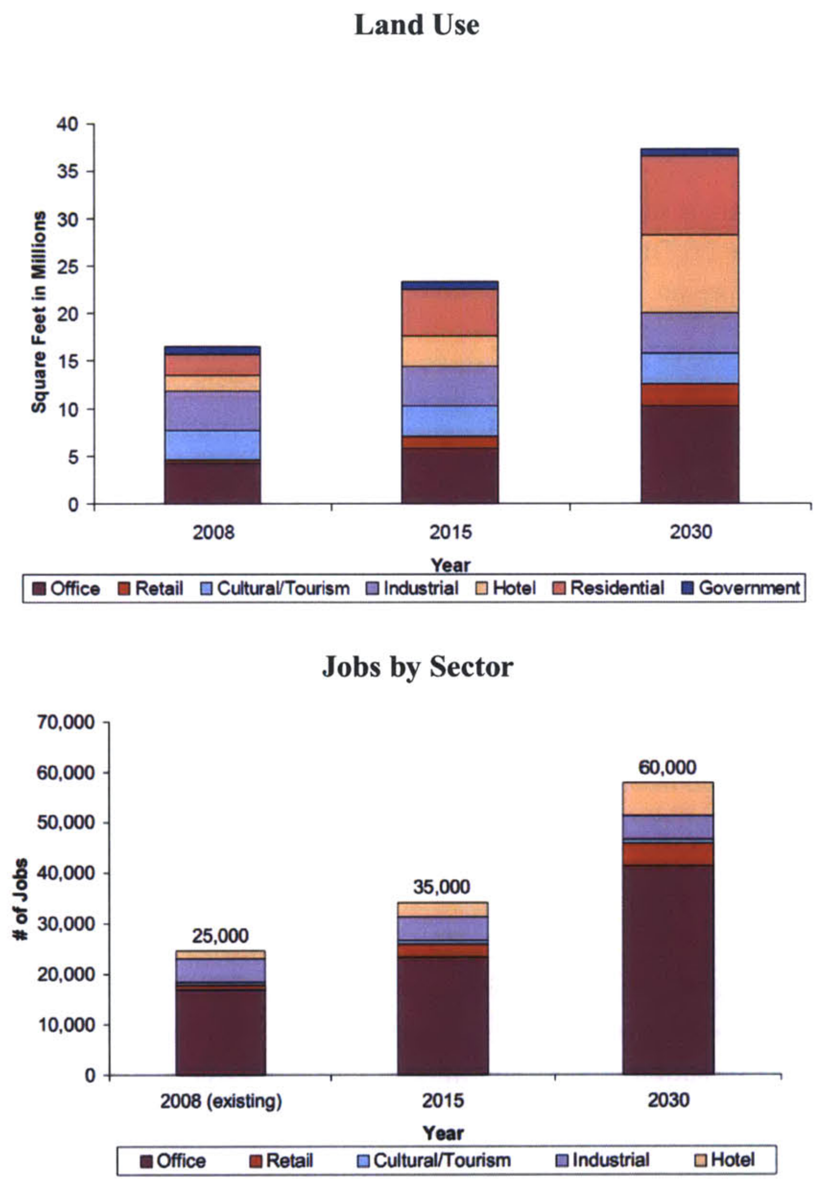

Figure 1-4: Forecast future development in the Seaport District (Source: ABC)

1.4 OBJECTIVES

The overall objective of the project is to explore strategies to ensure that in the future, the Seaport District will have multimodal transportation access to accommodate future economic development. More specific objectives of the project are:

A. Lessen road congestion at specific intersections and on major streets.

B. Optimize Silver Line operations.

C. Improve local bus service.

D. Assess and enhance bus-priority and parking policies.

Thus, the main goals in this project are to improve the mobility, accessibility and sustainability of the Seaport District by providing more and higher quality public transport and discouraging access by private car.

1.5 APPROACH

The scope and approach of this thesis were discussed and developed by the team together with their academic advisors. The thesis reviews the current state of the transportation system, conducts a sensitivity analysis to determine how much peak period demand can be accommodated, and finally recommends necessary changes that improve the current transportation system. The thesis mainly focuses on performing an in-depth analysis of the public transport and road networks and, when the results of our analyses suggest that the existing transportation network has reached capacity, alternatives to improve the various transport modes are developed and analyzed in order to ensure sustainable growth in the area.

1.6 OUTLINE

This thesis includes seven chapters. Chapter 2 provides the methodology used in the analysis of transportation alternatives in the Seaport District. The chapter starts by describing the future travel demand estimation process and finishes with a discussion of the methodology for analyzing the effectiveness of the current road and public transport networks, as well as the methodology for analyzing the transportation impacts of the proposed future improvements.

Chapter 3 reports on the current conditions in the Seaport District. First the public transport assessment is conducted, followed by the traffic and the parking assessment. Finally, Chapter 3 describes the sensitivity analysis conducted as part of the current traffic analysis.

Chapter 4 reports the results for the short-term analysis. The demand forecast for the short-term is summarized, followed by the analysis for the no-build scenario. Then, strategies for the public transport and the road network are analyzed. The chapter closes with a set of recommended strategies.

Chapter 5 describes the analysis for the medium-term conditions. The chapter starts with the forecast demand and continues with the analysis of the no-build scenario for the proposed medium-term demand. Strategies are analyzed for the public transport and road network. Based on the results, the recommended strategies are summarized for the medium-term conditions.

Chapter 6 reports the results for the long-term analysis. Similar to the previous two chapters, the chapter starts with the demand forecast, continues with the analysis of the no-build and alternative scenarios then closes with the set of recommended strategies.

Chapter 7 summarizes this thesis. In the first section, an overview presents a set of final recommendations, while the second section discusses recommended topics for future study.

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2 METHODOLOGY

This chapter describes the methodology used in both the traffic and the public transport analyses. The chapter begins with a description of the methods used and the results of the demand forecasts. Then, the modeling approach used for the traffic analysis is described. Finally, the data and process used for the public transport analysis is described.

2.1 DEMAND ESTIMATION

This section is split into two parts. The first describes trips that originate from, or are attracted to, the South Boston Seaport District. The second section describes the trips that pass through the area, mainly via the Interstate highway system.

2.1.1 Local Demand

Future transportation demand was estimated based on the Institute of Transportation Engineers (ITE) Trip Generation Manual[3]. The manual uses linear regression models to estimate generated trips for different land use types.

Before discussing how demand was estimated, there is an important issue to note. In 2008, ABC estimated that by 2030, approximately 21 million square feet of development will exist in the Seaport District. According to data from the Boston Redevelopment Authority (BRA)[4], approximately 2.5 million square feet of development has occurred to date (2014), as shown earlier in Table 1-1. In other words, only around 10% of the ABC's 2030 projections have already occurred, mainly due to the economic downturn.

ABC also projected that about 7 million square feet of new development would exist by 2015, as shown previously in Figure 1-4. Presently, the BRA lists approximately 2.7 million square feet of development as under construction, 4.5 million square feet are "Board Approved", and 0.2 million square feet are "Under Review." If we assume that the under construction projects will complete by 2017, and the "Board Approved" and the "Under Review" projects will complete by 2020, the total development would amount to roughly 7.5 million square feet by 2020. In other words, ABC anticipated the 7 million square feet will be built by 2015, while the current data suggests that only 7.5 million square feet will be built by 2020. Hence, we conclude

[3] Trip Generation Manual, 9th Edition. Institute of Transportation Engineers, Washington, D.C., 2012.
[4] Boston Redevelopment Authority http://www.bostonredevelopmentauthority.org/projects/development-projects?neighborhoodid=29&sortby=name&sortdirection=ASC&type=dev (visited 4/29/2014)

that most projects in the District have been delayed by five years. Note that the expected future developments were shown previously in Table 1-2.

From the above, two important points emerge. First, the development in the District will occur at a slower rate than ABC anticipated because roughly 50% of the development will occur by 2020 and not 2015. Second, we expect that the full 21 million square feet of development will be built in the District by 2035 instead of 2030. Therefore, all the ABC data that was originally attributed to 2030 will now be attributed to 2035.

As for demand, it was estimated for:

- Base year conditions based on ABC's data for the year 2008. These data are generally consistent with data available in the 2010 US Census.
- Long-term conditions based on ABC's projections for the year 2035.
- Short-term and medium-term conditions based on the development that will occur before 2035. It was estimated that trips will increase at a constant annual rate (different for each land-use type) from the base year until 2035. The annual increases vary from practically zero (for industrial land-uses) to 5%.

The ABC data, which are summarized in Table 2-1, show a significant increase in the number of jobs. The number of residential units currently available in the Seaport District was obtained from the 2010 US Census, and based on ABC's projection for population increase, the number of residential units for the year 2035 was estimated.

	2008	Added by 2035	Total (2035)
Office Jobs	17,000	18,000	35,000
Industrial Jobs	5,000	50	5,050
Hotel Rooms	2,000	4,800	6,800
Retail Jobs	1,000	2,200	3,200
Residential Units	1,300[5]	2,500	3,800

Table 2-1: Estimated future development

The ITE manual provides a number of land use types to describe office, industrial, hotel, retail and residential development. In this thesis, the following land use types are used to represent the development that will occur in the District and to estimate future transportation demand:

[5] Residential Units obtained from 2010 US Census

- General Office Building (land-use code 710) was used to estimate generated trips associated with office jobs.
- General Light Industrial (land-use code 110) was used to estimate generated trips associated with industrial jobs.
- Hotel (land-use code 310) was used to estimate generated trips associated with hotel accommodation.
- Two types of land uses related to retail were used to estimate the generated trips associated with retail jobs:
    - Quality Restaurant (land-use code 931)
    - Apparel Store (land-use code 876)
- Apartment (land-use code 220) was used to estimate generated trips associated with residential units.

The analysis focuses on estimating the number of originating and terminating person trips for the AM and PM peak hours by land-use type. The ITE manual however, provides regression models that estimate generation of vehicle trips. Because the study sites used for the estimation of the regression models are mainly suburban, where public transport access is limited and walking and bicycling are uncommon, the assumption was made that the estimated vehicle trips reflect the total demand for trips. Based on this assumption, and with the use of an average vehicle occupancy of 1.09[6], the generated person trips were estimated.

The results for the base year, the short-term, the medium-term and the long-term are shown in Table 2-2.

The estimated attracted trips in the area for the AM peak hour of the base year (2008), according to the ITE manual, are roughly 9,700. From the calibrated Origin-Destination (O-D) matrix, used in the simulation model, the total vehicle trips entering the area were 5,200, which corresponds to roughly 5,700 person trips (assuming average vehicle occupancy of 1.09). Based on the public transport demand analysis of this study (section 3.1), the total trips attracted by public transport was estimated to be 1,600. In addition, another 300 workers commute every morning to the District through private shuttle services. These numbers sum to roughly 7,600 peak hour person trips. This number seems to be consistent with the number estimated from the ITE manual, and corresponds to roughly 80% of total trips attracted to the District. The difference between the ITE manual's 9,700 total attracted trips and our 7,600 total attracted trips can be attributed to trips by other modes such as water transport, walking, and bicycling. Note that the 20% who use other modes include those who cover the 'last mile' by walking after having taken other public transport routes that do not directly serve the District, e.g. commuter rail passengers walking from South Station are counted under "other modes".

[6] Derived from the US Census 2010 data for the District

		Person Trips					
		AM Peak Hour			PM Peak Hour		
Year	**Zone Type**	**Total**	**Attracted**	**Generated**	**Total**	**Attracted**	**Generated**
2008	**Office**	6,023	5,301	723	6,922	1,177	5,745
	Industrial	2,072	1,802	269	2,034	590	1,444
	Hotel	712	406	306	723	210	513
	Retail	2,826	1,951	875	4,231	2,411	1,821
	Residential	756	219	536	869	530	339
	Total	**12,388**	**9,679**	**2,710**	**14,779**	**4,917**	**9,862**
2014	**Office**	6,915	6,085	830	8,118	1,380	6,738
	Industrial	2,076	1,806	270	2,038	591	1,447
	Hotel	914	521	393	856	248	608
	Retail	3607	2,490	1,117	5,480	3,117	2,364
	Residential	964	279	684	1,106	675	431
	Total	**14,476**	**11,182**	**3,294**	**17,598**	**6,010**	**11,587**
2017	**Office**	7,409	6,520	889	8,791	1,494	7,297
	Industrial	2,078	1,808	270	2,040	592	1,449
	Hotel	1,037	591	446	931	270	661
	Retail	4,076	2,814	1,262	6,237	3,544	2,693
	Residential	1,088	316	773	1,248	761	487
	Total	**15,687**	**12,048**	**3,639**	**19,247**	**6,661**	**12,586**
2025	**Office**	8,906	7,837	1,069	10,873	1,848	9,024
	Industrial	2,083	1,812	271	2,046	593	1,453
	Hotel	1,448	825	623	1,166	338	828
	Retail	5,644	3,896	1,747	8,811	4,994	3,816
	Residential	1,505	437	1,069	1,720	1,049	671
	Total	**19,586**	**14,807**	**4,778**	**24,615**	**8,823**	**15,792**
2035	**Office**	11,209	9,864	1,345	14,181	2,411	11,770
	Industrial	2,090	1,818	272	2,053	595	1,458
	Hotel	2,200	1,254	946	1,544	448	1,096
	Retail	8,477	5,853	2,625	13,579	7,674	5,904
	Residential	2,258	655	1,603	2,570	1,568	1,002
	Total	**26,233**	**19,443**	**6,790**	**33,926**	**12,696**	**21,231**

Table 2-2: Estimated demand

For the PM peak hour of the base year, according to the ITE manual estimation, the number of generated trips in the Seaport District is 9,900. This number is similar to the trips attracted during the AM peak hour. From the O-D matrix used in our traffic analysis, the vehicle trips generated in the District during the PM peak hour are 5,700, corresponding to 6,200 person trips. The trips generated in the area and accommodated through public transport are 1,800, while another 300 generated trips are provided through private shuttle services (as shown in Chapter 3). Hence, the total number of generated trips accommodated through public transport and/or automobile is 8,300, which is consistent with the trips estimated from the ITE trip generation manual, and corresponds to roughly 80% of the generated trips. Similar to the AM peak hour, the difference can be attributed to trips generated in the area and accommodated by other modes, such as water transport, walking, and bicycling.

Note from Table 2-2 that, from 2008 to 2035, demand in the area more than doubles. This increase is due to the tripling of housing units and the doubling of jobs by 2035. These immense changes in the District could lead to a significant increase in the walking and bicycling mode share because it is likely that many of the new residents will work in the District and hence will not need to use a vehicle for their daily commute to work.

2.1.2 Regional Demand

Regional demand corresponds to the trips that go through the District. The majority of these trips are on the Interstate system that passes through the area. The demand was estimated based on the "Massachusetts Turnpike: Metropolitan Highway System, Traffic and Revenue Study" prepared for MassDOT by Cambridge Systematics and Vanasse Hangen Brustlin (VHB) in 2010[7].

According to this study, it is estimated that, for the tunnels of the Metropolitan Highway System, traffic will increase from 2011 to 2014 at an annual rate of 1.4%. From 2014 to 2020, it is forecast that demand will increase by 1.1% annually. From 2020 to 2035, the annual increase is estimated to be 0.9%.

Before adopting the demand forecast of the "Traffic and Revenue" study, a validation check was made to ensure that the estimates are credible. We used 2013 traffic data available from MassDOT for the Ted Williams Tunnel and we compared them to the corresponding traffic forecast. The results, summarized in Table 2-3, show that the forecast demand is very close to the actual, at least in the short-term. While the annual rate of increase is not constant, the recorded cumulative increase records a difference between actual and forecast demand of only 0.1%. Therefore, this thesis will utilize the numbers provided from the "Traffic and Revenue" study, noting however that these numbers are estimates and must be used with caution.

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[7] Available online at:
https://www.massdot.state.ma.us/portals/0/docs/InfoCenter/financials/RefinanceTR_Study_042710.pdf (last visit 4/24/2014)

Year	Traffic	Annual Increase (%)	Estimated Annual Increase (%)
2010	7,594,383	-	-
2011	7,696,317	1.3%	1.4%
2012	7,765,747	0.9%	1.4%
2013	7,910,214	1.9%	1.4%
Total Increase (%)		4.2%	4.3%

Table 2-3: Actual and forecast growth for the Ted Williams Tunnel

Note the following two aspects about our demand estimation:

1. Given the nature of developments and activities in the District, visitor trips should be significant especially during the evenings. In our demand estimations and analyses, we considered that the 1.09 average vehicle occupancy incorporates the demand generated and attracted by visitors. This simplified approach was followed because detailed visitor demand data was not available for our analyses.
2. Port and construction activities generate and attract freight traffic. However, our analyses did not include truck-demand because (1) our analysis focused on peak hour trips and most of the freight activity happens at other times of day and (2) in order to accurately estimate the impacts of freight on the transportation network in the District, a detailed truck-only O-D matrix would be needed but was not available.

2.1.3 Mode Split

Demand forecasting for the Seaport District estimates the total number of person trips attracted to, or originating from, the area. Person trips are distributed to the various modes, creating the mode split for the Seaport District. Our analysis assumes that the mode split for the area will remain constant between cars, public transport and non-motorized transport, as long as both of the following statements hold:

- Parking demand during the AM peak hour does not exceed parking supply.
- Traffic conditions in the area are such that the forecast vehicle trips can be accommodated.

If either these conditions does not hold, then we assume that mode split will change, since more people will shift to public transport. More specifically, we assume that the deficit between parking (or road) supply and vehicle demand must be accommodated by public transport.

It should be noted that this simple assumption fails to capture the importance of the changes in the public transport network. It is generally recognized that public transport changes can shift commuters to public transport, regardless of the traffic or parking conditions in the area. Introduction of new public transport services that connect the Seaport District with other part of Boston, or frequency improvements on the existing bus routes (especially the Silver Line routes) can significantly influence mode split. However, in order to estimate changes in mode choice a specific mode split model (e.g. a nested logit model) is required. Development of this kind of model was not possible for this thesis given our limited resources and limited availability of data.

2.2 TRAFFIC

This section describes the approach used to assess the current and future traffic conditions in the Seaport District. A microscopic simulation model was developed for the area which is used to conduct operational analysis for the road network in the District under various scenarios. The model can forecast at the network level, as well as at the link and intersection level. The inputs required for this model are a simulation database network that represents accurately the physical road network, the demand for vehicle trips (through an O-D Matrix), as well as the components and operational characteristics (e.g. headways) of the public transport network. Parameters (such as the vehicle fleet) can be introduced in the model, if information regarding these parameters is known. A detailed description of the simulation project is provided in Appendix A1.

2.2.1 Inputs

This section reports the input data used for the development of the microscopic model for the Seaport District. These include the road and public transport networks, the initial O-D matrix and the vehicle fleet.

Road network

The road network was developed based on an existing network which was transferred from a regional four-step model[8]. While this four-step model provided the basis for the simulation network of the area, significant improvements were required in order to enhance the network geometry. In addition, the simulation model includes on-street parking spots as well as off-street parking locations, which were not included in the initial (transferred) regional model. The parking data was collected from the City of Boston and a detailed description will be provided in section 3.3.

Intersection control information was also included in the road network. The intersection information was collected from the 2009 Seaport Square Study. As part of this study, 29

[8] Courtesy of MIT lecturer and research associate Mikel Murga

signalized and 4 un-signalized intersections were analyzed in the broader Seaport area. From the 29 signalized intersections, 19 are inside our scope and were thus included in the model. The 19 signalized intersections are listed in Table 2-4 and shown in Figure 2-1.

There are additional signalized intersections in the area today (for instance Melcher Street and A Street was an un-signalized intersection in 2009 and is signalized today), however these were not included, as no control data were available.

	Intersection
1	Seaport Boulevard and Sleeper Street
2	Seaport Boulevard and Boston Wharf Road
3	Seaport Boulevard, East Service Road and Old Northern Avenue
4	Seaport Boulevard and B Street
5	Northern Avenue, D Street (Southbound) and Fish Pier Street
6	Northern Avenue and D Street (Northbound)
7	Congress Street, A Street and Thompson Place
8	Congress Street, West Service Road and Boston Wharf Road
9	Congress Street, I-90 (Eastbound) Off-Ramp, I-93 Off-Ramp and East Service Road
10	Congress Street, I-90 (Westbound) Off-Ramp, I-90 (Westbound) On-Ramp and B Street
11	Congress Street and D Street
12	D Street and Silver Line Way
13	Summer Street and Melcher Street
14	Summer Street and World Trade Center Avenue
15	Summer Street and D Street
16	Summer Street, Dry Dock Avenue and Pappas Way
17	A Street and West Second Street
18	A Street and West Broadway
19	Dorchester and West Broadway

Table 2-4: Signalized intersections included in the model

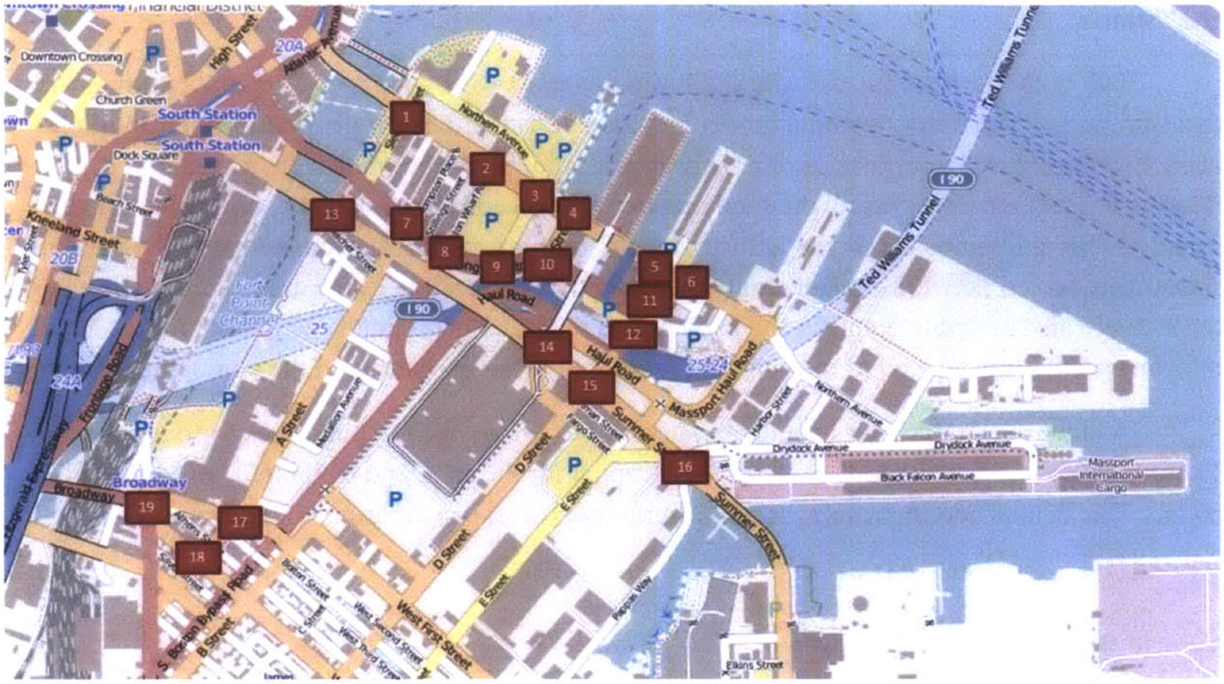


Figure 2-1: Signalized intersections included in the model

Public transport network

The public transport network was also included in the simulation model. Incorporating the public transport system of the Seaport District in the model contributes in quantifying the impacts of traffic congestion in the system. The input data for the public transport network were based on MBTA information and the public transport analysis conducted as part of this study. The data includes:

- All bus routes operated by the MBTA including:
    - The Silver Line routes (SL1, SL2 and SL Shuttle)
    - Routes 4, 7 and 11 (outbound only)
    - The express lines 448, 449 and 459
- The headway for the AM and PM peak hours for all routes.
- An estimated standard deviation for each headway.
- An estimated average passenger load of buses entering the network.
- The arrival rate of passengers for each bus stop in the District.
- The number of boardings per bus route and stop.
- The number of alightings per bus route and stop.

Headway information was used in order to estimate the bus trips in the area, while data per stop were provided in order to simulate dwell times.

O-D Matrix

The O-D Matrices for the AM and PM peak hours were estimated from the regional demand model. The initial regional model included 986 centroids for the Boston Metropolitan Area, however, for the purpose of our analysis nine additional centroids were added in the Seaport District area, increasing the total number to 995 centroids. Socioeconomic data for the year 2010 were input based on the US Census. In addition, road links were added to the network, since the modeled network included only the main traffic corridors of the area. The existing bus routes were also added (except for the express bus routes). Finally, intersection control information was introduced in the network, similar to those introduced in the simulation model.

A sub-area analysis was conducted in order to extract the O-D matrices for our scope. These matrices were input to the microscopic model for the area, and calibrated based on traffic counts. The details and the results of the calibration process are described in section 2.2.2.

Vehicle fleet

As part of the Seaport Square Transportation Study, the number of heavy vehicles and cars in the general traffic was collected from field observations. Based on those counts, we estimated the average proportion of heavy vehicles for both the AM and PM peak. Table 2-5 summarizes the results which show that the proportion of heavy vehicles is higher during the AM peak.

Period	Cars	Heavy Vehicles
AM Peak	91%	9%
PM Peak	96%	4%

Table 2-5: Vehicle fleet mix

2.2.2 O-D matrix calibration

This section describes the method used for the calibration of the O-D matrix, and the results for the AM and PM peak hours.

Method

The traffic simulation software used (TransModeler[9]) includes an option for O-D matrix calibration which requires two inputs:

- An initial O-D matrix. The matrix extracted from the regional model was used.
- Link flows. Two data sources were used for different parts of the network:
    - Highway link flows were used for the highway system that passes through the District, as well as the exit and entry ramps. The data were for 2010 and were obtained from the Massachusetts Department of Transportation.
    - Traffic counts for the rest of the road network. The counts were collected over a period of two years (from March 2007 to April 2009) as part of the Seaport Square study. Counts were conducted at all the signalized intersections listed in section 2.2.1, as well as at the following two un-signalized intersections:
        - Melcher Street and A Street
        - South Boston Bypass Road and West Service Road

    The link flows were estimated from the point traffic counts. The derived link flows for the AM and PM peak hours are shown in Figure 2-2 and Figure 2-3 respectively.

The estimated O-D matrix is a result of an iterative process between O-D estimation and traffic assignment. For both AM and PM peak hours, 100 iterations were conducted for O-D estimation, each involving 1000 iterations for traffic assignment.

Results

Two methods were used to assess the calibration of the AM and PM O-D matrices:

- Route Square Mean Error (RMSE) which is a statistical measure of the difference between values predicted from a model and observed values.

$$RMSE = \frac{\sqrt{n\sum_{i=0}^{n}(Y_i - \hat{Y}_i)^2}}{\sum_{i=0}^{n} Y_i}$$

Where Y_i are the observed values, $\hat{Y}_i$ are the simulated values and n the number of observations. RMSE is a measure of accuracy, therefore low values are desirable.

[9] Caliper Corporation (2013), "TransModeler Traffic Simulation Software – Version 3.0 User's Guide", Newton, MA.

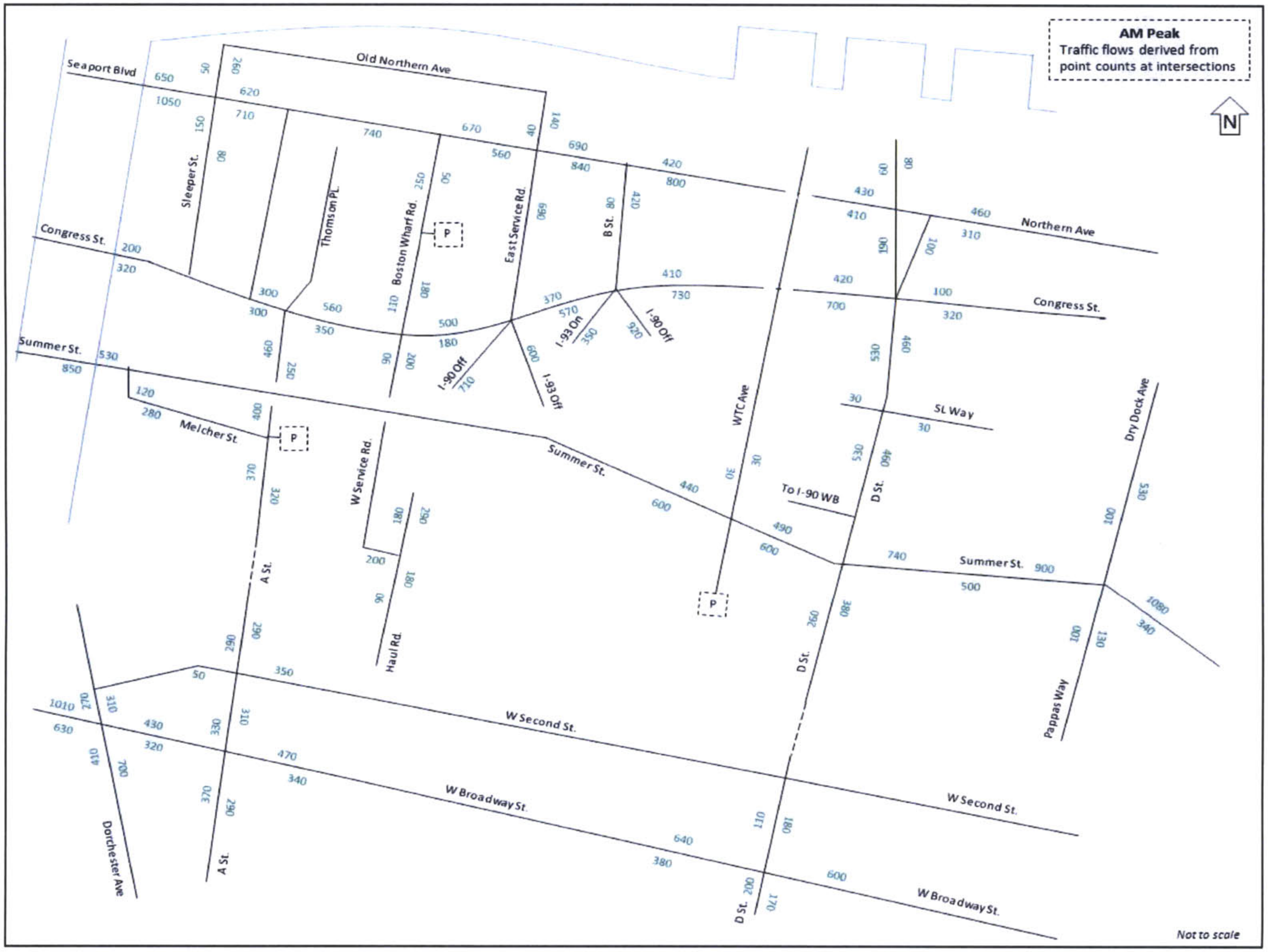


Figure 2-2: Link flows – AM peak hour (2009)

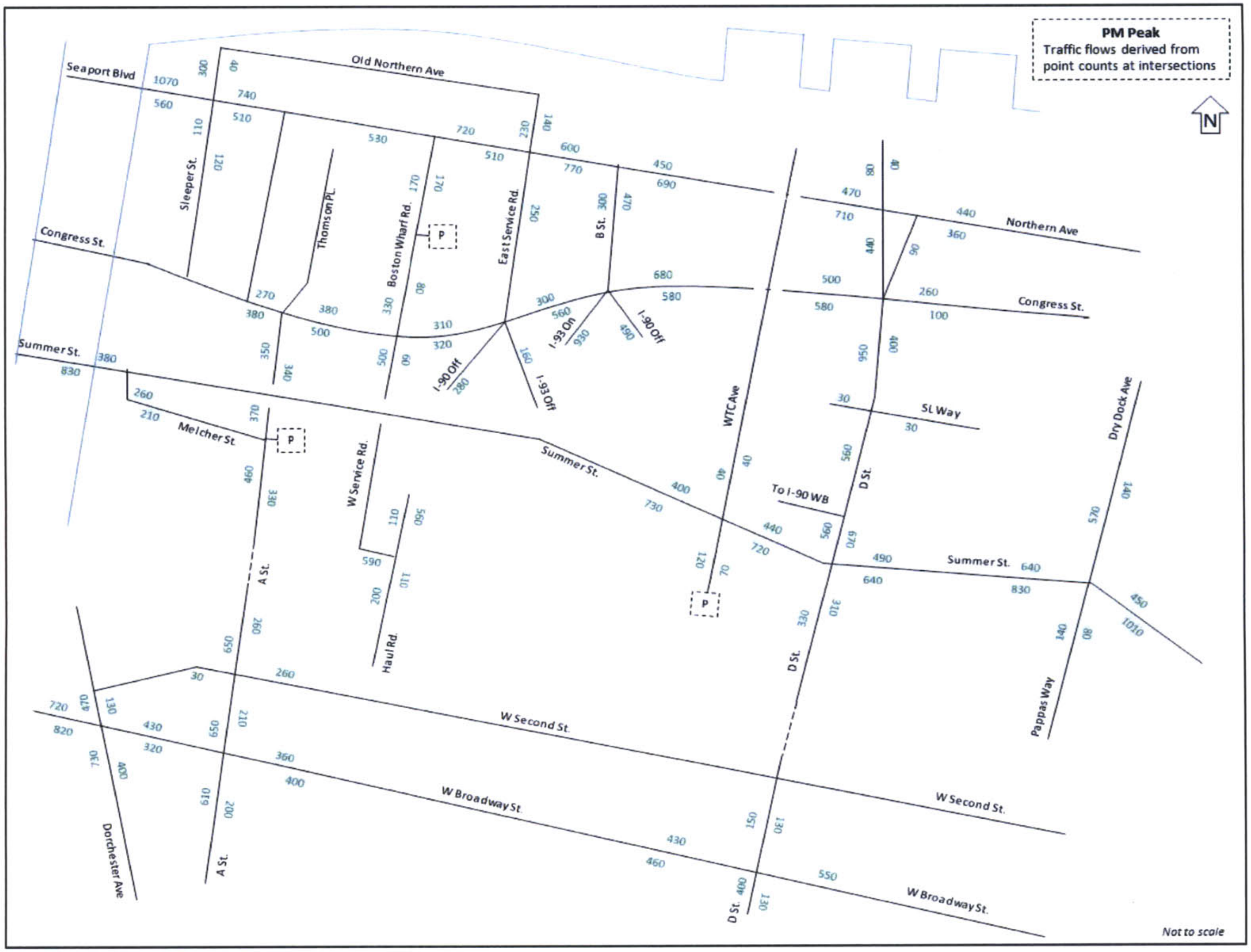


Figure 2-3: Link flows – PM peak hour (2009)

- A scatter plot that describes the relationship between simulated and counted traffic flows. More specifically, counted flows are presented on the "x" axis, while simulated flows are presented on the "y" axis. A good calibration result will show points close to the 45 degree line. In addition, R-square was used to estimate the correlation between simulated and observed data.

The results for the AM and the PM peak hours are as follows:

- AM peak hour. For the AM peak hour 112 segment flows were available. The results reveal a good fit of the calibrated data, with an RMSE of 18.6%. In addition, the scatter plot (Figure 2-4) shows that the simulated flows are close to the observed flows since they both cluster around the 45 degree line (red color in the graph), with an R-square of 0.9492.

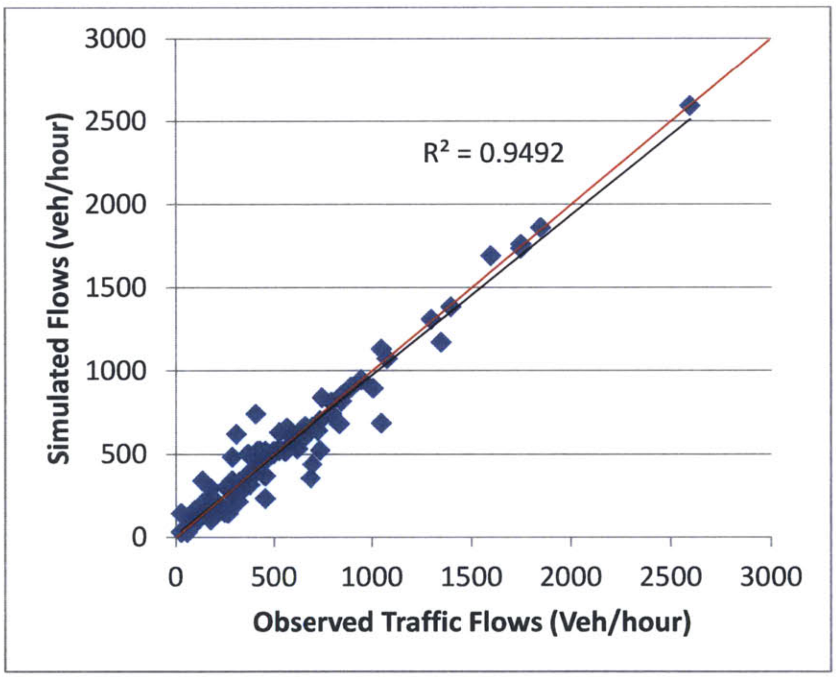


Figure 2-4: Calibration results – AM peak hour

- PM peak hour. For the PM peak hour 114 segment flows were used for the calibration. The results show a good fit between the calibrated and the observed data (better than the AM peak hour) with an RMSE of 14.2%, and the scatter graph (Figure 2-5) also reveals good correlation, with an R-square of 0.9782.

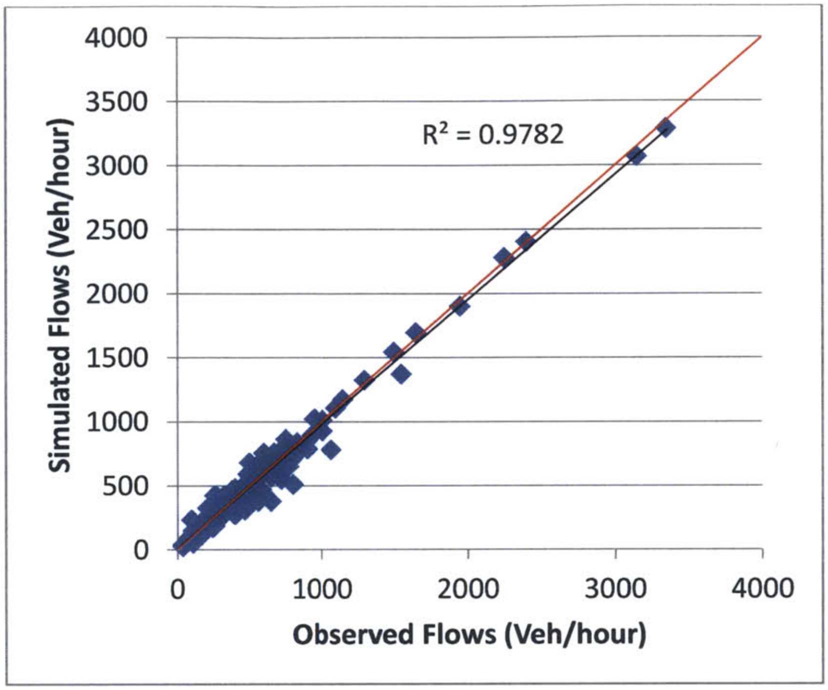


Figure 2-5: Calibration results – PM peak hour

2.2.3 Metrics

This section describes the indicators that reflect the performance of the network. Given the stochastic nature of simulation, results for each indicator are extracted averages of an iterative process. In addition, this section also describes the reason behind choosing the selected indicators, the advantages of the indicators, as well as their limitations. In our analyses, we chose to view the traffic conditions in the District from three perspectives.

- The first provides an overall view of traffic trends and network performance
- The second describes the performance of key intersections in the network
- The third estimates the performance of specific corridors in the District.

Finally, it should be noted that the results for each of the indicators will not only provide information for the assessment of the network in each condition, but will also provide a basis of comparison as we analyze future network conditions.

Overall performance

To capture a broad picture of network conditions in the District, we chose three indicators:

1. Average speed (mph). This is the average speed of all vehicles in the network. This indicator is an intuitive measure that could be compared against general street travel speeds as well as posted speeds in the District. It should be noted that this indicator is calculated based on all trips that originate, terminate and go through the study area, including highway trips.
2. Average delay (minutes per vehicle). This is the estimated average delay recorded in the network. The indicator is estimated for every vehicle that enters the network regardless of destination and route. Therefore, it is important to note that for vehicles which use the urban network the average delay probably underestimates the true delay, since vehicles that go through the highway system are also included in this measure.
3. Total number of trips. This indicator is derived from the input O-D Matrix and shows the total vehicle trips originating from, terminating in, and passing through the District.

We note that the aggregate statistics provide a general overview of the network. For a more in-depth analysis these statistics must be combined with detailed views of intersection and link performance.

Intersection performance

Our analyses focused on 23 key intersections in the District, of which 19 are signalized and 4 were un-signalized. The 19 signalized intersections are those identified in section 2.2.1. The additional intersections include:

- A Street and Melcher Street (20)
- Congress Street and Northern Avenue (21)
- Haul Road and West Service Road (22)
- Summer Street Pump House Road (23)

Figure 2-6 shows the location of these intersections.

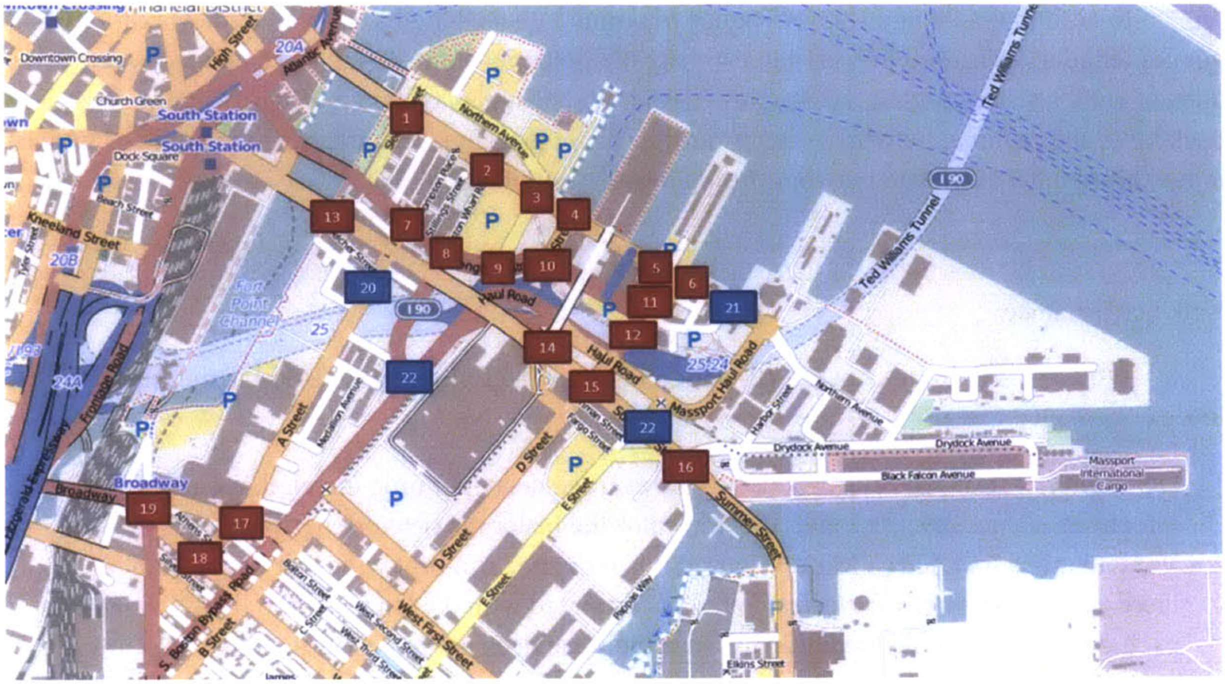


Figure 2-6: Signalized (red boxes) and un-signalized (blue boxes) intersections analyzed

In order to understand the performance of intersections in the network, the following indicators were assessed:

1. Average number of stops per vehicle at the intersection. Ideally, this indicator ought to be less than or equal to 1 which, for the case of signalized intersections means that vehicles were able to go through the intersection within one cycle.
2. Average delay (sec/veh) at the intersection. The lower this indicator, the better the intersection performance. The average corresponds to the entire intersection.
3. Level of Service (LOS) of intersection. This is derived from average delay by following the Highway Capacity Manual's standards as shown in Table 2-6; LOS D or better is considered satisfactory in our analyses.

LOS	Signalized Intersection	Un-signalized Intersection
A	≤ 10 sec	≤ 10 sec
B	10 – 20 sec	10 – 15 sec
C	20 – 35 sec	15 – 25 sec
D	35 – 55 sec	25 – 35 sec
E	55 – 80 sec	35 – 50 sec
F	≥ 80 sec	≥ 50 sec

Table 2-6: Highway Capacity Manual's LOS standards

In addition, I-90 and I-93 off-ramps maximum queue lengths are recorded. Maximum queues lengths (measured in feet) can estimate the potential spillovers that are created when queued vehicles are entering the Seaport District via the highway system. Significant queues can back up to the regional network generating significant problems and affecting the vehicles which move through the Interstate network during the AM and PM peak hours.

Link performance

We analyzed 40 links in the network and chose the following statistics as measures of link performance:

1. Delay (min/mile). This corresponds to the average delay per mile traveled, recorded for both directions. Generally, the lower this indicator the better the network performance.
2. Vehicle miles traveled (VMT). We used this indicator as a proxy for link usage, although there are two important caveats: first, it is correlated with the length of the link. Second, we excluded highway links in our analysis as their use does not represent the District's street conditions.

2.3 PUBLIC TRANSPORT

In this thesis, the approach to public transport analysis was to first examine the current situation, in terms of both the service provided and the demand served. MBTA data was obtained, in particular AVL and APC for October 2013, as well as more standard sources such as the agency's website or Blue Book. This was then analyzed to find ridership figures (boardings, alightings), based by time, stop and route, as well as bus loadings. On the capacity side, the headway, cycle times and hourly capacities were calculated for each route by time period. The capacity and demand values were then compared to see how much of the capacity was being used. To this end, since the highest loadings and ridership occur during the peak hours, this was the timeframe that received most focus.

Once the current assessment has been conducted, future demand was then estimated using ITE, thus resulting in three future analysis periods: short-, medium- and long-term. Within each of these analyses, strategies were then recommended to cope with the growing demand and provide a good level of public transport service. Various strategies and alternatives were examined based on whether they help improve accessibility and mobility to the Seaport District, while at the same time bearing in mind financial and political realities. Hence, at the end of each analysis chapter, recommendations are made to provide a quick template for further action.

3 CURRENT ASSESSMENT

This chapter examines the current transportation situation in the Seaport District, first the public transport available in the area and then the road network. The approach is to look at the what, when and where of travel demand, particularly during the peak. This can then be compared with the capacity currently available to see if there is any congestion.

In the discussion that follows, it can be seen that most public transport trips are handled adequately through the Silver Line; although there is occasional overcrowding during the peak, this is not severe. All other bus routes carry relatively few District passengers, with the private shuttles transporting the most commuters after Silver Line in the District. However, it is clear that in the near future, capacity will be exceeded once major development projects are completed (such as Seaport Square), so potential constraints such as the Silver Line grade-crossing at D Street and limited MBTA vehicle fleet and resources must be addressed.

With respect to the road network, the overall level of service currently provided is generally adequate, with only a few intersections at LOS E and F. Potential hotspots include the intersection of the I-90 on/off ramps at Congress Street as well as the D Street intersection, where backlogs can quickly build up during the peak if traffic volumes increase further. Parking is also examined since it represents a major constraint on road traffic in the area. Currently, there is ample parking to accommodate cars in the District (and hence generate traffic), but future growth in the area could mean loss of these parking lots, requiring higher dependence on public transport use in the area, adding to the future demand increase for public transport.

3.1 PUBLIC TRANSPORT

This section first describes the public transport system in the Seaport District. Following the general description, current demand and capacity of each MBTA bus route and individual private shuttle serving the Seaport District will be analyzed. Both weekday and peak hour conditions are discussed. Note that the weekday peak hour is defined as following, based on when the highest loadings occur:

- AM Peak hour (8:00-9:00)
- PM Peak hour (16:45-17:45)

3.1.1 Route Overview

Silver Line 1, 2 and Shuttle (SL1, SL2 and SLW)

The Silver Line currently serves as the backbone for public transport access to the Seaport District and has the highest ridership. As shown in Figure 3-1, SL1 connects South Station to Logan Airport via the Seaport District while SL2 operates between South Station and the Design Center. SLW mainly operates during peak hours and provides service only between South Station and Silver Line Way. All three lines operate between South Station and the World Trade Center Station in an exclusive 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 the Silver Line Way stop. The Silver Line operates on electrical power from overhead wires within the exclusive tunnel section. The bus then switches to diesel power at Silver Line Way which requires the driver to get off to check, imposing an additional stop for passengers. Then the SL1, SL2 and SLW separate at the Silver Line Way stop: SL1 heads northeast to Logan Airport, SL2 heads southeast to Design Center and SLW turns back toward South Station.

Figure 3-1: The Silver Line system

Surface bus routes

- Route 4 is a commuter route which provides service only on weekdays, connecting the Seaport District with North Station, via the World Trade Center, the Courthouse and South Station. This bus route is designed to serve the Federal Courthouse, Children's Museum, Quincy Market, Blue Line, Red Line, Orange Line, Green Line, Silver Line and commuter rail.
- Route 7 bus connects City Point to the Financial District of Downtown Boston, via Summer Street, providing service on Weekdays and Saturdays.
- Route 11 provides service between the Bayview area of South Boston and Downtown Boston. Outbound trips pass through Innovation/Seaport District via A Street.

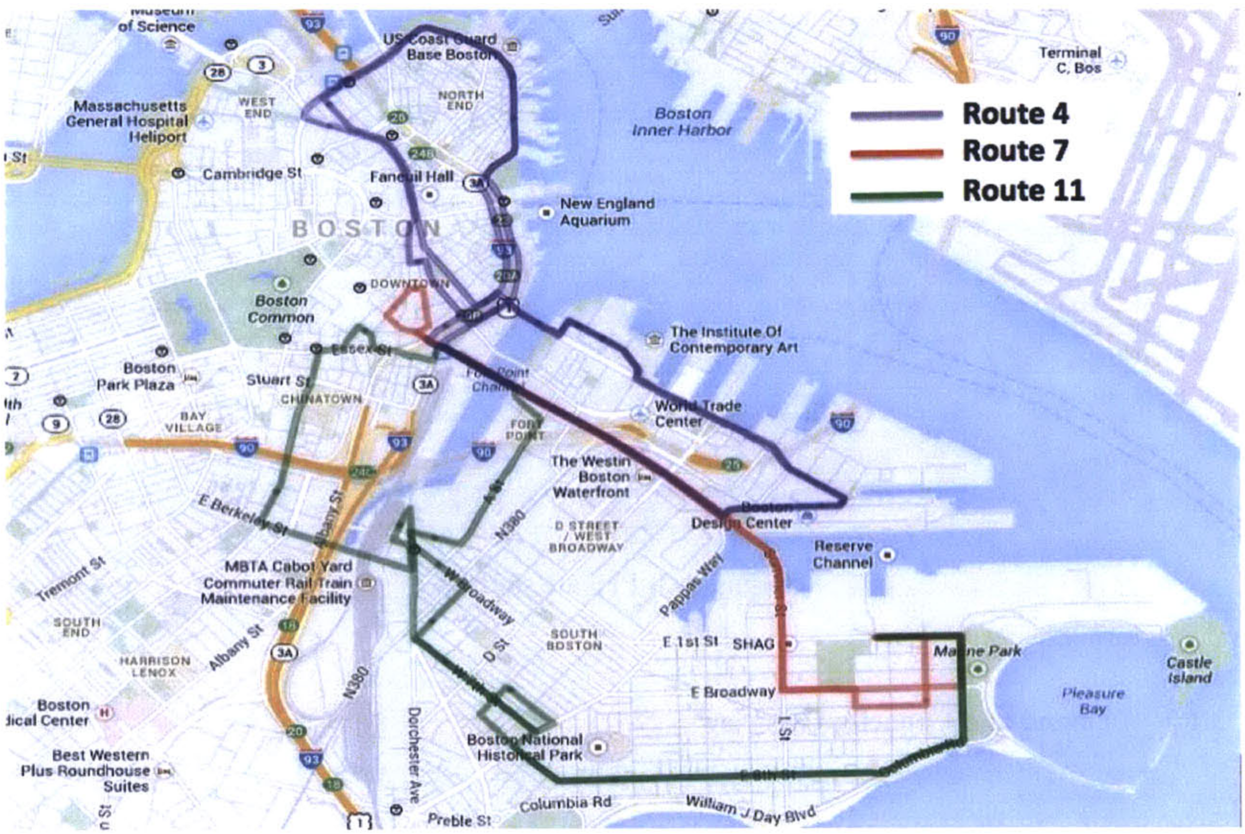


Figure 3-2: Surface bus routes

Private Shuttles

In addition to the Silver Line and public bus routes, more than a dozen privately operated shuttles serve the Seaport District, as illustrated in Figure 3-3. These services are primarily provided by the employers for employees and visitors. The private shuttles complement the existing limited MBTA surface public transport network in the district, providing quick, direct and comfortable connection to rapid transit in downtown Boston.

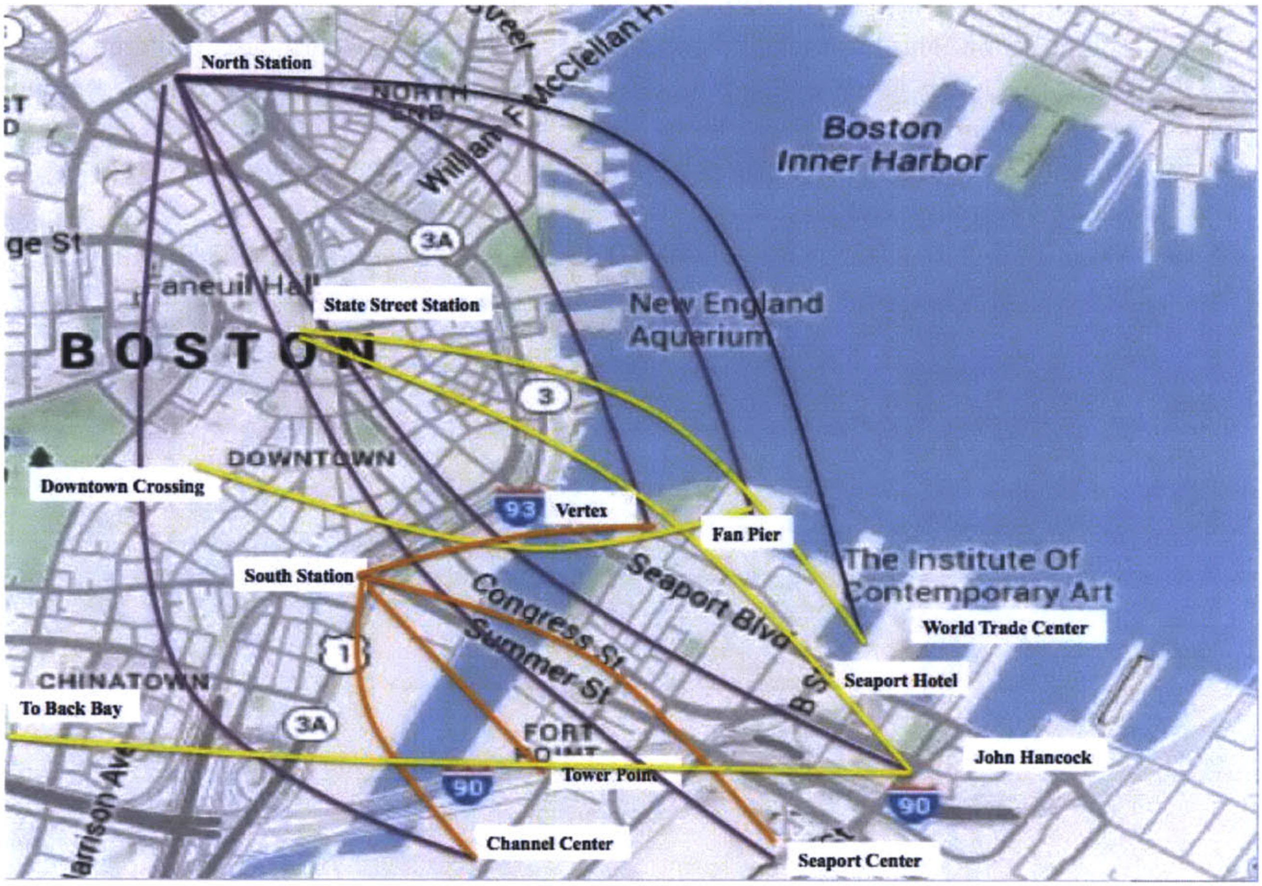


Figure 3-3: Private shuttles

3.1.2 Demand and Capacity Overview

Demand

The total District daily MBTA boardings and alightings, based on APC data, in 2013 were 6,511 and 7,482 passengers respectively while private shuttles are estimated to accommodate 944 passengers into and out of the district, as shown in Figure 3-4. Note that these numbers do not included South Station totals. Figure 3-5 also shows aggregate demand split by time and route; note that there is very limited ridership on the private shuttles from the District during the AM Peak and to the District to the PM.

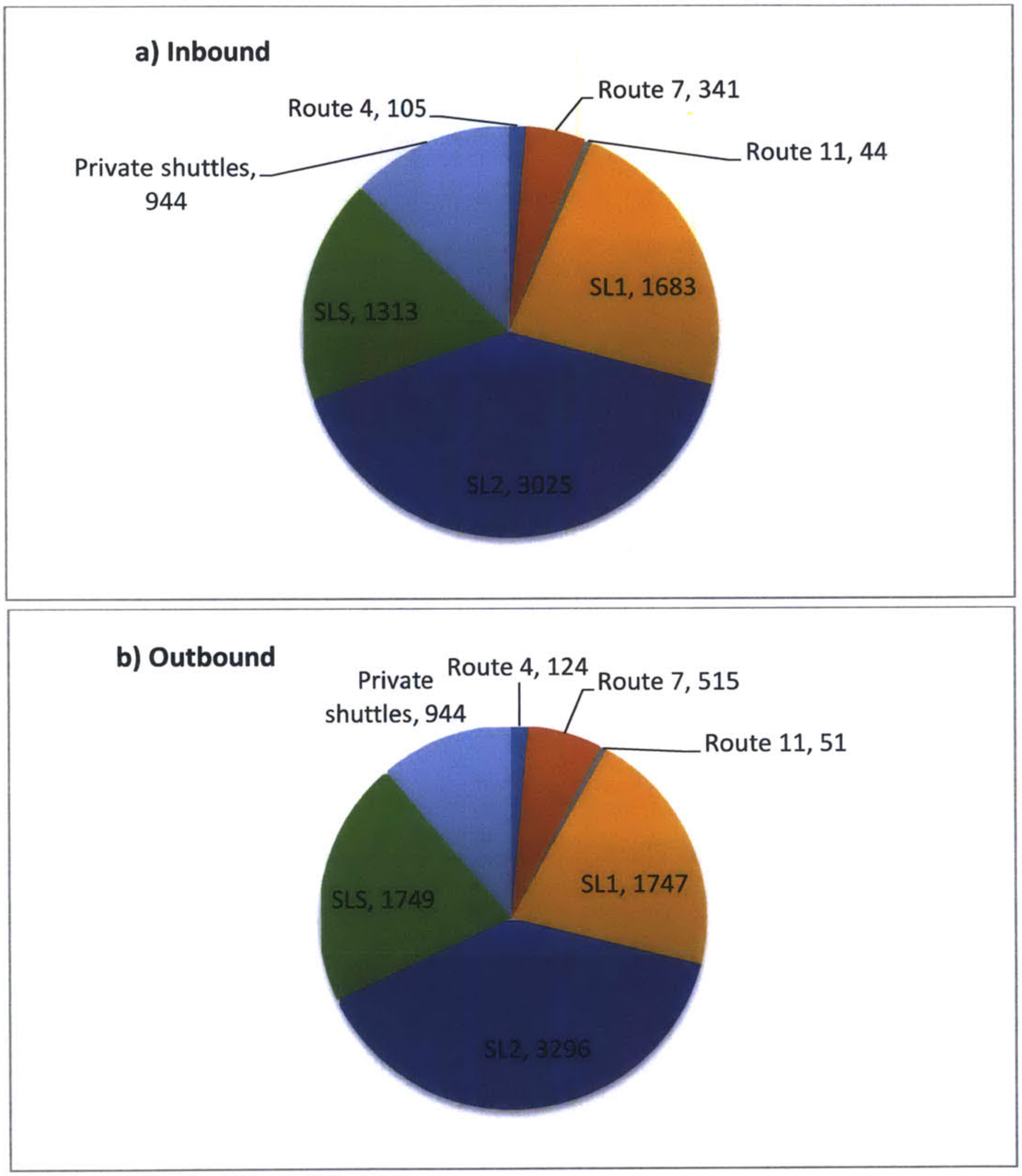


Figure 3-4: Weekday public transport ridership

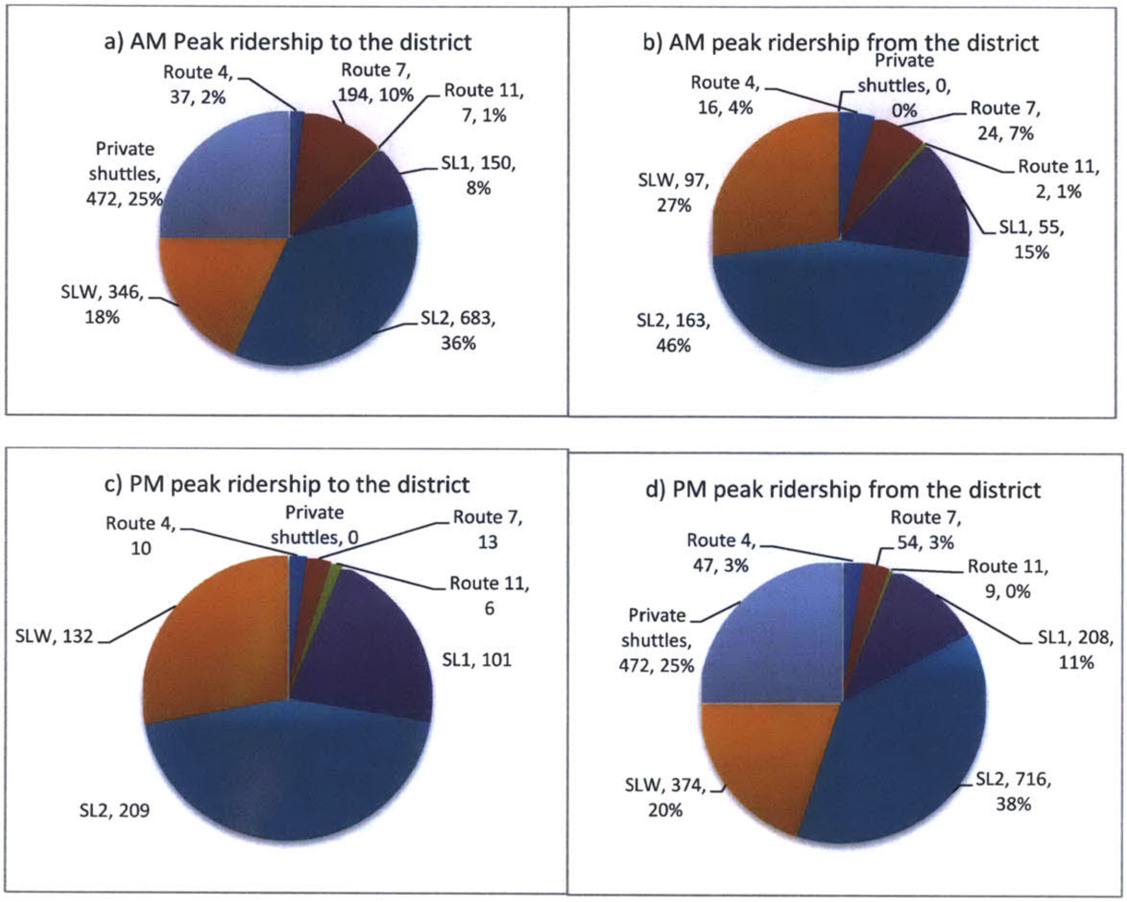


Figure 3-5: Peak hour ridership distribution to and from the District

As can be seen in the pie charts in Figure 3-5, the lion's share of the boardings within the Seaport District belongs to the Silver Line, in particular to Silver Line 2. This is not surprising since the bulk of public transport travel to/from the District occurs during the peak hours, and this demand is largely served by SL2, which is a classic commuter route intended for workers to the District. SL1's ridership is the 2nd highest since it shares all the major stops within the District with SL2, although due to the higher headways during rush hour, the number of passengers using it is lower, hence the lower share. SLW also plays a sizeable role, since it offers good headways (5 minutes) during the rush hour and thus transports a significant number of the work trips. But perhaps the most significant point to note here is that around 80-85% of all public transport trips to/from the District are coming from South Station (some of the passengers go to the Airport), and since South Station is an intermodal hub for many public transport lines, it is likely that many people access the District from routes that feed in to that hub. What this implies, especially for future scenarios, is that changes to anything related to South Station, will certainly have a large impact on public transport use to/from the District.

Figure 3-5 shows the peak hour ridership distribution across public transport services in the District. A sense of the magnitude of Silver Line's ridership relative to other routes can also be gleaned from Figure 3-5. Although the Silver Line's impact is reduced during the peak hour, peak direction, due to the private shuttles, which serve about 25% of ridership, it still provides much more service than any other MBTA bus route: the No. 7 has a small share, despite the fact that it serves a large residential neighborhood in close geographic proximity, because there is a clear disconnect between the residents and the types of jobs available in the District. In fact, the 7 is mostly a 'pass through' route, with very high ridership from South Boston yet low on/off in the District, with most passengers go to downtown instead. Route 4 is somewhat disappointing since it was explicitly designed to allow commuters to travel easily from North Station, yet has low ridership, while the No. 11 passes through a small part of the District in the outbound direction only, so is not much use. A final point to note on the data, for all routes, is that there seems to be a discrepancy between boardings and alightings: this is partly a result of counting errors since no data collection is ever perfect, and also since the District offers a number of entertainment venues (restaurants, shops), it is possible that passengers go to the area by public transport but head back by other means, such as taxi, walking or auto pick-up. Please note that throughout this thesis, "Inbound" and "Outbound" represents the MBTA-defined sense of the word, i.e. to and from downtown Boston respectively.

Capacity

Overall, these routes provide adequate capacity during the off-peak, although there is overcrowding on some routes during the peak. The headways for all routes in the District are shown in Table 3-1:

	Weekday AM Peak	Weekday Off-peak*
South Station (rail)	4.5	7
SL1	10	10
SL2	5	10
SL shuttle	5	N/A
#4	15	N/A
#7	4.5	20

Since weekday PM Peak headways are similar to AM Peak, they are not listed separately.
* Weekday off-peak hour headways at around midday

Table 3-1: Scheduled headways[10]

[10] MBTA Fall 2013 schedules

During rush hour, all local buses and the Silver Line offer fairly frequent service (headways of 15 minutes or less), so waiting time is not a significant problem for customers. Additionally, although there are differences between average scheduled and actual headways, this is not a big issue since the headways are still low. However, the off-peak headways are high (or service is non-existent) on all the buses, aside from the Silver Line. This means that only the northern part of the District can be reasonably accessed by public transport. While this is currently not a serious issue since most of the development is concentrated in the northern areas, it will become a problem as development spreads since there will not be enough public transport capacity, leading to increased car use and associated congestion and pollution.

Table 3-2 shows the maximum load during the peak hour (calculated by taking the sum of the maximum load of each bus during an hour). This is more appropriate for comparisons since capacity is calculated by taking the capacity of each bus, summed over an hour. From this, we can see that the demand is around 1,350 passengers during the peak hour (highlighted in yellow), in the AM Outbound direction. This is below the 1,878 available capacity (see Exhibit 3-1), so currently there is enough capacity. Nevertheless, during sections of the peak hour, crowding does occur, with some passengers unable to board the first bus that arrives. It is likely that peak of the peak hour, the demand may exceed capacity, especially if there are delays on the line. Indeed, the SL1 currently fails the MBTA loading standards during weekday peak hours, so there is certainly a real problem for passengers (see Silver Line analysis section 3.1.3 for details). As for the local buses (Route 4, 7, 11), the capacity is currently adequate, with all the routes complying with the MBTA loading standards, with the exception of the Route7 during the peak, but note that the heavy ridership is not generated by the Seaport District, as will be explained in the analysis.

	Inbound		Outbound	
Routes	**AM Peak**	**PM Peak**	**AM Peak**	**PM Peak**
4	127	22	18	72
7	537	122	167	390
11	407	55	28	172
SL1	200	312	230	239
SL2	79	547	606	192
SLW	68	383	511	146

Table 3-2: Peak hour maximum load for MBTA routes[11]

[11] APC fall 2013 data

Silver Line Current Maximum Service Capacity:

Frequency = 6+12+12 = 30 buses/hour (from the headways of SL1, SL2, SL shuttle)

24*65 (planned capacity per bus) + 6*53 (SL1 buses have less room due to luggage racks) = **1,878** passengers per hour per direction

Exhibit 3-1

3.1.3 Silver Line Analysis

Capacity Analysis

Table 3-3 shows the fleet size and capacity of Silver Line vehicles, according to MBTA bluebook. Based on the schedules on the MBTA website, the daily seated capacity for SL1 and SL2 is around 11,000 on weekdays, as shown in Table 3-4. Therefore, current demand is already beyond the seated capacity of the Silver Line, particularly during the peak hour. From both field counts (taken on Nov. 26 2013 A.M. peak hour), there are sometimes up to 30 passengers who cannot board the first SL bus they were waiting for and have to wait for the next one. MBTA service book (2012 data) shows the SL1 fails to meet the daily load standard, again highlighting the existing capacity concerns during the peak.

Fleet ID	Fleet Size	Seats	Planned Capacity
1125-1124 (SL1, SL2 & SLW)	24	47	65
1125-1132 (SL1)	8	38	53

Table 3-3: Silver Line vehicle fleet

SL1/SL2 Weekday trip number		
Weekdays trips		
	Inbound	Outbound
SL1	108	107
SL2	139	142
SL1 Weekday Capacity		
Seated Capacity	4,104	4,066
Planned Capacity	5,724	5,671
SL2 Weekday Capacity		
Seated Capacity	6,533	6,674
Planned Capacity	9,035	9,230

Table 3-4: Silver Line's weekday capacity

Headway Analysis

An important part of capacity analysis is examining the headway, which dictates how many passengers can be handled on a given route. Furthermore, the mean and variability of the headway are crucial factors in determining whether many travelers will choose to take public transport or not. The level of service provided is shown through Table 3-5:

	Weekday AM Peak	Weekday Off-peak*
SL1	10	10
SL2	5	10
SL shuttle	5	N/A
Combined Average	2	5

* Weekday Off-peak headways at around midday

Table 3-5: Silver Line headways[12]

The Silver Line can be characterized as a high-frequency service, allowing passengers to simply 'walk-up' without consulting schedules for the whole day since headways are 10-15 minutes or less; this is an excellent way to encourage public transport use to the District. However, the performance of the route is another matter altogether because the reliability is

[12] MBTA fall 2013 schedules

poor. The metric used to measure this is to look at the standard deviation of the headways, rather than on-time performance because of the Silver Line's designation as a walk-up service: most passengers do not consult schedules when using the Silver Line, so even if a bus is late, but the headways are maintained to a high standard, then travelers are not affected significantly. With this in mind, the Silver Line's reliability leaves something to be desired, due to the high standard deviation[13] – many buses arrived after short or long headways compared with the scheduled headway, which can cause frustration for customers waiting at the stops. For example, the standard deviation is 40-60% of scheduled headways on SL1 and SL2, which is very high.

Nevertheless, the overall service level for the District during the peak is good, with a combined average headway of 2 minutes provided, reducing waiting time for passengers, so that even if the standard deviation seems high when expressed as a percentage, the actual time delay itself is only a few minutes. Note though that this is an average headway, and the actual schedule currently has a longer gap of 4 minutes between some buses, as will shortly be explained.

Schedule Analysis

Table 3-6 and Table 3-7 show the timetables at each stop in Silver Line's trunk section. Overall, it can be seen that the service provided is very good, with scheduled headways ranging from 1 to 4 minutes in the peak (outbound) direction (the recurring headway pattern is: 2-2-1-4-1; which can be seen starting with the 7:58 am outbound bus), however, there might be concerns in the future of heavy passenger loading on the bus following the 4 minute gap, so more even headways should be sought.

A key point shown in Table 3-7 is that SL1 has very long layovers at South Station. This is because of the complex nature of this route and because it does not have a layover at the airport end of the line. Thus, the recovery time as a percentage of total running time is 32%. This is on the high side, since the actual 95th percentile travel time is 45 minutes, as shown in Table 3-8, so there is the potential that the scheduled cycle time could be reduced from its current 50 minutes. SL2's recovery time is similar, at 30%, but is appropriate due to its short length; this is confirmed by the 95th percentile travel time data. Note that in the outbound direction only, SL2 has to loop around the Design Center, which is why the travel time is higher. As for the Shuttle, its recovery time is 54% of the running time, which is very high, and this is confirmed by the large gap between cycle and 95th percentile times (20 vs. 13 minutes, respectively), so improvements can be made in this regard. Another key issue in improving efficiency is the D Street intersection, which can easily add 1-3 minutes to any journey. In fact, grade-separation addresses two issues at once, allowing increased capacities during peak hours (by allowing shorter headways) and reducing travel times for passengers.

[13] For more details on SL1 and SL2 headways analysis, see Appendix A4.

Silver Line Currently Scheduled Services						
Inbound				**Outbound**		
Silver Line	SL Way	South Station		Line	South Station	SL Way
Shuttle	7:52	7:58		Silver Line	7:50	7:57
1	7:52	7:58		Shuttle	7:52	7:59
2	7:55	8:01		2	7:53	8:00
Shuttle	7:57	8:03		Shuttle	7:57	8:04
2	8:00	8:06		2	7:58	8:05
Shuttle	8:02	8:08		1	8:00	8:57
1	8:02	8:08		Shuttle	8:02	8:09
2	8:05	8:11		2	8:03	8:10
Shuttle	8:07	8:13		Shuttle	8:07	8:14
2	8:10	8:16		2	8:08	8:15
Shuttle	8:12	8:18		1	8:10	8:17
1	8:12	8:18		Shuttle	8:12	8:19
2	8:15	8:21		2	8:13	8:20
Shuttle	8:17	8:23		Shuttle	8:17	8:24

Table 3-6: Silver Line AM peak schedule[14]

Peak Hour Only Silver Line Trunk Section (Silver Line Way to South Station)			
	Inbound Travel Time	South Station Layover	Outbound Travel Time
SL1	6	12	7
SL2	6	2	7
SLW	6	4	7
All values in minutes			

Table 3-7: Trunk section scheduled travel and layover times[15]

[14] Fall 2013 schedule

[15] Fall 2013 schedule and AVL data

SL1	Duration	SL2	Duration
Cycle time (percentile)	50 (99.2%)	Cycle time (percentile)	30 (95.8%)
Actual 95th percentile travel time	45	**Actual 95th percentile travel time**	30
SLW			
Cycle time (percentile)	20 (99.9%)		
Actual 95th percentile travel time	13		

Table 3-8: Scheduled vs. actual cycle times[16]

A more detailed look at travel times across all Silver Line routes is presented in Table 3-9. The values were obtained by collecting travel time data during the worst 1-hour period during the AM Peak, to provide a reliable basis for bus scheduling. Comparing the median actual total travel times with the scheduled times, the values match exactly for SL1 and SL2, however SLW travel time is lower in practice (13 vs. 10 minutes). Similarly, median travel times in each direction are about the same, although the actual travel times are lower for SLW in both directions than the scheduled. As mentioned earlier, SL2 is operating at maximum efficiency with respect to the scheduling, while SL1 can be improved somewhat and SLW considerably. Thus, this reduction in cycle time should come from the layover time for SL1, which is currently too long, while for SLW, both the travel and layover times should be reduced.

-A-

SL1	Duration	SL2	Duration	SLW	Duration
Inbound (Ter. A to South Station)	23	Inbound (Dry Dock/DC to South Station)	9	Inbound (Silver Line Way to South Station)	6
South Station Layover	12	South Station Layover	2	South Station Layover	4
Outbound (South Station to Ter. A)	15	Outbound (South Station to Dry Dock/DC)	14	Outbound (South Station to Silver Line Way)	7
Ter. A Layover	0	DC Layover	5	Silver Line Way Layover	3
Cycle time	50	Cycle time	30	Cycle time	20

[16] MBTA and AVL fall 2013 data

-B-

AM Peak			
	95th percentile	Median	Average
	SL1		
Inbound	29.2	23.9	23.9
Outbound	16.2	14.2	14.7
	45.4	38.1	38.6
	SL2		
Inbound	10.4	8.2	8.5
Outbound	20.0	14.4	14.9
	30.4	22.6	23.4
	SLW		
Inbound	6.0	4.8	5.0
Outbound	6.8	5.5	5.7
	12.8	10.3	10.7

Table 3-9: Scheduled travel/layover times (A) and actual travel times (B) for the Silver Line

The average speed of Silver Line vehicles along the routes over time periods is shown in Table 3-10. The 2013 MEng thesis[17] suggests that the speed of SL1 in the Transit Way is consistent across time periods due to its exclusive right-of-way. In contrast, the speed between World Trade Center and Silver Line Way is much lower for the simple and obvious reason of the D Street intersection and the technological transition. The former demonstrates very clearly the need for better signal priority and (eventually) full grade separation at D Street, while the latter is particularly inefficient since the buses stop immediately before the Silver Line Way station (when heading eastbound) to change from electric power to diesel and then stop again to let passengers off; it would save time if these two actions were combined. Note that between Silver Line Way and South Station, the speed for SL2 is similar since it follows the same route.

Route Segment	AM peak hour	PM peak hour	Daytime	Late Night
South Station to Courthouse	19	19	19	19
Courthouse to World Trade Center	25	25	25	22
World Trade Center to Silver Line Way	8	7	8	8

Table 3-10: Average speed of SL1 within the District

[17] Cao, O'Connor, and Were "Improving Public Transportation to Boston Logan International Airport" MIT MEng Transportation thesis (2013).

Demand Analysis

The bar chart in Figure 3-6 shows the ridership on SL1, SL2 and SLW in 2012. SL1 accommodates highest ridership, including both to airport and district demand. SL2 ranks second and SLW has approximately half the SL2 ridership. More detailed distribution of total weekday ridership across SL1, SL2 and SLW is shown in Figure 3-7. The symmetric characteristic of the total ridership of inbound and outbound directions is noted. The greatest ridership occurs in the trunk, South Station to Silver Line Way, with more than 7,000 riders in each direction. Logan Airport has around 3,000 daily riders and the Design Center loop has relatively low ridership, around 1,000 for both directions for a typical weekday.

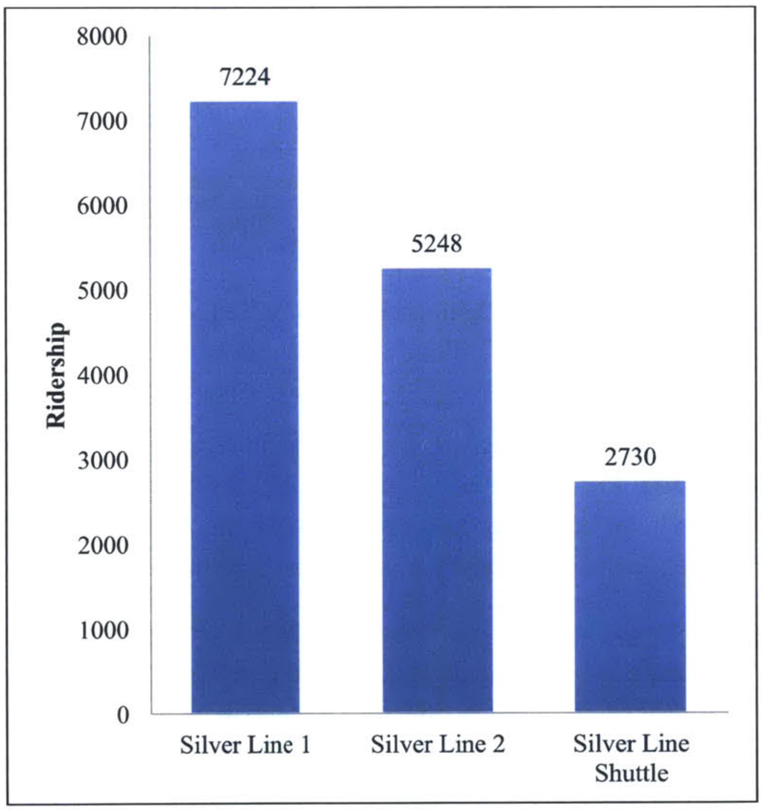


Figure 3-6: Silver Line ridership in Seaport District per route (for the year 2012)

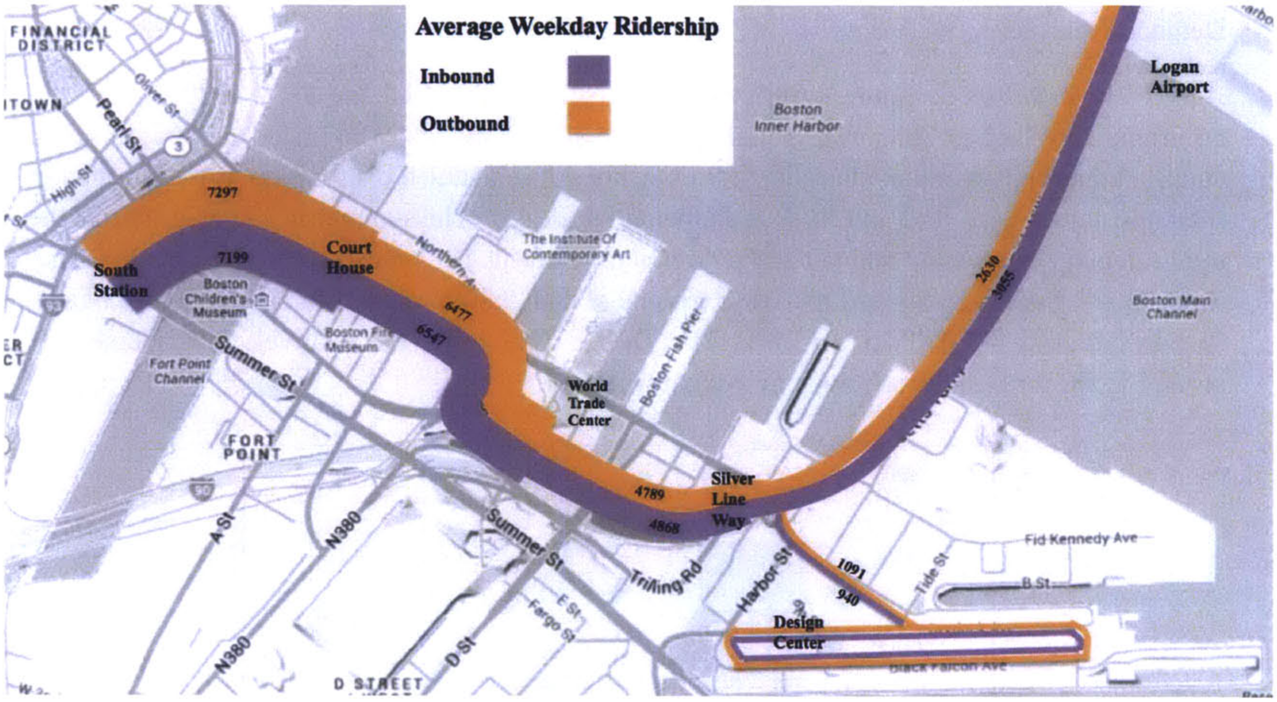


Figure 3-7: Silver Line ridership in Seaport District

Since we are only considering the accessibility of the Seaport District, only the passengers travelling to/from the district are of interest, and not the public transport demand to Logan. Thus, for SL1, only the boardings at the stops within the Seaport District, which includes Courthouse, World Trade Center and Silver Line Way, will be considered.

Yet, as Figure 3-8 suggests, SL1 is more designed for air passengers than for those whose destination is WTC (around 33% of ons/offs occur at the airport, 21% in the District, with the remainder at South Station). More detailed ridership data show that for SL1, a sizeable proportion of passengers travel directly from South Station to the Airport (outbound) and vice-versa, while for the District itself, the WTC station seems to be the most popular because of its easy access to major destinations like the World Trade Center and Convention Center. These passengers will make the crowded SL1 even more crowded and also make their own trips less satisfactory due to the already tight space being taken up by passengers with luggage. However, currently there is no effective separation between SL1 (Airport) and SL2 (Design Center) passengers and people whose destination is within the District who will get on whichever bus comes first. Nevertheless, it is possible that more effective bus dispatching at South Station and Silver Line Way could enable the routes to be more separated and reduce the incidence of bunching.

Turning to SL2, unsurprisingly, the busiest stop is also WTC, for the reasons mentioned above. Courthouse and Silver Line Way stops receive generally higher ridership than SL1 too because SL2 operates at half the headway of SL1 during the peak, so capturing more commuters who often represent the largest share of ridership group in the day. For the stops around the Design Center, the ridership is fairly evenly distributed. Indeed, Figure 3-8 and Figure 3-9 demonstrate a pertinent fact about public transport in the District in general: the area is still closely linked to South Station, with little intra-district travel, as evidenced by the big difference between passengers getting on and off at each stop (e.g. in the inbound direction, most people are boarding, with very few alightings). That is, the link to South Station through the Silver Line is critical for transporting workers to jobs, ensuring the viability of the District. But at the same time, the overwhelming reliance on the SL for this task could be a concern if something happened that affected the operations of the route, for example an accident in the bus tunnel or a security threat, which would essentially deprive the District of high capacity public transport service. Therefore, new routes that are created to accommodate future demand should also consider this factor and provide added redundancy for transport links to the area; this will be explored in detail in a later chapters.

Finally, as illustrated in Figure 3-10 the SLW reflects the SL2 in terms of relative passenger activity – most at WTC, then at Silver Line Way, with Courthouse lagging. The reasons for this are as discussed earlier. Note that in absolute terms, the SLW has lower ons/offs than the SL2 because it only operates during the peak.

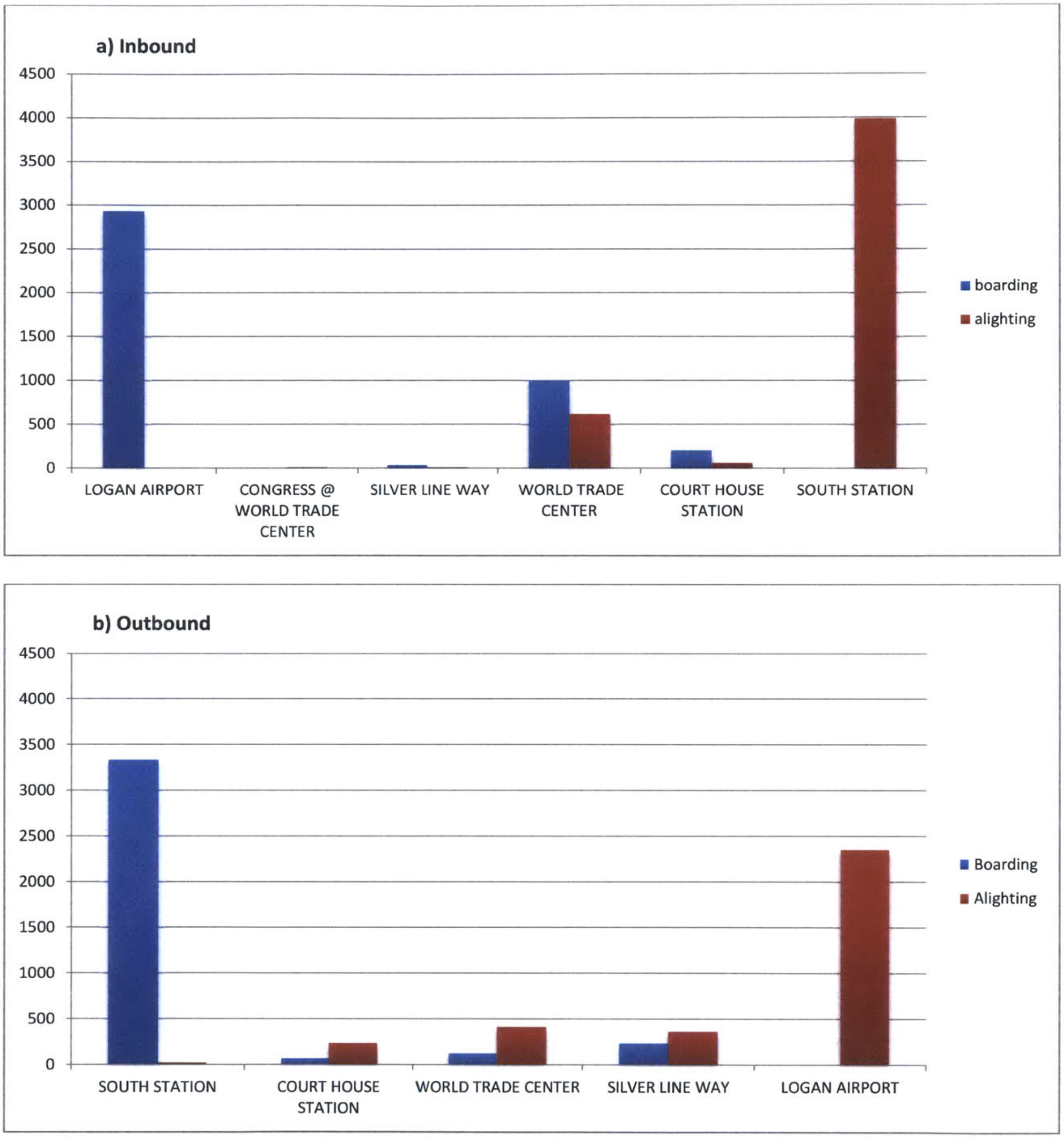
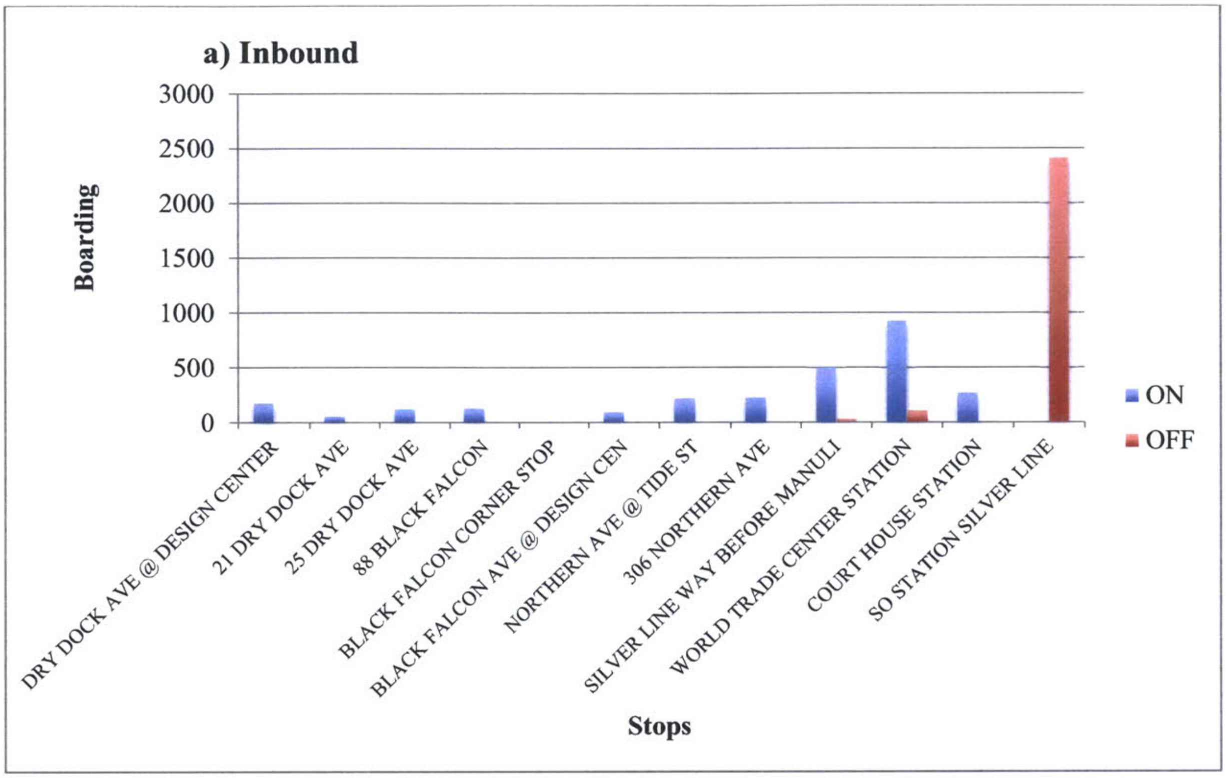


Figure 3-8: Silver Line 1 boardings and alightings per stop



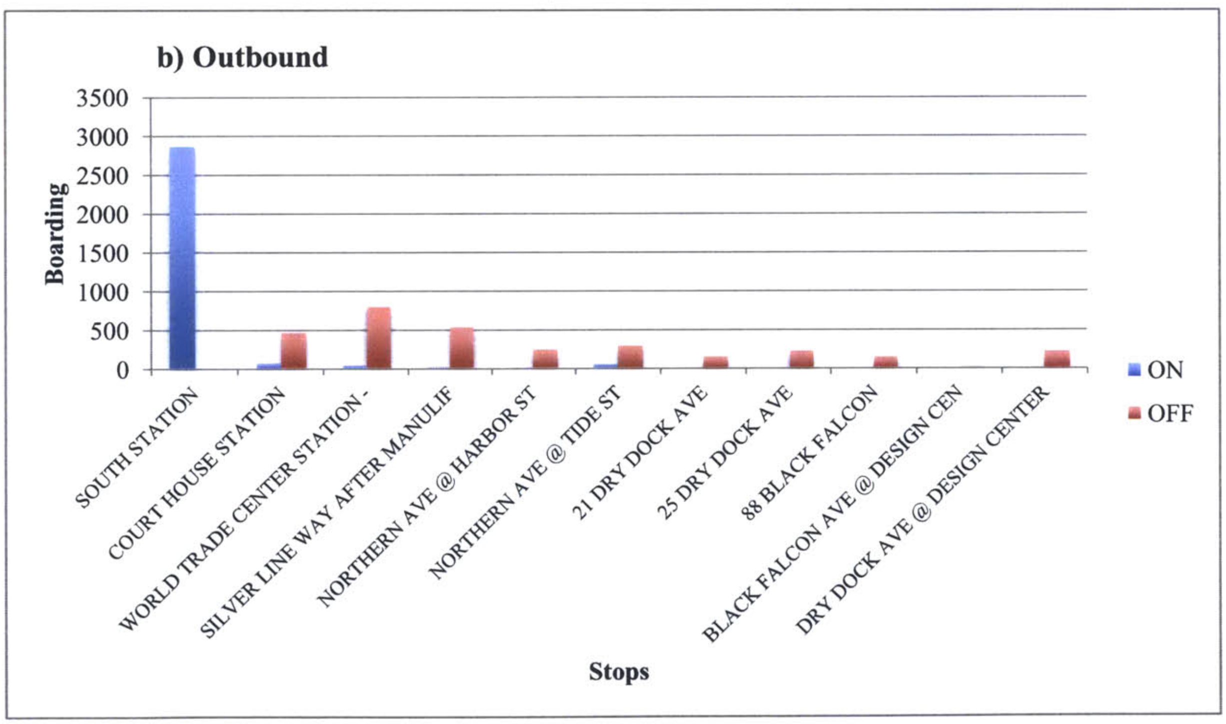
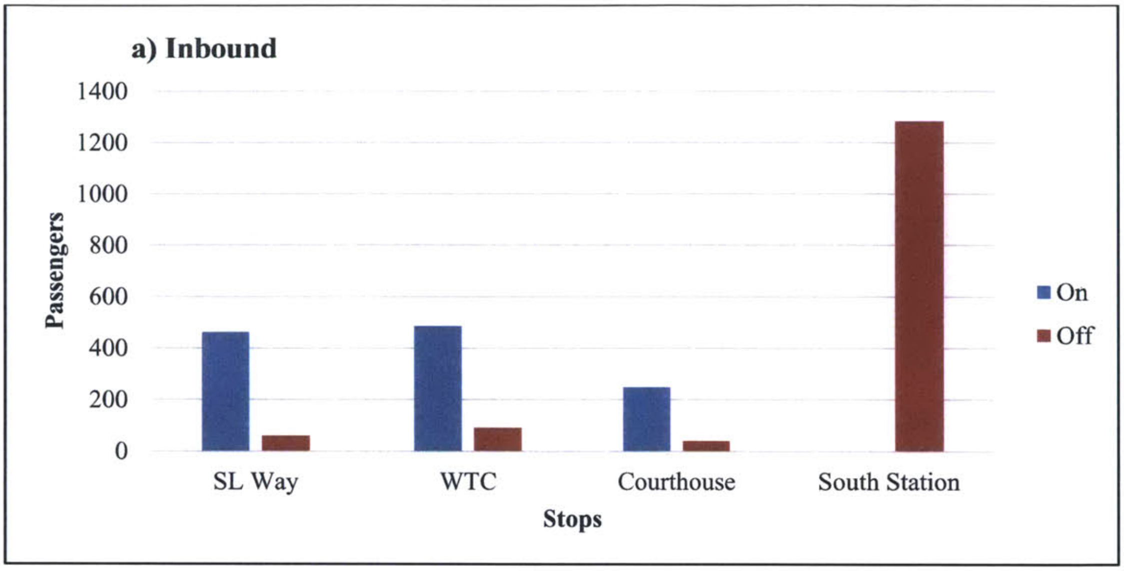


Figure 3-9: Silver Line 2 boardings and alightings per stop



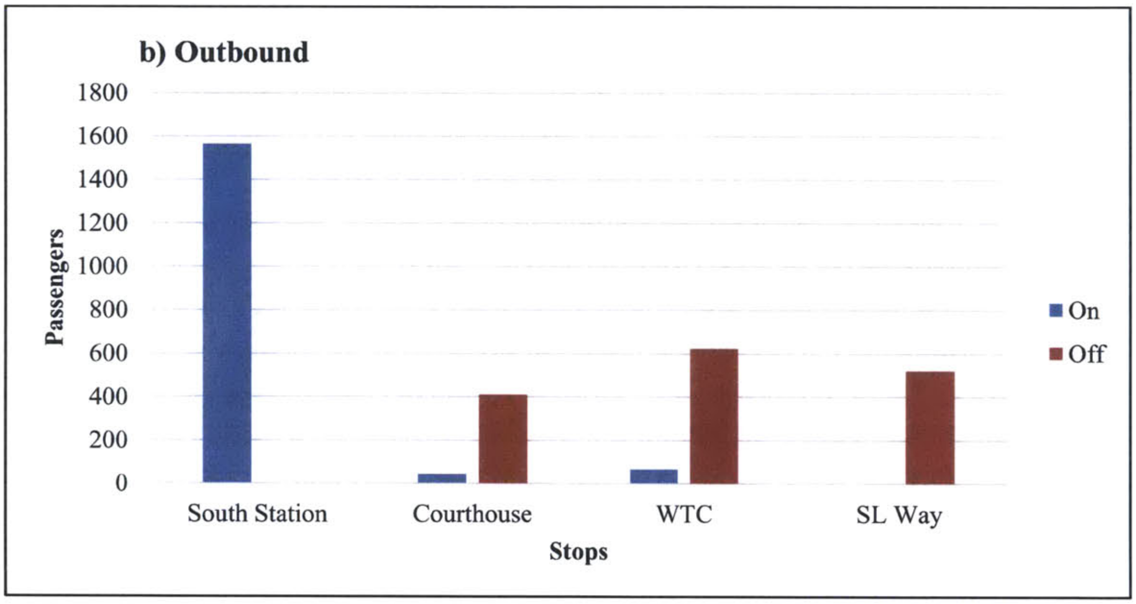


Figure 3-10: Silver Line Shuttle boardings and alightings per stop

Figure 3-11 illustrates the hourly average maximum load of each SL1 vehicle within the Seaport District. The maximum hourly average load of inbound vehicles is around 52 and 46 for inbound/outbound SL1 trips, respectively. Considering the fact that the planned capacity of Silver Line vehicles is 65, the current average load is still below but is likely to reach this number in the near future. However, according to the APC data (not shown on the charts), the maximum load for inbound trips on a single bus occurs at 15:15, with 74 passengers, which is beyond the planned capacity. The maximum load for outbound trips occurs at 19:40, with 54 passengers. Note also that the load is fairly evenly distributed throughout the day, thanks to the airport destination which means that there are always some passengers traveling. Generally, the loads are higher in the inbound direction due to the free-fare policy at the airport.

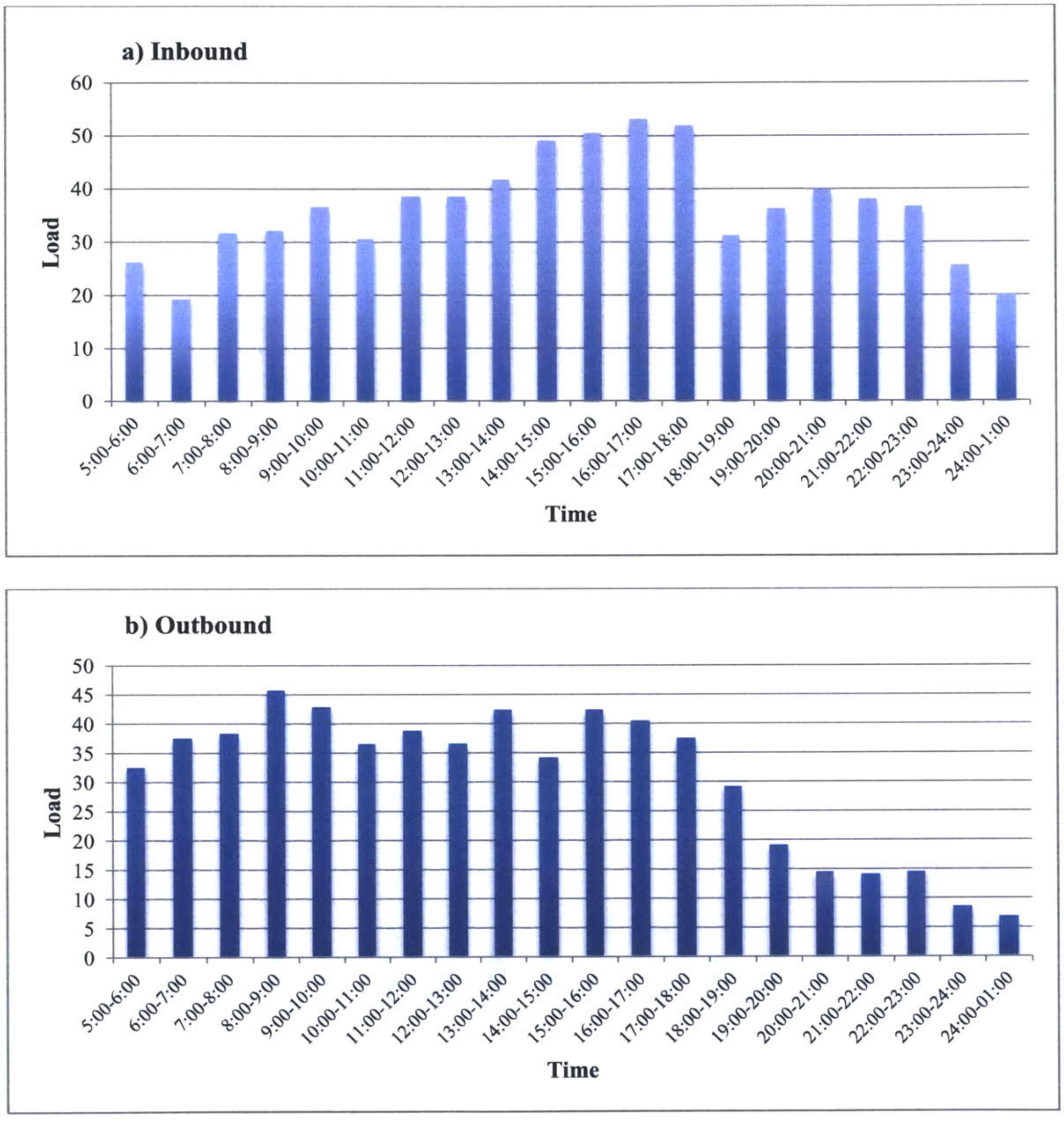


Figure 3-11: Silver Line 1 average maximum vehicle load per hour

For SL2, the average maximum load for weekday trips by time period is shown in Figure 3-12. The average maximum loads occur during the 17:00-18:00 peak inbound with 46 passengers and 06:00-07:00 outbound, with 51 passengers. Though the average maximum loads by hour is still under the planned capacity, the maximum load of the day is already beyond capacity, with 76 passengers crammed in the inbound vehicle which departs Design Center at 17:02. The outbound trip maximum load is 62 passengers, which is also almost at capacity of SL2. Notice that SL2 demonstrates the loading pattern of a commuter route, with much higher loadings in the peak directions.

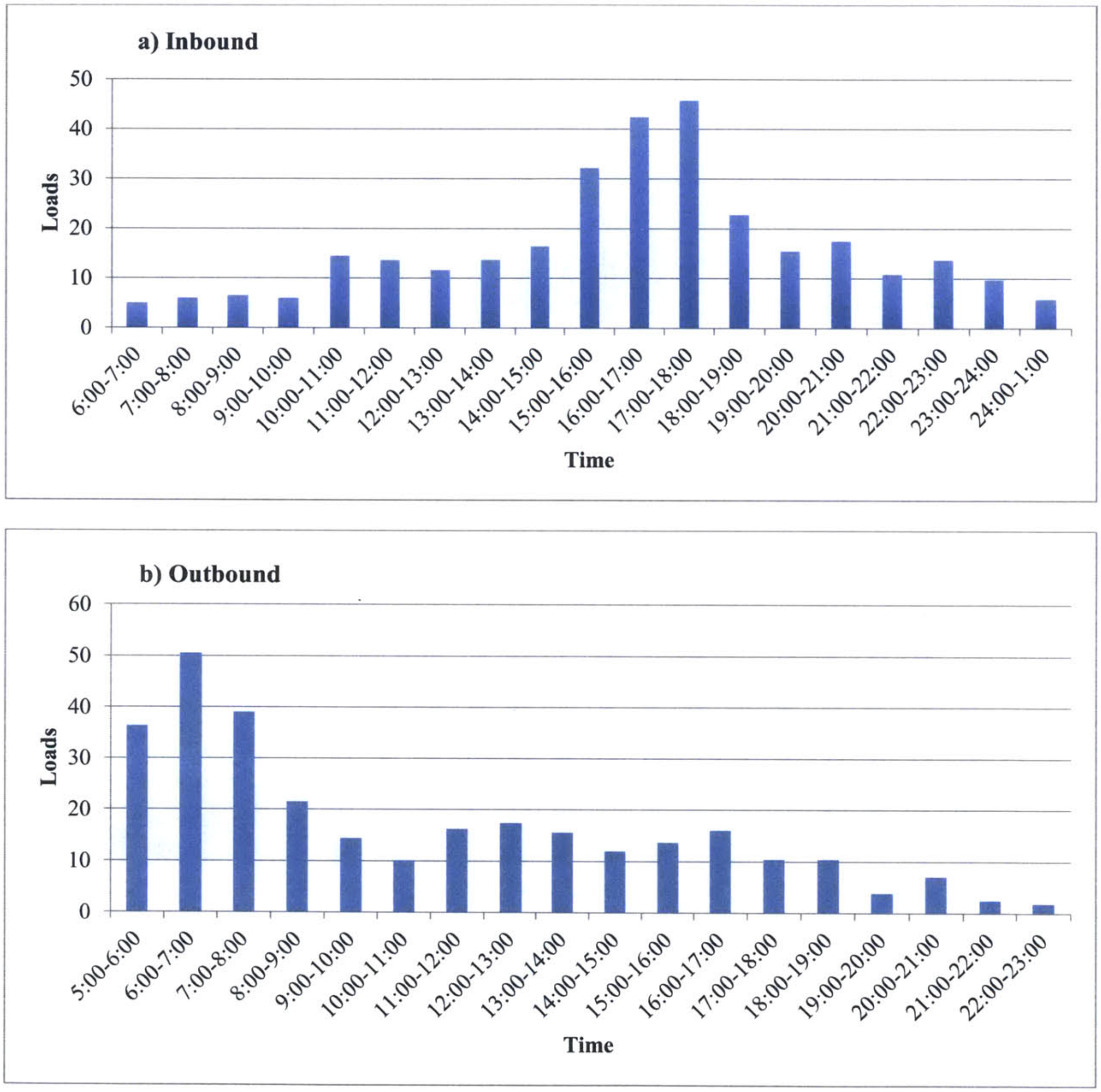


Figure 3-12: Silver Line 2 average maximum vehicle load per hour

SLW offers similar loading patterns to SL2, albeit at a lower level, as illustrated in Figure 3-13. This is because the shuttle only serves 3 stops in the District, so has less demand than SL2 which also connects with workplaces around the Design Center. There is ample capacity left on the shuttle, with the maximum average load occurring in the outbound AM peak, at only 43 passengers, considerably less than the planned capacity of 65.

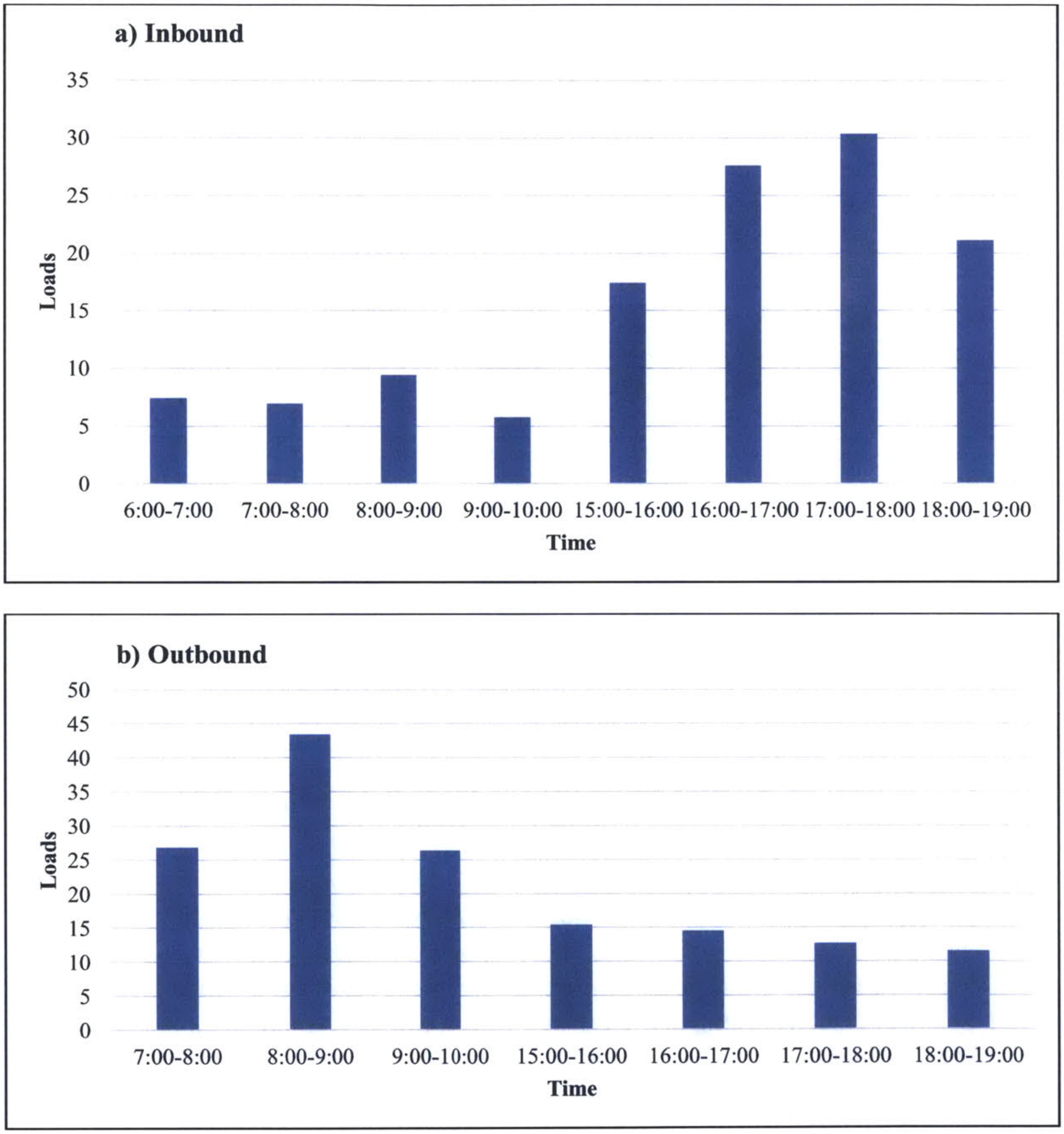


Figure 3-13: SLW average maximum vehicle loads

From Figure 3-11 and Figure 3-12, the trend and pattern are clear. SL1 loads are consistently high across the day compared with the standard peaking pattern on the SL2. It is mostly because passengers from South Station to Logan Airport are well distributed throughout the day. Whereas, people who take SL2 are largely comprised of employees who go to work in the AM peak and return home in the PM peak.

From the discussion above, the capacity of the Silver Line is a major concern for the future development of the Seaport District. The ridership on SL1 and SL2 has been continuously growing during the past five years, up to by about 10%, as shown in Figure 3-14, and has a total average weekday ridership of 16,000.

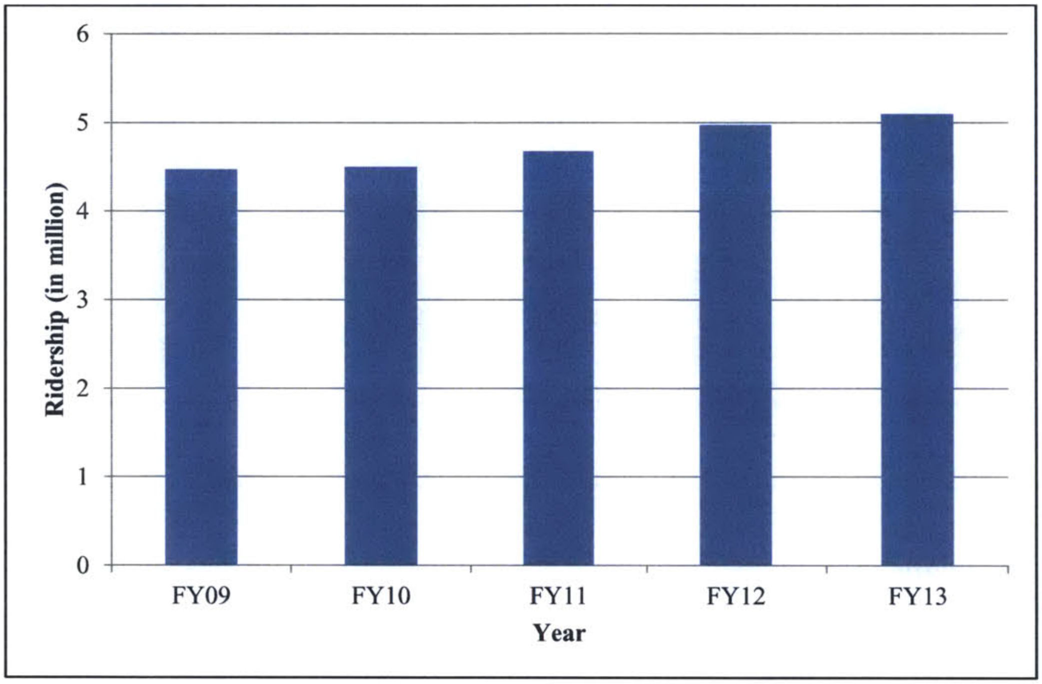


Figure 3-14: Silver Line total annual ridership

During parts of the peak hour, it is evident that the demand is over capacity, with the load higher than planned capacity on some buses. In fact, empirical evidence suggests that the South Station stop is already experiencing many passengers unable to board due to limited space and seats of the Silver Line fleet during the rush hour. Thus, it will be very likely that future demand will not be accommodated by the capacity of the current Silver Line fleet of 32 buses. Furthermore, additional buses of the type currently used are no longer available due to the failure of the manufacturer (Neoplan), which is particularly problematic since the fleet needs a mid-life overhaul, as well as future expansion. All of these issues will greatly restrict the Silver Line's capacity, so it is imperative that new, innovative solutions be examined. It is crucial for the

District since the Silver Line, which is the most significant public transport access to the area, is already nearing capacity and thus improvements are urgently needed.

Peak Hour Silver Line District Analysis

Table 3-11shows the maximum ridership[18] of each route during the rush hour. Aside from the expected direction of the peak flows, it is interesting to see that the PM peak ridership occurs relatively early (except for SL2 outbound), i.e. not the usual 5-6 pm, which suggests that most workers leave their offices fairly promptly. SL1 PM outbound has surprisingly high ridership, almost as much as in the morning, most likely due to people traveling to Logan. Whereas SL2 PM outbound has considerably less, as is expected, but at a much later time, possibly catering to a combination of people who live in the District returning home (with some time taken to get from their workplace to the Silver Line) and those coming to dining/entertainment venues in the area after work. As for the SL Shuttle, the ridership figures are similar to SL2 because it shares the three main stops as well as offers the same 5 minute headway.

SL1 (inbound)			SL1 (outbound)		
AM Peak	8:15-9:15	419	AM Peak	8:15-9:15	305
PM Peak	16:45-17:45	622	PM Peak	16:45-17:45	266
SL2 (inbound)			SL2 (outbound)		
AM Peak	7:45-8:45	101	AM Peak	8:00-9:00	674
PM Peak	16:45-17:45	597	PM Peak	17:45-18:45	246
SLW (inbound)			SLW (outbound)		
AM Peak	8:00-9:00	117	AM Peak	8:15-9:15	576
PM Peak	16:30-17:30	591	PM Peak	16:30-17:30	253

Table 3-11: Peak hour ridership across routes

Overall, we can see that the peak times occur in the PM inbound and AM outbound directions, at around 1,800 passengers per hour, as shown in Table 3-11. The headways of Silver Lines during peak hour (AM and PM) are listed in Table 3-12. Assuming the planned capacity of each SL2 and SL2 vehicle is 65 while SL1 vehicle is 53 because of the seats taken up by luggage, the total capacity of the current Silver Line network is 1878 during peak hours, if no more new alternative vehicles added in the existing 32 articulated buses.

[18] Calculated by summing the total 'ons' along the whole route.

AM Outbound	Silver Line 1	Silver Line 2	Silver Line Shuttle
Headway	10 min	5 min	5 min
Capacity	318	780	780
Ridership	316	625	535

Table 3-12: Peak hour capacity of Silver Lines

1) AM Peak

Ridership distribution across SL1, SL2 and SLW is shown in Figure 3-15. In the AM peak, outbound is the peak direction, with much higher ridership especially in main trunk. No big difference of ridership on trips to/from Logan airport is observed and ridership on this segment of SL1 is quite low, compared with main trunk. Design Center demand is relatively low, with only 300 riders on outbound trips in AM peak hour.

Figure 3-16 summarizes the inferred origin-destination matrix across SL1, SL2 and SLW. The red bar represents demand to/from Logan Airport on SL1, green bar to/from Design Center on SL2 and blue between South Station and Silver Line Way.

Figure 3-17 shows the ridership share on SL1, SL2 and SLW. For AM peak hour peak direction, outbound trips, SL2 has the lion share of ridership, 42% of total outbound ridership on Silver Line. SLW ranks second, with 36% share. SL1 accommodates the remaining 22%.

The share of different origin-destination passengers on Silver Line outbound trips during AM peak is shown in Figure 3-18. 68% of them go from South Station to Silver Line Way, 20% to Design Center and another 12% to Logan Airport.

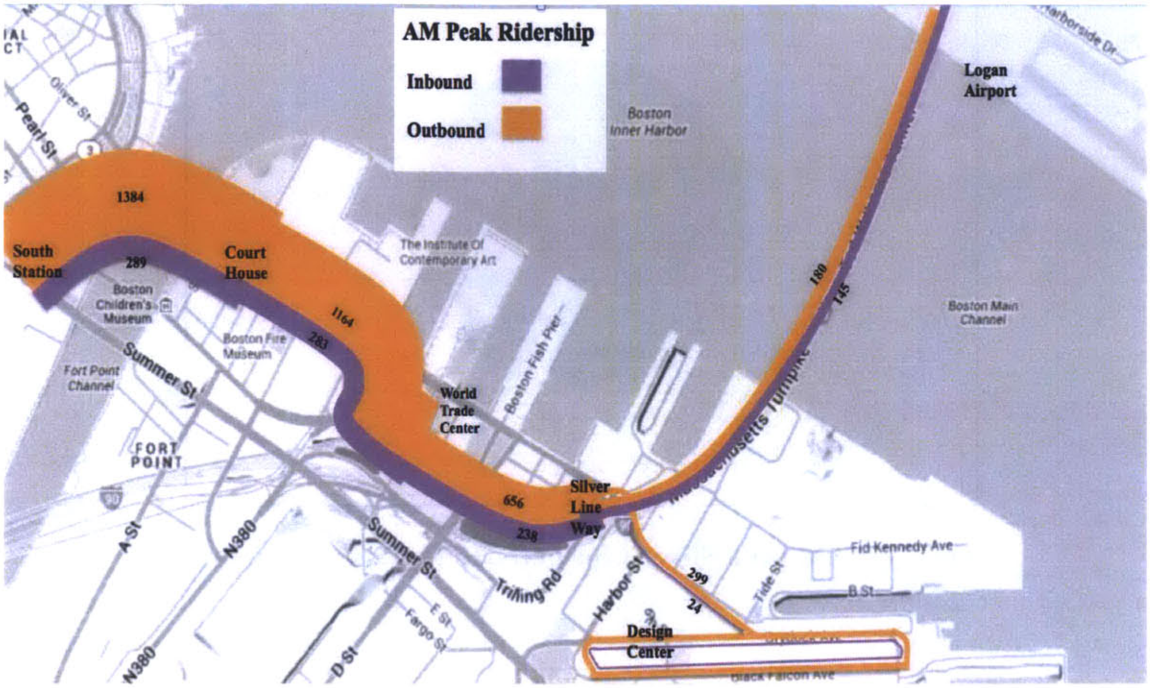


Figure 3-15: Silver Line District AM peak ridership distribution

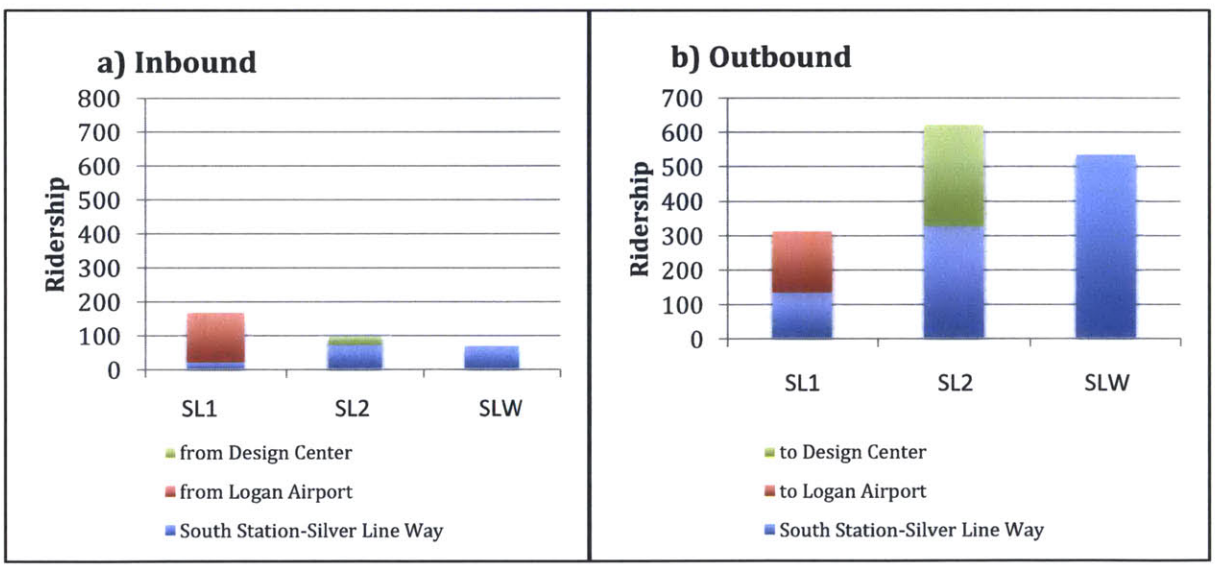


Figure 3-16: Silver Line District AM peak ridership

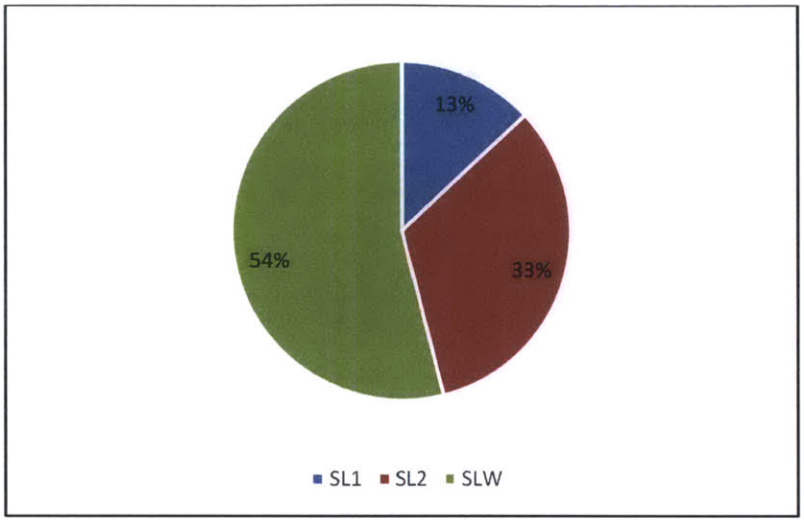


Figure 3-17: AM peak Silver Line outbound ridership distribution

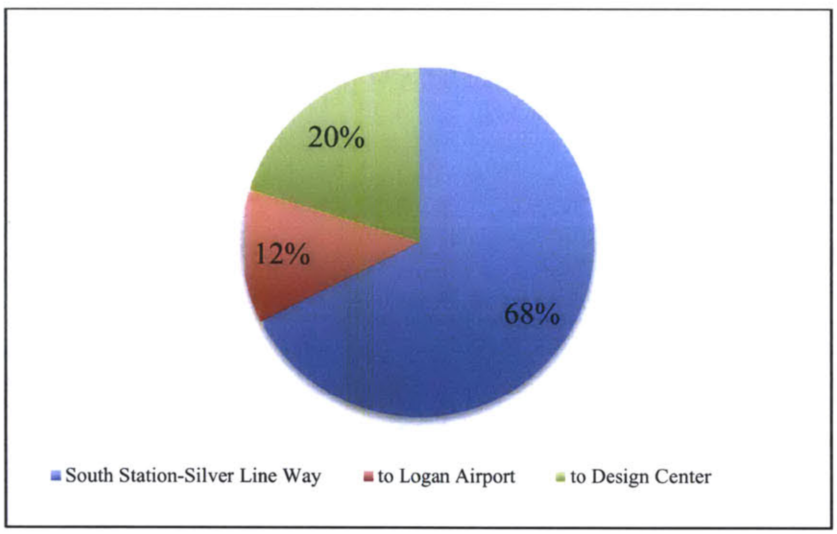


Figure 3-18: AM peak Silver Line outbound ridership distribution

For AM peak outbound trips, a total of 1476 ridership, most passengers (68%) travel from South Station to Silver Line Way. This branch of the route can be served by all Silver Line routes with an approximate 2-minute headway or lower, if all the Silver Line buses are evenly spaced. Logan Airport is the destination of 12% of the AM Peak passengers (180 riders), which can only be served by Silver Line 1. The ridership on Silver Line 1 occupies only 22% of the total and nearly half the ridership of Silver Line 2, which is quite reasonable given its ten-minute headway, compared with 5-minute headway of Silver Line 2 and Silver Line shuttle. It can be further deduced that a fair number of passengers whose destination is World Trade Center or Courthouse would get on whichever Silver Line bus comes first.

For the South Station to Silver Line Way section where the most demand is concentrated (68% of Silver Line Waterfront total ridership, 997 ridership), 54% use SLW, 33% take the Silver Line 2 and only 13% choose to take the Silver Line 1, as shown in Figure 3-19. Still, this thirteen percent of passengers make up the 43% of total Silver Line 1 ridership, considering its relatively low overall ridership.

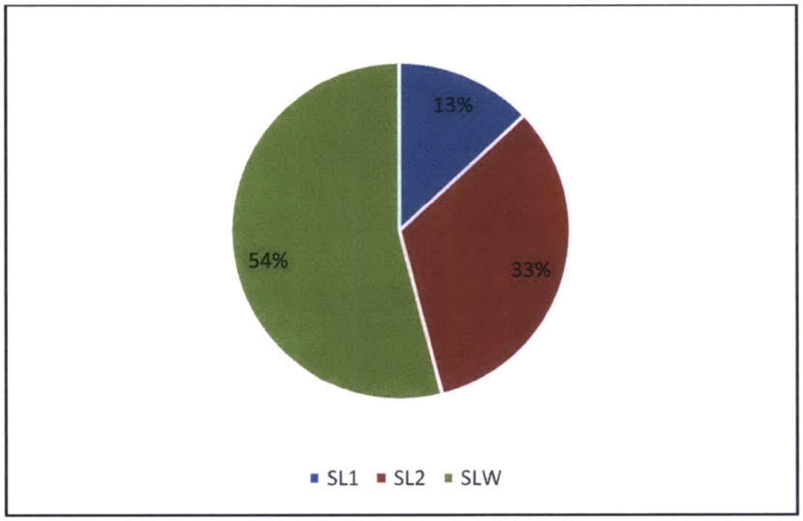


Figure 3-19: AM peak South Station to Silver Line Way ridership distribution

2) PM Peak Ridership

Ridership distribution across SL1, SL2 and SLW during PM peak hour is shown in Figure 3-20. It is clear that inbound direction is the peak direction during PM peak. Still, similar to AM peak, most passengers are using the trunk portion of the Silver Line. There is no imbalance of ridership on trips to/from Logan airport and ridership on this segment of SL1 is quite low, compared with the trunk. Design Center demand is relatively low, with only 300 riders on inbound trips, which is similar to AM peak outbound trips.

Figure 3-21 summarizes the inferred origin-destination matrix across SL1, SL2 and SLW. The red bar represents demand to/from Logan Airport on SL1, the green bar to/from Design Center on SL2 and the blue between South Station and Silver Line Way.

Figure 3-22 shows the ridership share on SL1, SL2 and SLW. For AM peak hour peak direction, outbound trips, SL2 has the lion share of ridership, 42% of total outbound ridership on Silver Line. SLW ranks second, with 36% share. SL1 accommodates the remaining 22%.

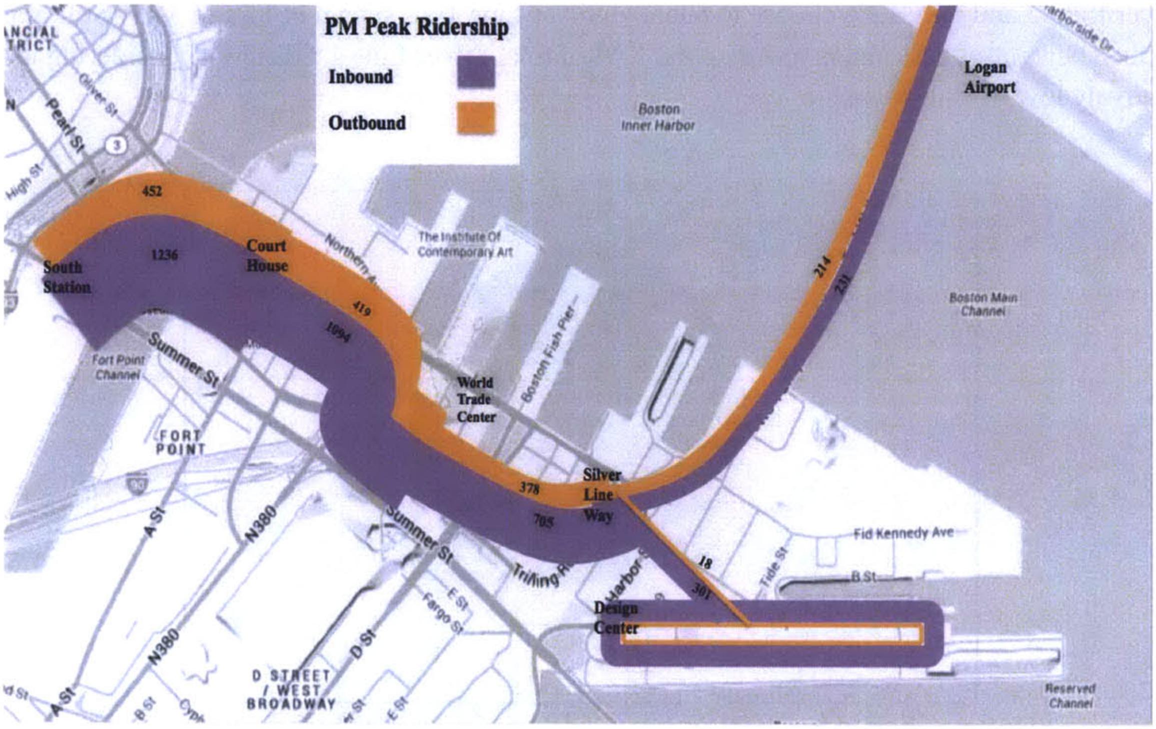


Figure 3-20: Silver Line District PM peak load distribution illustration

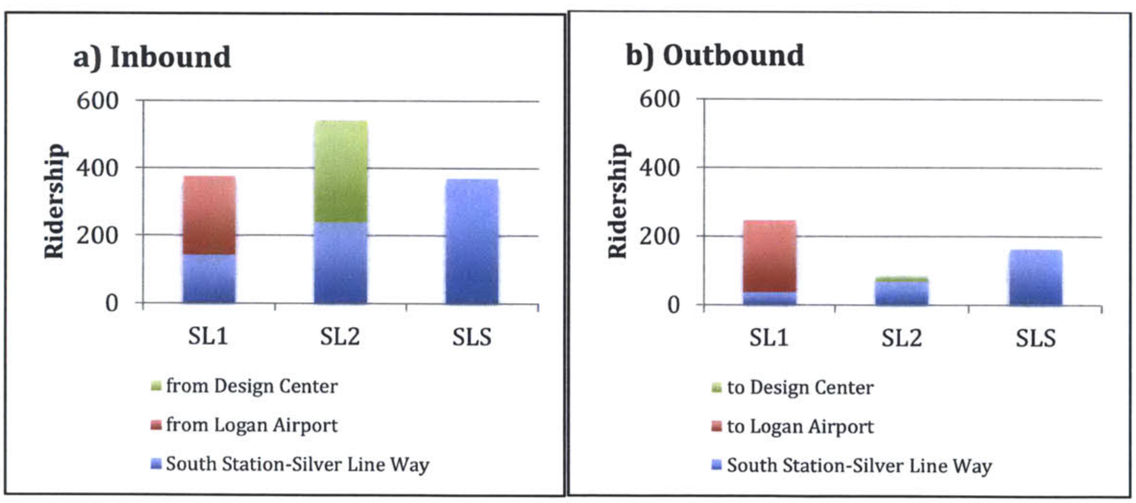


Figure 3-21: Silver Line District PM peak ridership

The share of different origin-destination passengers on Silver Line inbound trips during PM peak is shown in Figure 3-22. 59% of them are on the trunk section, 23% to Design Center and another 18% to Logan Airport. This share of demand distribution doesn't change much, compared with AM Peak hour peak direction shown in Figure 3-18.

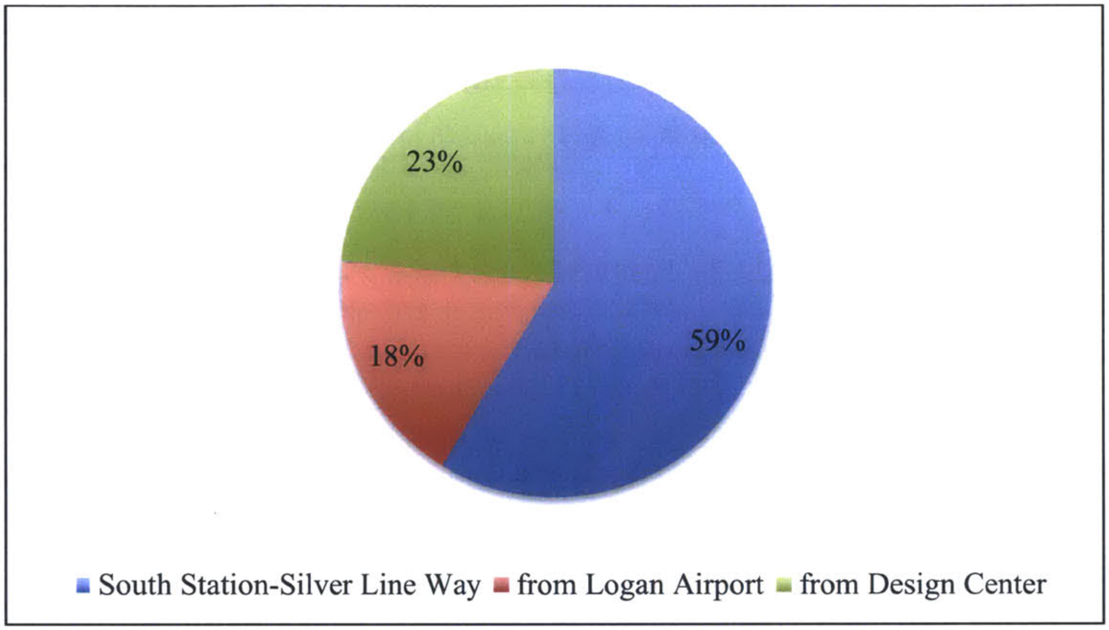


Figure 3-22: PM peak Silver Line inbound ridership distribution

3.1.4 Route 4 Analysis

There are 10 trips in total from 06:44 to 09:05 with headways between 12-16 minutes and 9 trips in the afternoon from 15:46 to 18:27 with 19-22 minutes headway. Route 4 fails the MBTA's service span standard (to have service running until 18:30), because the last trip departs Northern Ave & Tide Street at 18:10.

Demand Analysis

As is shown in Table 3-13, there is a total ridership of 474 for a typical weekday in the spring of 2013, which is fairly low despite the fact that this is already an increase of 160 compared to 2010 when the ridership of Route 4 ranked 150th among all MBTA bus routes. Part of the reason is because of the private shuttles, 8 of which essentially replicate the Route 4 bus, drawing away potential riders. Nevertheless, the current role that Route 4 plays in the Seaport District is fairly important and could be improved if the service span can be extended and frequency enhanced. If the ridership is separated into AM and PM periods, the lion's share of the ridership concentrates in AM inbound and PM outbound trips, which goes on Congress Street and Seaport Boulevard.

	Weekday Ridership		
	Inbound	Outbound	Total
Spring, 2013	260	214	474
April, 2010	176	138	314

Table 3-13: Weekday ridership of Route 4

From Figure 3-23, Figure 3-24, Figure 3-25, and Figure 3-26, it can be inferred that in the morning, the majority of passengers board at North Station and, although a sizeable number alight at Congress/Franklin Street, alightings also occur at stops within the district (around 110 passengers total, out of 220 alightings). Besides, since most boarders occur at the first three stops, most at North Station and few boarders at the following stops, it is reasonable to infer that the alightings in the district are from downtown, especially from North Station. Thus the morning inbound route provides effective connections between the Seaport District and North Station. As for the morning outbound trips, the boardings that take place within the Seaport District are much lower, with the maximum of only 5 passengers. More passengers get on the bus at Summer/Dorchester Avenue and get off at Commercial Street and North Station. Thus the morning outbound route actually serves more as a circulator within downtown Boston rather than the District.

For the afternoon inbound trips, most passengers board at North Station or downtown and get off at South Station, with fewer passengers alighting within the study scope. Comparatively, much more people get on the Route 4 buses during the PM hours on the outbound trips, going to Haymarket or North Station where transfers can be made to the T and Commuter Rail; More specifically, 91 passengers board in the District out of 163 total boardings on an average weekday.

	Inbound			Outbound		
	Total	**Into district**	**Percent**	**Total**	**Out of district**	**Percent**
AM	225	112	50%	51	14	27%
PM	36	12	33%	163	91	56%

Table 3-14: AM and PM inbound/outbound ridership

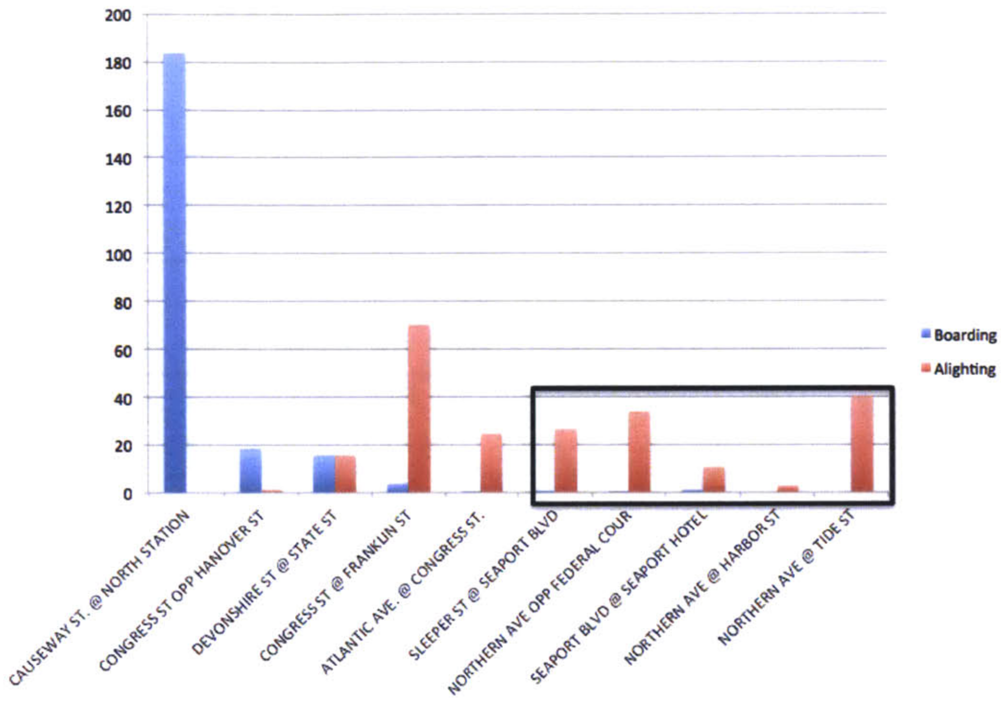


Figure 3-23: Route 4 AM inbound boarding and alighting

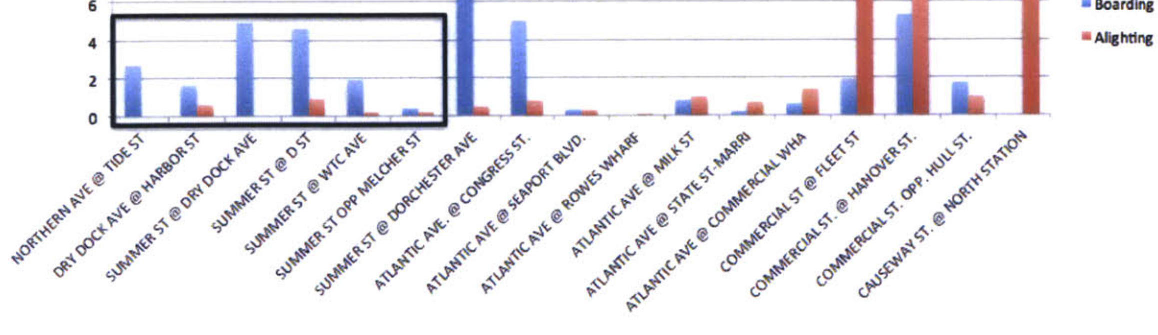


Figure 3-24: Route 4 AM outbound boarding and alighting

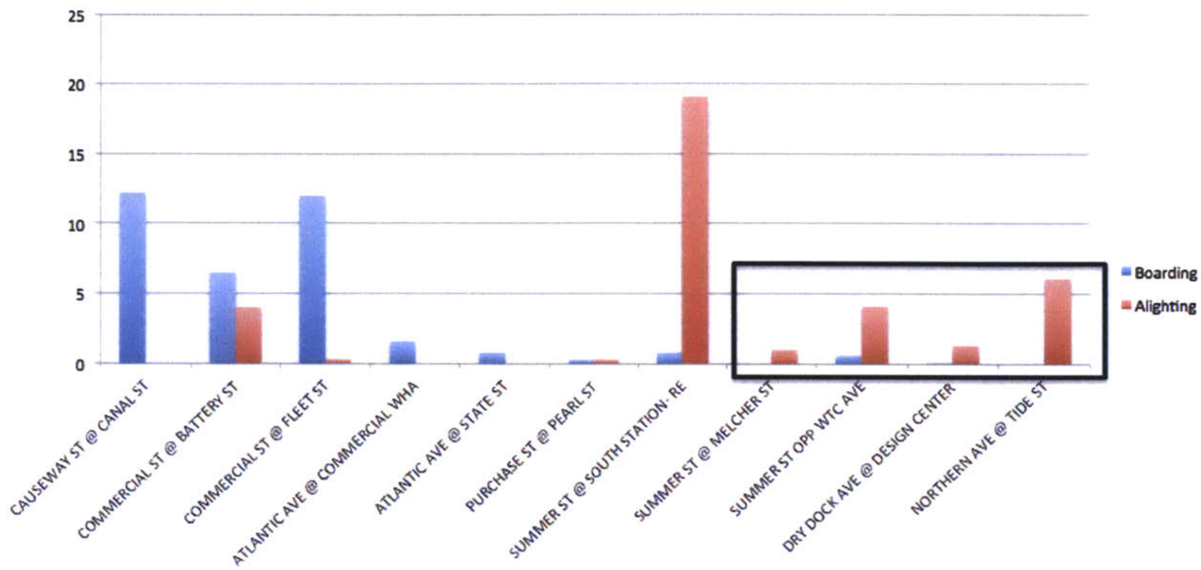


Figure 3-25: Route 4 PM inbound boarding and alighting

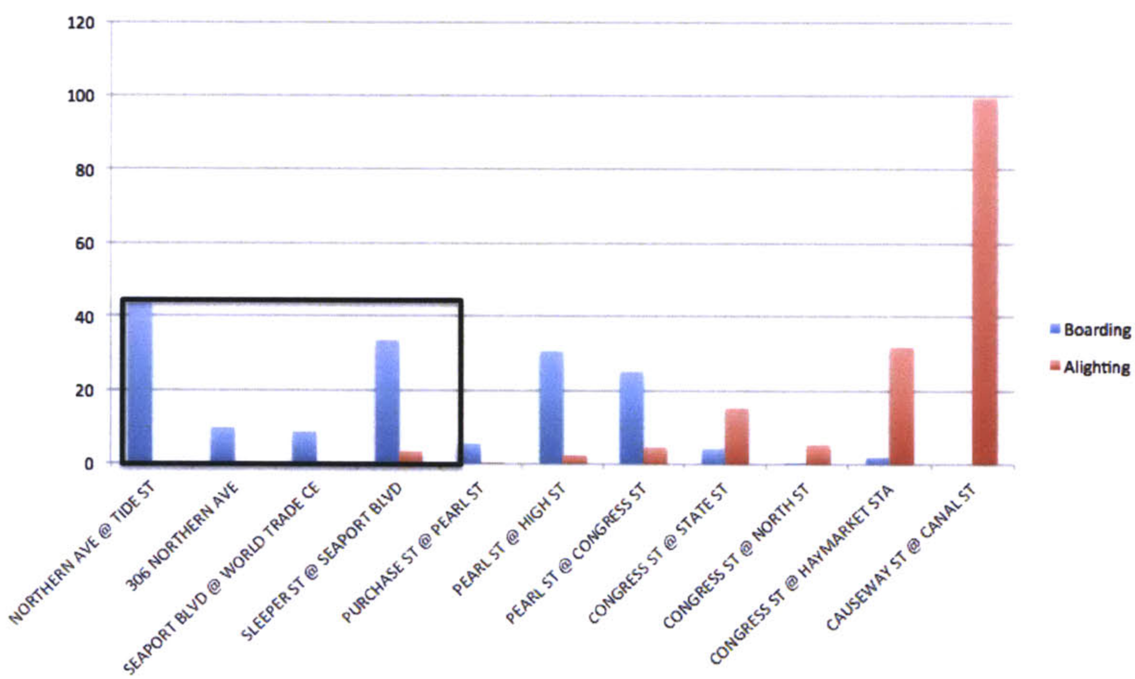


Figure 3-26: Route 4 PM outbound boarding and alighting

Figure 3-27 and Figure 3-28 illustrate the demand on Route 4 into and out of the district. Most passengers use this route to get to North Station, which can be inferred from the boarding and alighting charts above. In the morning, 112 people take this route to the district, especially Seaport Boulevard. And for afternoon trips, 91 passengers exit the district, mainly to North Station on Route 4. The explanation may be that demands from the district utilize this bus as a commuter route, connecting them to North Station. A similar trend for the peak hour ridership is shown in Figure 3-29: 54 AM peak hour inbound riders travel from the district to downtown Boston while 43 PM peak hour outbound riders travel in the reverse direction. The ridership into and out of the district in the peak direction occupies 50% or so of the whole day's ridership. This indicates the main function of Route 4 is to serve commuters in the district, although the total ridership is small.

Figure 3-27: Route 4 weekday ridership (into the District)

Figure 3-28: Route 4 weekday ridership (out of the District)

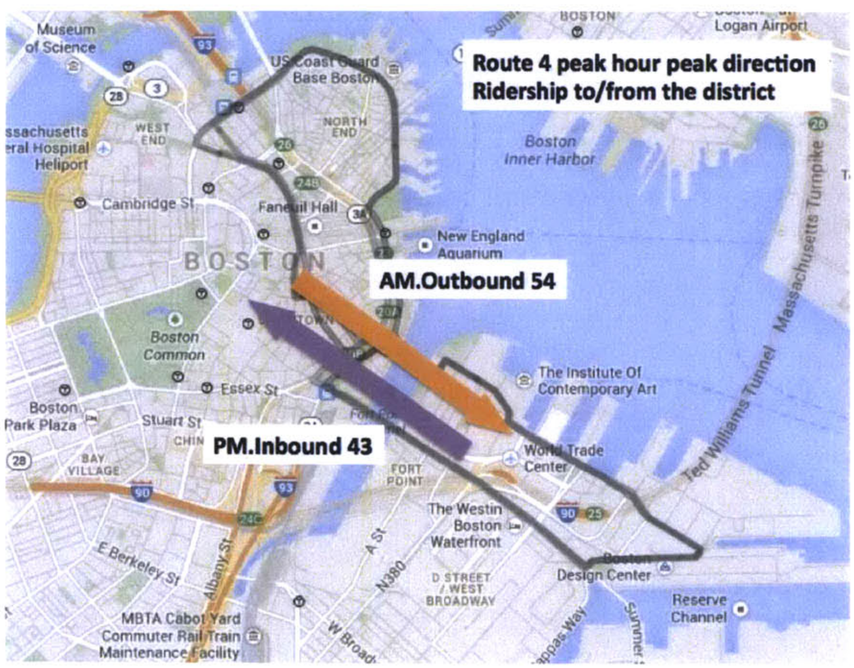


Figure 3-29: Route 4 weekday peak hour ridership (into/out of the District)

Capacity Analysis

Finally, Figure 3-30 shows the average maximum loading for Route 4 by hour. As expected, the inbound direction (from North Station towards the Seaport District) has higher loading during the AM Peak, and vice-versa. Nevertheless, the average max load is very low, at only 23 passengers between 07.00-08.00 – even during rush hour, the demand is well below the number of seats available (39). In the PM Peak, the demand is lower still, which begs the question of whether resources are being used efficiently: as mentioned earlier, there are numerous private shuttles operating in a similar fashion to this bus route, so perhaps consolidation efforts might be wise to help reduce costs for both the private operators and the MBTA as well as benefiting more riders through better headways.

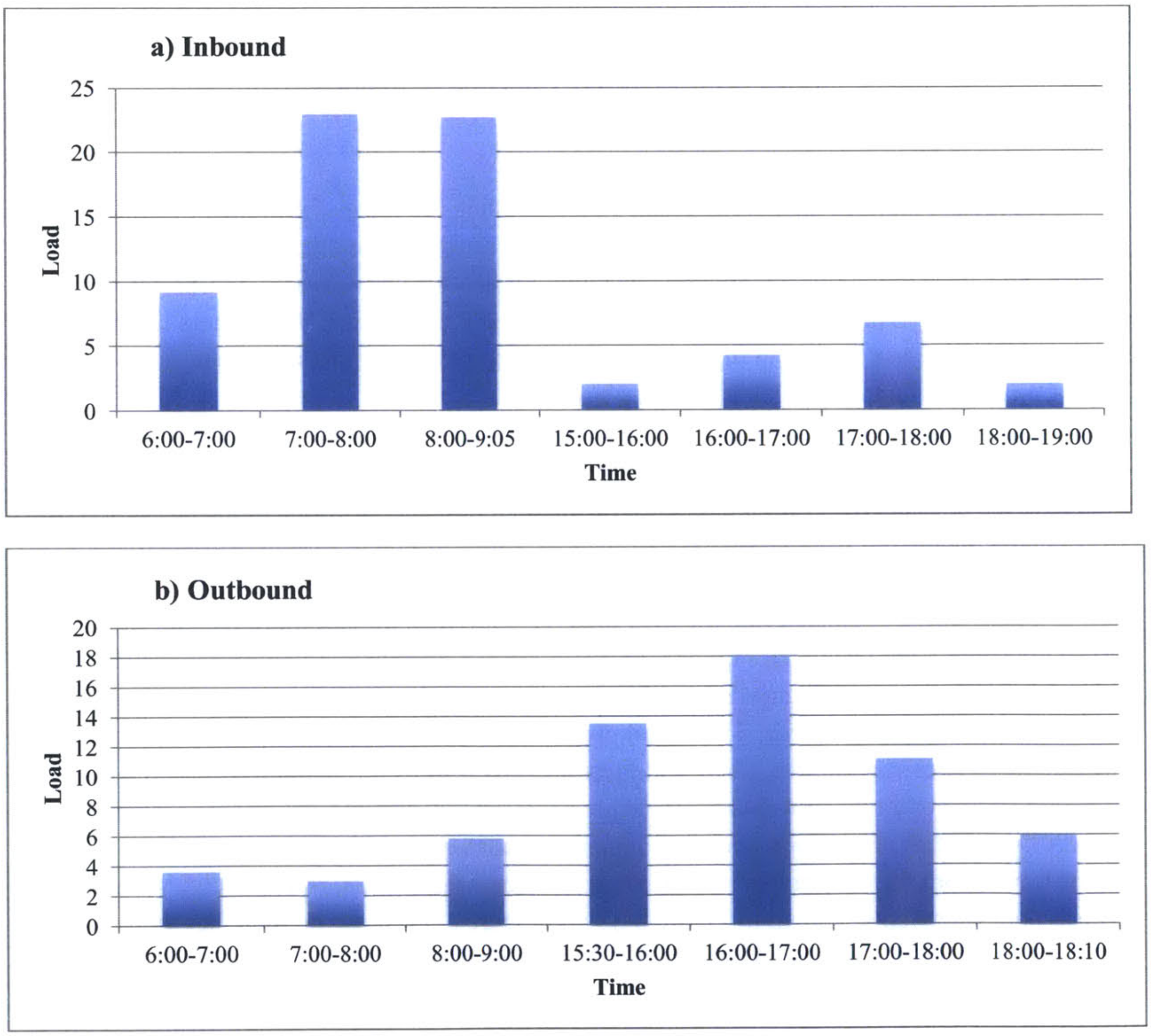


Figure 3-30: Average maximum load for Route 4

3.1.5 Route 7 Analysis

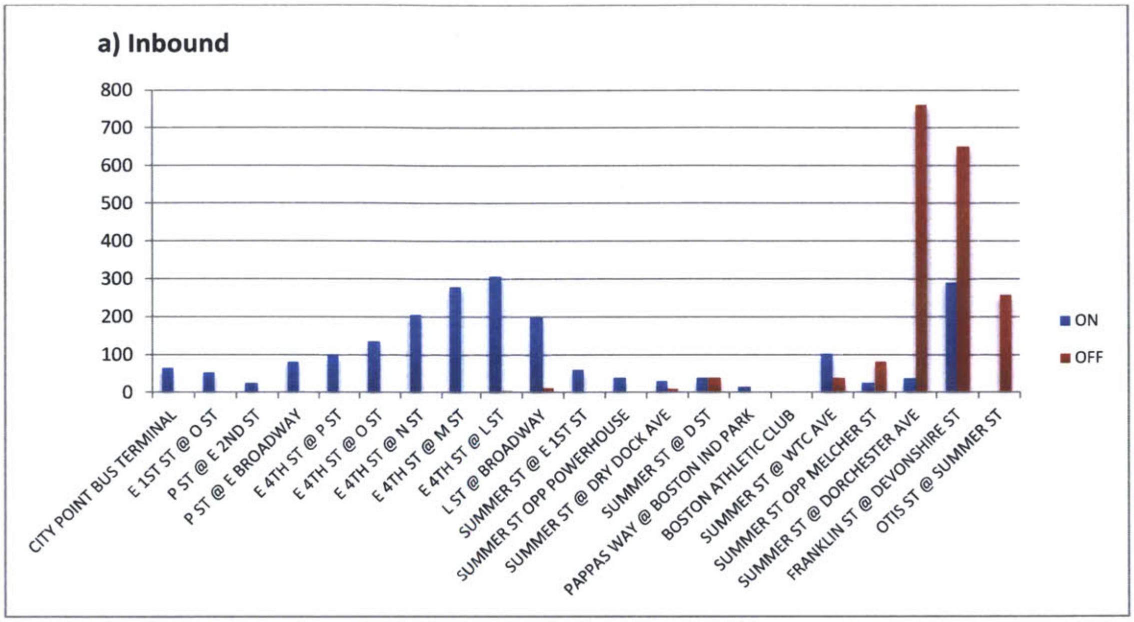
Route 7 services run from 05:15 (inbound) to 22:20 (outbound) with about 100 trips in each direction.

Based on APC data and MBTA Blue Book, Table 3-15 shows the ridership of Route 7 in 2013 and 2010. As is shown, the total weekday ridership of Route 7 bus in spring 2013 amounts to 3,872, and 2,674 in 2010, which ranks number 47 among all the MBTA bus routes in 2010.

	Weekday Ridership		
	Inbound	Outbound	Total
Spring, 2013	2,101	1,771	3,872
April, 2010	1,375	1,299	2,674

Table 3-15: Weekday ridership of Route 7

Figure 3-31 shows the boarding and alighting along the route. From this, it can be gathered that for the outbound trips, the majority of passengers get on the bus at Otis/Summer St., which is close to the financial district, or South Station which is a major transportation hub providing services to passengers from commuter rail and the Red Line. Passengers largely alight at stops in South Boston, beyond the Seaport District, however, within the district, the World Trade Center and Summer/Melcher St. stops have a sizable number of passengers. Most passengers come from City Point and E 4^{th} Street, south of the district and largely residential. As expected, the most number of people get off at the financial district and South Station stops, which are the ones boarding outbound. Despite the high ridership of Route 7, the utilization of this route by the district is quite low, as can be clearly seen in Figure 3-31. The route mainly serves the demand between City Point and the Financial District and the district segment can be seen as a pass-through, considering the high total demand. Despite this, more District riders are served by Route 7 than Route 4. Figure 3-32 illustrates the ridership into/out of the district on Route 7, which is inferred from MBTA APC data, assuming that no passengers are boarding and alighting only within the district. This assumption holds for most cases since Route 7 just passes through the district via Summer Street and there are only 6 stops for inbound trips and 4 stops for outbound ones. For a typical weekday, there are a total of 170 and 345 passengers entering the Seaport District from City Point and the Financial District, respectively. Another 126 and 215 people travel from the district to City Point and the Financial District, respectively. With respect to peak hour ridership as shown in Figure 3-33 and Figure 3-34, it can be seen that there is a significant number of people coming into the district from downtown in the morning, while the ridership in the afternoon is low across-the-board.



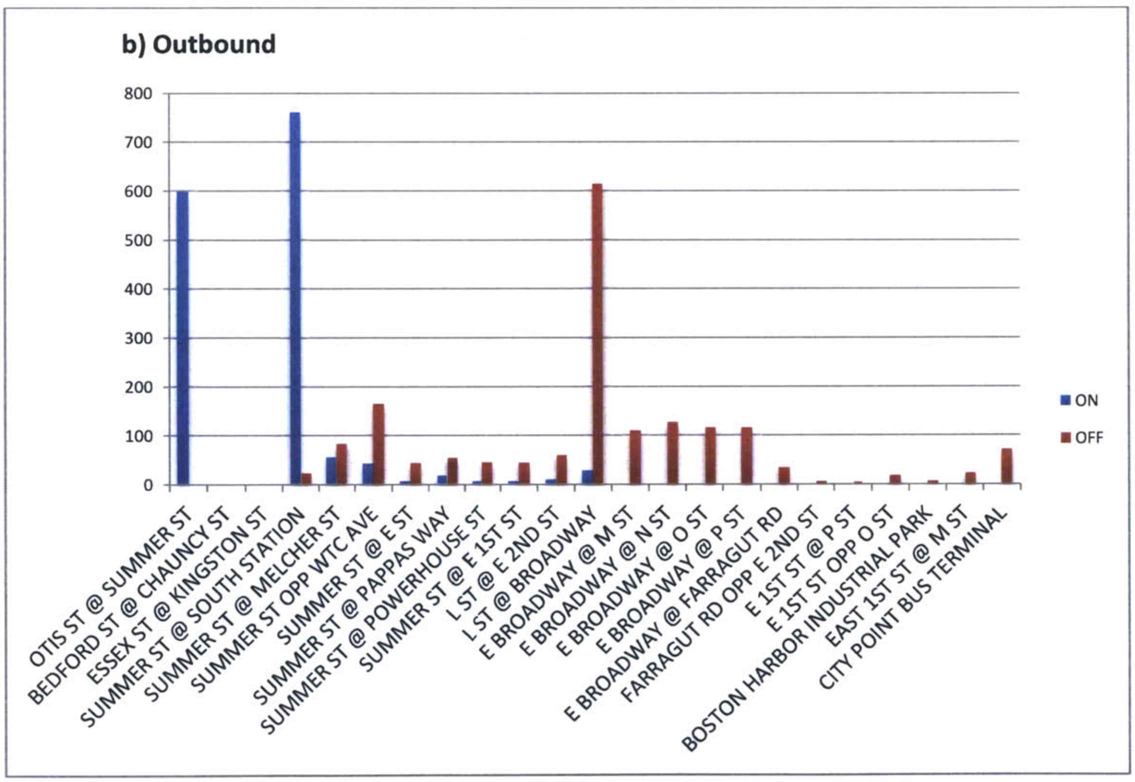


Figure 3-31: Route 7 boardings and alightings

Figure 3-32: Route 7 district ridership

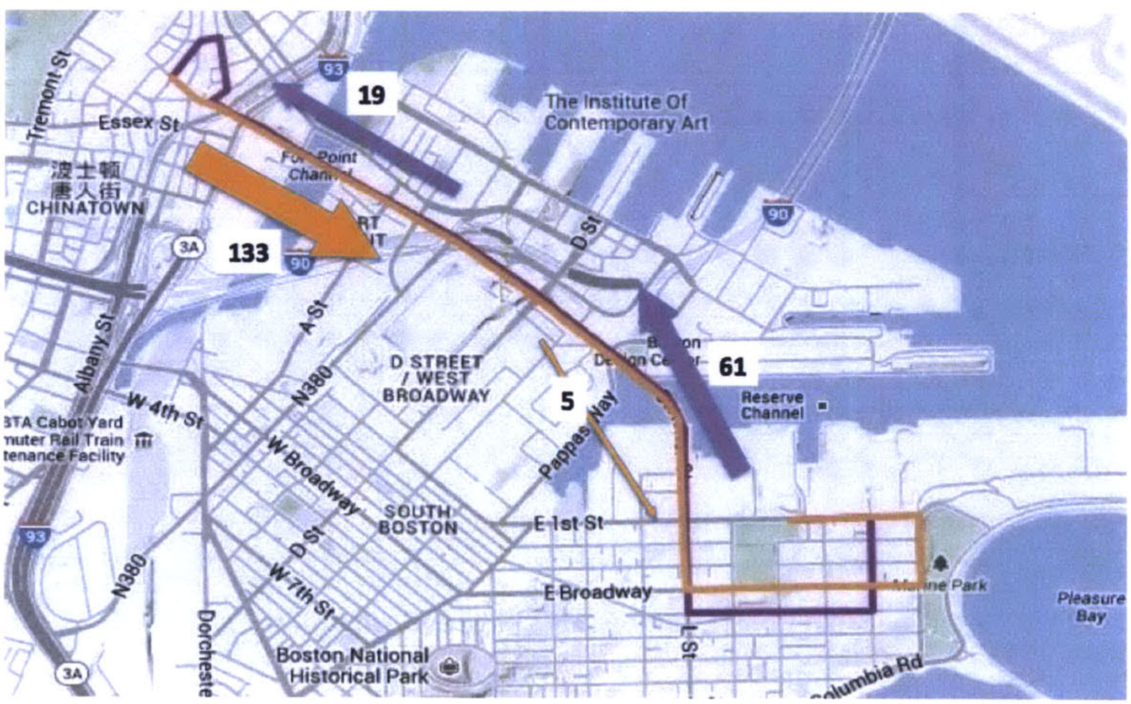


Figure 3-33: Route 7 district AM peak ridership

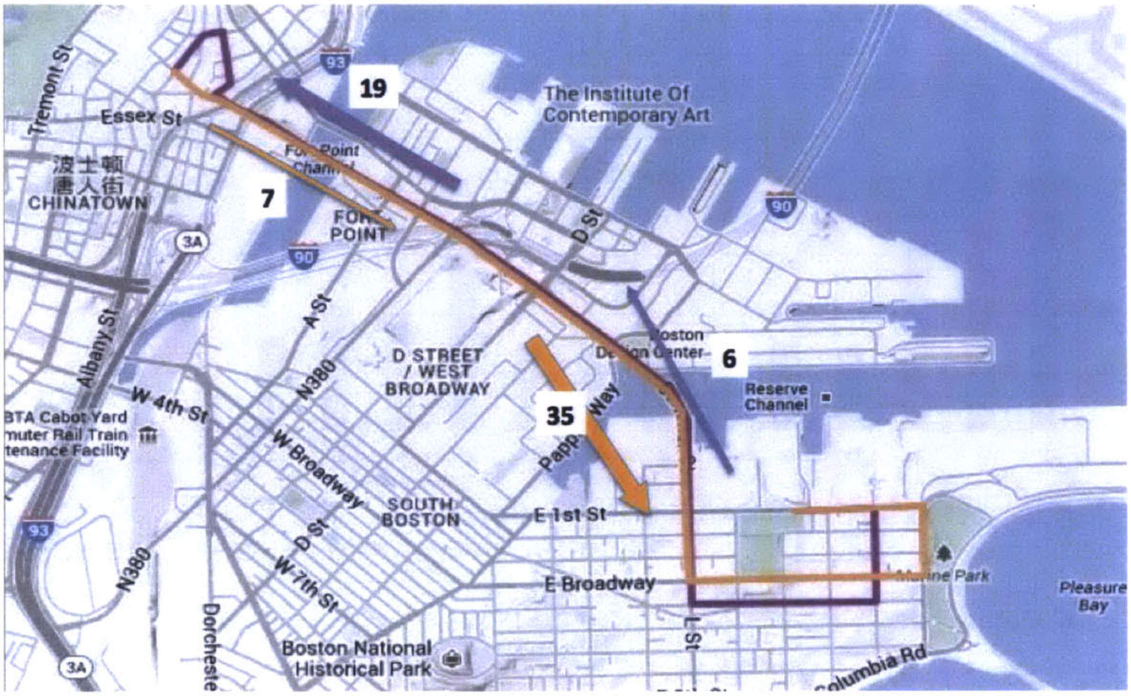


Figure 3-34: Route 7 district PM peak ridership

Capacity Analysis

Route 7 is so crowded in the peak periods that passengers are regularly passed by at some stops and have to wait for next bus. Indeed, this is supported by the APC data: in spring 2013, the highest load on the inbound bus is 69 passengers which occurred on the 07:59 departure while the outbound had 57 passengers on the 17:23 departure, both higher than the planned capacity of 54. Figure 3-35 shows the hourly average maximum load, which is bound to be lower than the highest load of the whole day. The inbound AM peak trips have seen the highest passenger load, with an average of 62, and the ridership of the following an hour doesn't decrease too much, with an average near 60. Outbound trips' highest maximum load occurs during PM peak. Yet the peak spreads, with lower maximum load compared with AM peak and a longer peak load time periods. Though the total contribution of the district to ridership is not great, district passengers suffer most because the stops in the district have loads very close to the maximum for the whole route.

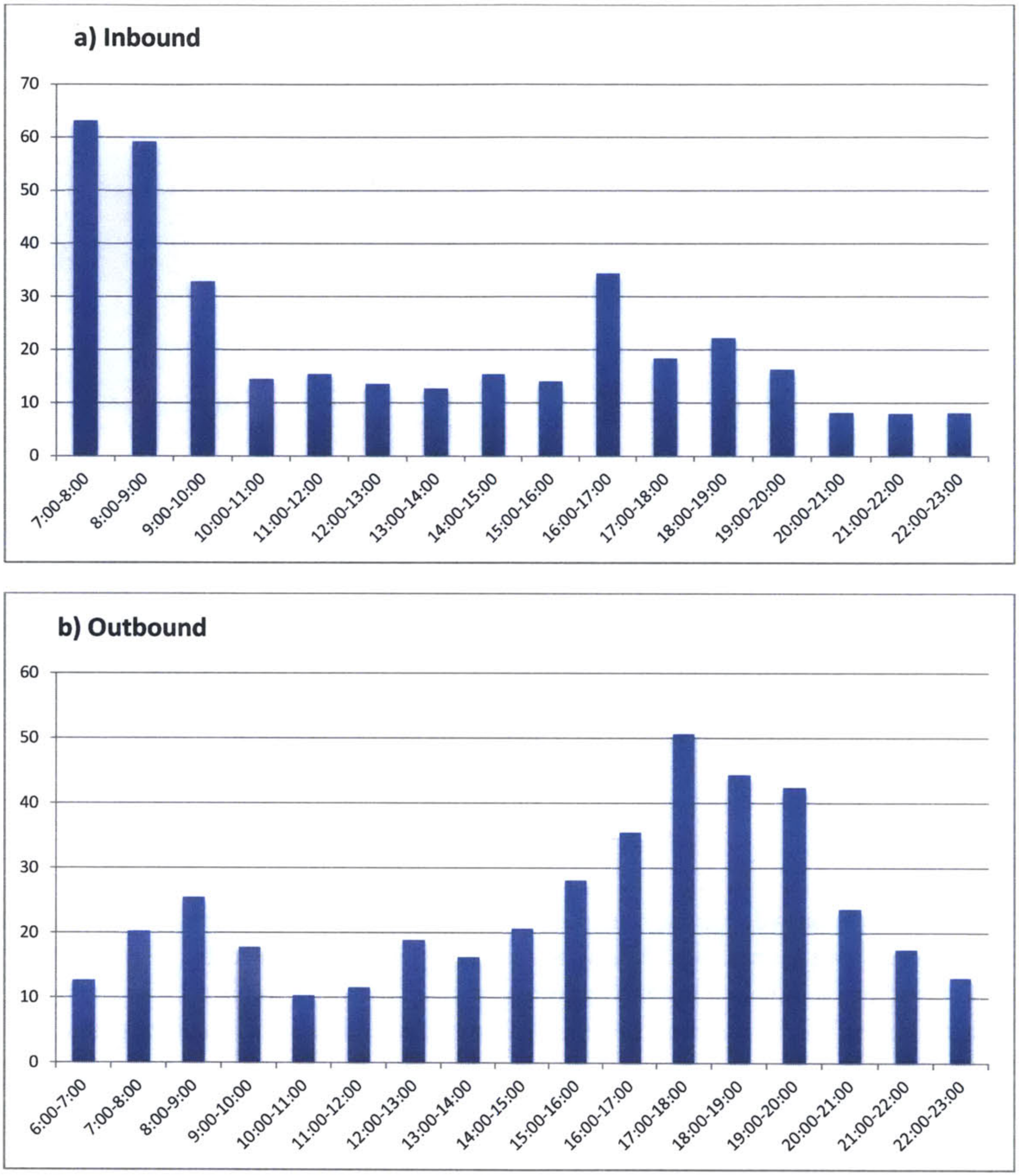


Figure 3-35: Route 7 average maximum load

3.1.6 Private Shuttle Analysis

The benefits of the private shuttles for the whole system are quite clear: less auto usage and easier access to the district, especially when considering the fact that the current public transport network in the Seaport District is limited. Yet the continuing growth and development of the Seaport District, which will lead to more jobs and visitors, will likely require substantial expansion of the current shuttle network, if the public transport system as is now. However, the expansion of the private shuttle network to meet the expected demand of the built-out scenario of the Seaport District would make the district's transportation system less ordered and less cost-effective for employers as well. Thus, it is appropriate to consider the possibility of coordinating or consolidating the private shuttles to support the mixed development of commercial, residential and other land use.

Existing Conditions

Based on field observations[19] and input from the Seaport Transportation Management Association (TMA), a total of 14 private shuttle routes operate to/from the Seaport District, which directly linking the Seaport District to downtown Boston. These 14 routes include: 6 shuttle services to North Station, 4 shuttles to South Station, 2 shuttles to State Street Station and 2 more to Downtown Crossing and Back Bay. These routes are illustrated in Figure 3-36 and the detailed service characteristics are shown in Table 3-16. These services are commuter-oriented, with higher frequency during the AM and PM peak hours and little or no service during midday and evening. The majority of shuttles connect the district to South Station and North Station, reflecting their public transport hub nature, which provide access to commuter rail, Red Line, Orange Line and Green Line. A couple of shuttles link the District to State Street Station, Downtown and Back Bay, which also provide transfers to rapid transit. It is estimated that there are about 472 people who use the private shuttle to access the Seaport District during peak hours. The data show a total of 393 daily vehicle-hours of private shuttle service in the District. Please note that these are basic estimates, given the limited resources and time available, so should be used as a basis for further investigations, and not taken as completely accurate. More detailed information about the services are presented below.

[19] Field counts were conducted on three consecutive days in March 2014 at North Station, South Station, and selected office locations.

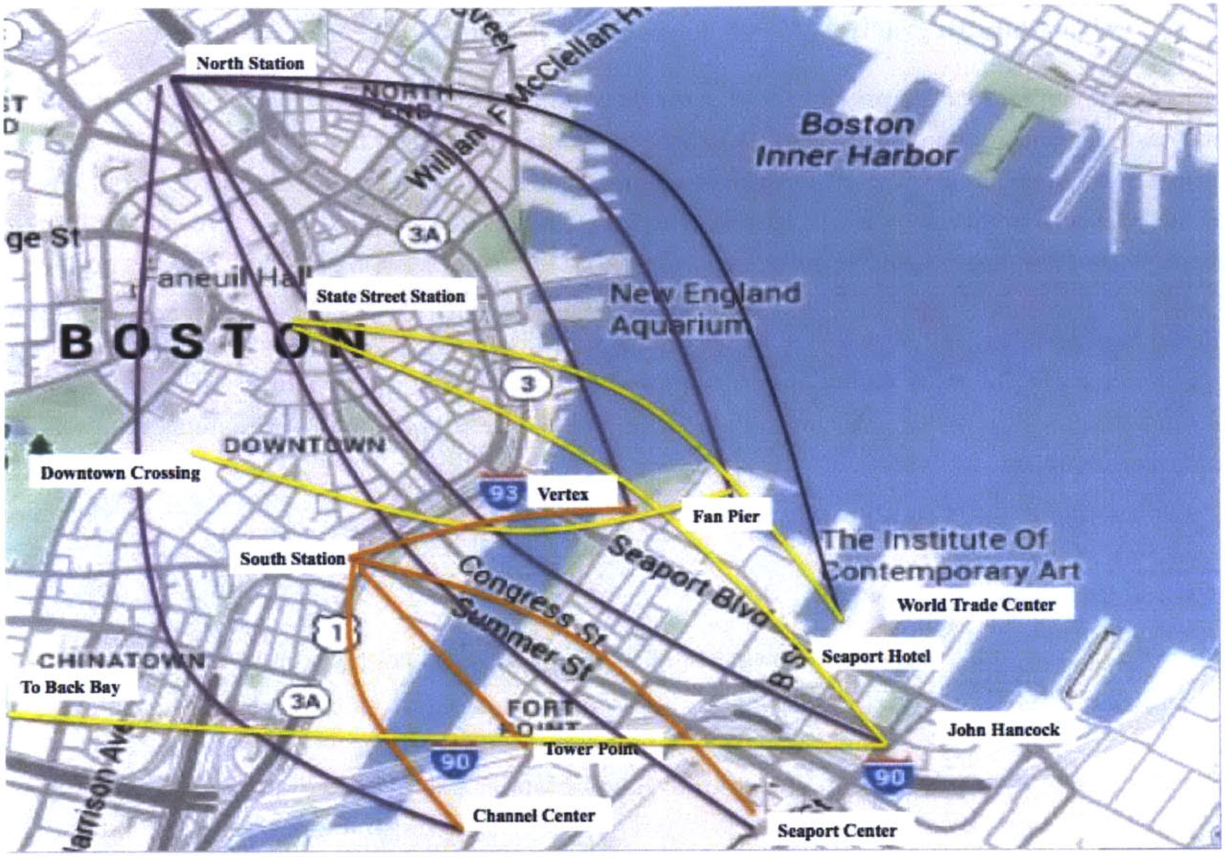


Figure 3-36: Private shuttle services

	Operator	Service Span	Cycle Time*	Headway	Fleet Size**	Boarding	Peak Hour Ridership	Vehicle Hour
South Station								
Channel Center	Central Parking System	7:00 am - 7:00 pm	29 min	10 min	3	10	60	36
Tower Point		7:00 am- 6:30 pm	26 min	15 min	2	13	52	24
Vertex	A&A Metro	6:00-10:00 am 3:00-7:00pm	21 min	15 min	3	6	24	24
Seaport Center	MBT worldwide	6:40 am - 8:40 pm	33 min	30 min	2	15	30	28
State Street Station								
John Hancock	MBT worldwide	6:25- 9:45 am 4:10-8:10 pm	25 min	20 min	2	10	30	14
World Trade Center/ Seaport Hotel/ Fidelity	Boston Coach	6:15 am - 7:00 pm	25 min	10 min	5	10	60	65
North Station								
Seaport Center	MBT worldwide	6:30 am - 7:00 pm	37 min	15 min	3	5	20	36
Fan Pier		7:30- 8:45 am 4:30-6:05 pm	26 min	40 min	1	7	14	3
John Hancock	MBT worldwide	6:30-9:30 am 4:05-8:10 pm	36 min	20 min	2	18	54	14
World Trade Center/ Seaport Hotel/ Fidelity	Boston Coach	6:15 am - 7:00 pm	31 min	10 min	5	10	60	65
Channel Center	Central Parking System	7:00 am - 7:00 pm	32 min	15 min	4	13	52	48
Vertex	A&A Metro	6:00-10:00 am 3:00-7:00pm	25 min	15 min	3	4	16	24

*Running time is estimated using Google Map during peak hour period. Assume shortest path is selected because private shuttles provide point-to-point connections to the District. Both drivers and passengers report that the shuttle running time depends on the traffic situation. So it is reasonable to treat private shuttles as general autos to estimate the travel time. Layover time is assumed to be 20% of running time.

** Underline values are the fleet size reported by the shuttle drivers or validated by direct observation. For those we lack the data, we assume the fleet size cycle time divided by headway.

Table 3-16: Private shuttle service in the Seaport District

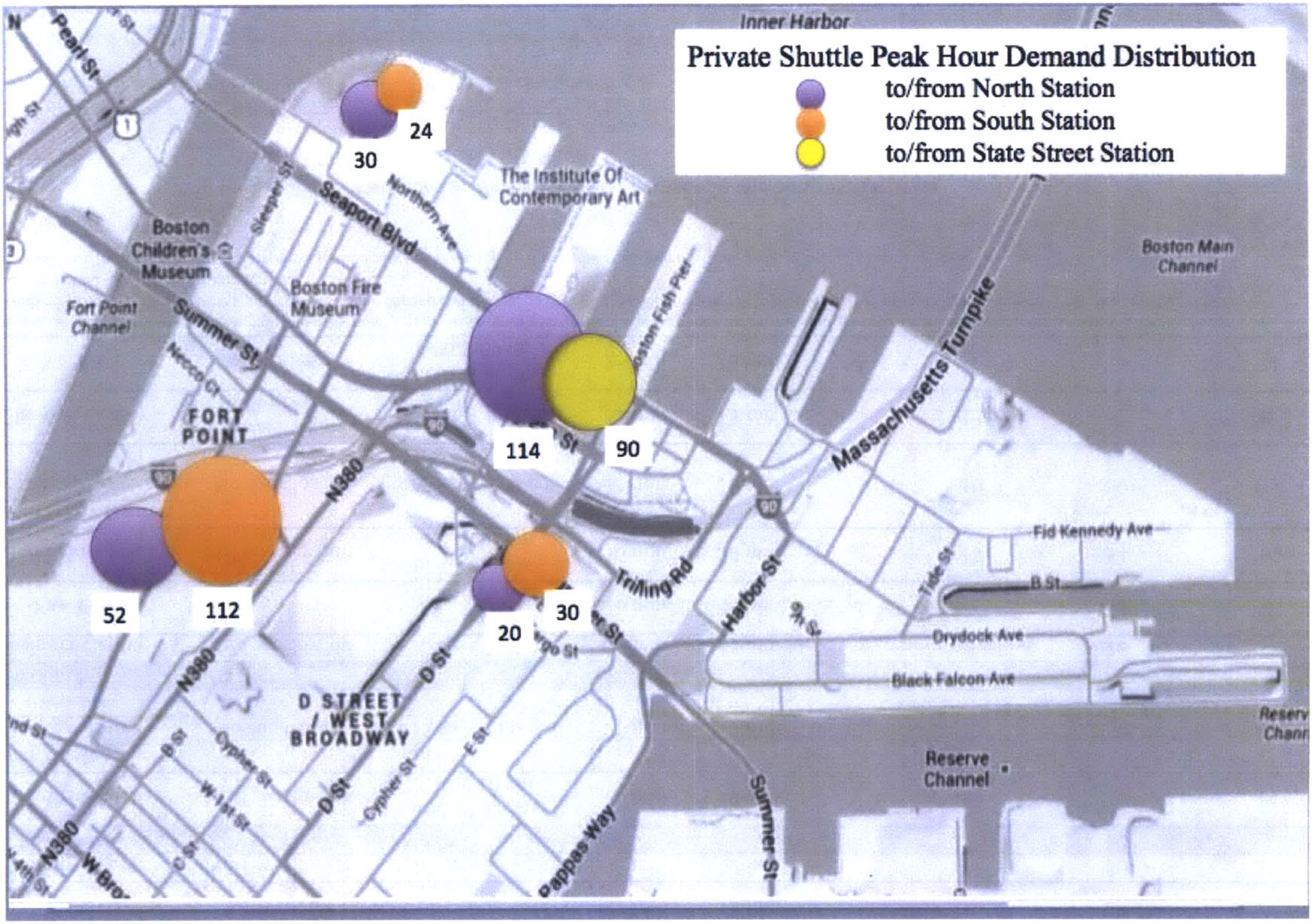


Figure 3-37: Private shuttle current demand

- South Station Shuttles

1. Channel Center Shuttle: Channel Center is located in the southern part of the Seaport District where there is a gap in MBTA service. The shuttle is operated by Central Parking System and provides services from 07:00 to 19:00. During peak hours, shuttles arrive at South Station every ten minutes and there is an estimated of 10 people taking this shuttle to/from Channel Center.
2. Tower Point Shuttle: Tower Point is also located on A Street as well and is close to Channel Center. This shuttle operates from 07:00 to 18:30 and provides services at 15 minutes headways during peak hours and 30 minutes during mid-day. Around 13 people board/alight the shuttle during the peak hour.
3. Vertex Shuttle: Vertex lies to the northeast of the Seaport District. This shuttle is operated by A&A Metro and provides limited service to Vertex employees from 06:00-10:00 and from 15:00-19:00, 15 minutes headways and an estimated boarding of 6 passengers.
4. Seaport Center Shuttle: Seaport Center is located at D Street and Summer Street, with the shuttle continuously serving employees of Seaport Center from 18:40 to 20:40, arriving at South Station every 30 minutes. This shuttle is operated by MBT worldwide. An estimated of 15 passengers who are employees of Seaport Center take each shuttle during the peak.

- North Station Shuttles

5. Seaport Center Shuttle: This shuttle is also operated by MBT worldwide and provides continuous service to North Station from 06:30 to 21:00 at a 45 minute headway. During the peak hour, an estimated 5 people take each shuttle.
6. Fan Pier Shuttle: Fan Pier is located at the northeastern part of the Seaport District, very close to Vertex. This shuttle provides very limited services to the employees of Fan Pier, available only from 07:30-08:45 and from 16:30-18:05 with 40 minutes headways. Around 7 passengers ride on that shuttle during the peak hour.
7. John Hancock Shuttle: John Hancock is at D Street and Congress Street, with the shuttle providing point to point service for employees of the company during peak hours: between 06:30-09:30, and 18:05-20:10. An estimated of 18 employees board the shuttle during peak hour. The shuttle is operated by MBT worldwide.
8. World Trade Center Shuttle: This shuttle is operated by Boston Coach and provides continuous service to employees and guests from World Trade Center, Fidelity and Seaport Hotel from 06:15 to 19:00 with a 10 minute headway during peak hour and 15 minute headways during the off-peak. Each shuttle bus has a ridership of around 10 passengers during the peak.
9. Channel Center Shuttle: this shuttle is operated by the Central Parking System and provides services to employees of Channel Center from 07:00 to 19:00. During peak hour, the shuttles arrive at North Station every 15 minutes and have an estimated ridership of 13 people.

10. Vertex Shuttle: this shuttle serves the employees of Vertex during peak hour only from 06:00-10:00 and from 15:00-19:00. This shuttle is operated by A&A Metro and has an estimated ridership of 4 people per trip.

- State Street Station Shuttles

11. John Hancock Shuttle: John Hancock also provides shuttle service to State Street Station every 20 minutes during peak hours for employees. This shuttle is contracted out to MBT worldwide and has an estimated ridership of 10 employees per trip.
12. World Trade Center Shuttle: From 06:15 to 19:00, the shuttles provide services to people working at World Trade Center, Fidelity and guests at Seaport Hotel every 10 minutes during peak hour and 15 minutes (or longer) during mid-day. It is estimated that around 10 people board the shuttle buses during peak hour.

Peak Hour Ridership

During the peak hour only, the ridership on these private shuttles is around 470, based on field data collection at North Station, South Station and some of the offices listed. Among all the destinations, North Station has the greatest number of the shuttle routes, from Channel Center, Seaport Center, John Hancock, World Trade Center, Fan Pier and Vertex, which are scattered throughout the whole District. 216 people take those shuttles during this time period, which comprises 46% of the total private shuttle ridership in the district. This not only reflects the demand between the District and North Station but also indicates the inadequacy of existing public transport connections to North Station. The current services accommodate demand from the northeast of the district, A Street corridor, D Street @ Summer Street, and World Trade Center area, where the current developments are located. This demand distribution further supports the conclusions that connections between North Station and the District needs improvement. Meanwhile, shuttles to/from South Station also serve the northeastern part of the District, A Street corridor and D Street @ Summer Street, with lower ridership than North Station shuttles. 166 people take these shuttles to access South Station, which is around 35% of total shuttle riders. From the demand distribution map shown in Figure 3-37, it is noted that no private shuttles serve Congress Street or the Design Center, which are covered by the high frequency and high capacity MBTA Silver Line service. Compared with data[20] collected a decade ago, the previous high concentration of shuttles along the World Trade Center-South Station route is now dispersed and the shuttles' level of activity to South Station has dramatically decreased because of the operation of the Silver Line Shuttle and Silver Line 2. Yet the A Street corridor is still in need of good connections to South Station, which has a demand of 112 passengers, considering that the coverage radius of SL is limited in this area, with few bus stops

[20] VHB/Vanasse Hangen Brustlin, Inc (April 2003), "Shuttle Efficiency Study South Boston Seaport District"

along A Street. Another concentration of private shuttle users is located at Seaport Street and Congress Street, with a destination of State Street Station, which provides direct connections to the Orange and Blue Lines. The total ridership during peak hour only is around 90 and this demand comes from the World Trade Center and John Hancock.

3.1.7 Route 4 vs. Private Shuttle

Route 4 has almost the same route for AM inbound and PM outbound, connecting North Station and the Design Center via Seaport Boulevard, with service similar to some of the shuttles. Since AM outbound and PM inbound trips have really low ridership (highest boarding is 11), only peak hour peak direction will be discussed. The boarding and alighting at each stop of Route 4 peak hour peak direction are shown in Table 3-17.

Route 4 (AM peak-inbound)	ON	Off
CAUSEWAY ST. @ NORTH STATION	89	0
CONGRESS ST OPP HANOVER ST	9	0
DEVONSHIRE ST @ STATE ST	9	9
CONGRESS ST @ FRANKLIN ST	3	36
ATLANTIC AVE. @ CONGRESS ST.	0	11
SLEEPER ST @ SEAPORT BLVD	0	12
NORTHERN AVE OPP FEDERAL COUR	0	13
SEAPORT BLVD @ SEAPORT HOTEL	1	4
NORTHERN AVE @ HARBOR ST	0	2
NORTHERN AVE @ TIDE ST	0	24

Route 4 (PM peak-outbound)	ON	OFF
NORTHERN AVE @ TIDE ST	23	0
306 NORTHERN AVE	3	0
SEAPORT BLVD @ WORLD TRADE CE	5	0
SLEEPER ST @ SEAPORT BLVD	15	3
PURCHASE ST @ PEARL ST	1	0
PEARL ST @ HIGH ST	13	1
PEARL ST @ CONGRESS ST	11	4
CONGRESS ST @ STATE ST	2	6
CONGRESS ST @ NORTH ST	0	2
CONGRESS ST @ HAYMARKET STA	1	13
CAUSEWAY ST @ CANAL ST	0	46

Table 3-17: Route 4 peak hour peak direction ridership

- For the AM in the outbound direction, North Station has highest number of boardings (80.1%) and almost all boardings occur at the first three stops (96.7%).
- Franklin Street and Tide Street stops alone have around 54% of total AM Peak alighting with Sleeper Street and Federal Courthouse stops also assume 23% of the total alighting.
- Since there are almost no passengers boarding in the District apart from alighting, it is reasonable to conclude that there are around 55 passengers accessing to the District by Route

4 during the AM Peak hour. Half of these passengers' destination is Tide Street (Design Center) and the other half is Sleeper Street and Courthouse.

- It could be inferred that during PM peak hour, a total of 47 passengers are served by Route 4 who board within the District, since there are almost no passengers alighting at the stops within the District. This symmetric pattern is reflected in the AM and PM trips.
- Unsurprisingly, the Route 4 does not carry many passengers to the Seaport Hotel/WTC, considering the high level of shuttle service provided.

Route 4 (PM hour peak direction)	AM	PM
NORTHERN AVE @ TIDE ST	24	23
306 NORTHERN AVE	2	3
SEAPORT BLVD @ WORLD TRADE CENTER	4	5
NORTHERN AVE OPPOSITE FEDERAL COURT	13	N/A
SLEEPER ST @ SEAPORT BLVD	12	15

Table 3-18: Route 4 peak hour peak direction district ridership

- Comparing the AM and PM peak hour peak direction ridership, the consistency of the ridership can be seen from Table 3-18, confirming the symmetric pattern, and the commuter nature of the passengers on Route 4.
- The only difference between AM inbound and PM outbound trips lies at the Courthouse stop. Since the Sleeper Street @ Seaport Boulevard stop is quite close to Courthouse, it is expected to accommodate the ridership shifted from the Courthouse stop. Yet no conversion effect is seen since the Sleeper Street ridership remains almost the same for PM outbound trips.
- The much lower ridership on Route 4, compared with the private shuttles, as shown in Figure 3-38: North Station –Seaport District peak hour demand distributio, can be explained by the following reasons. First, the coverage of private shuttles is great. Route 4 covers just the Seaport Boulevard corridor while private shuttles provide connections to the A Street and D Street corridors. Second, the higher aggregate frequency of the shuttles results in a more attractive service. Third, the point-to-point link provided by shuttle services reduce the walk time of passengers and the clock-face headways are easy to memorize.
- Yet Route 4 fill a gap of private shuttles as well, as it accommodates about 20 passengers during the peak hour at the Design Center where no private shuttles operate currently.
- Considering the current demand (around 270 passengers) between the Seaport District and North Station, a consolidated bus routes circulating within the district and then directly going to North Station would be suggested in Chapter 5

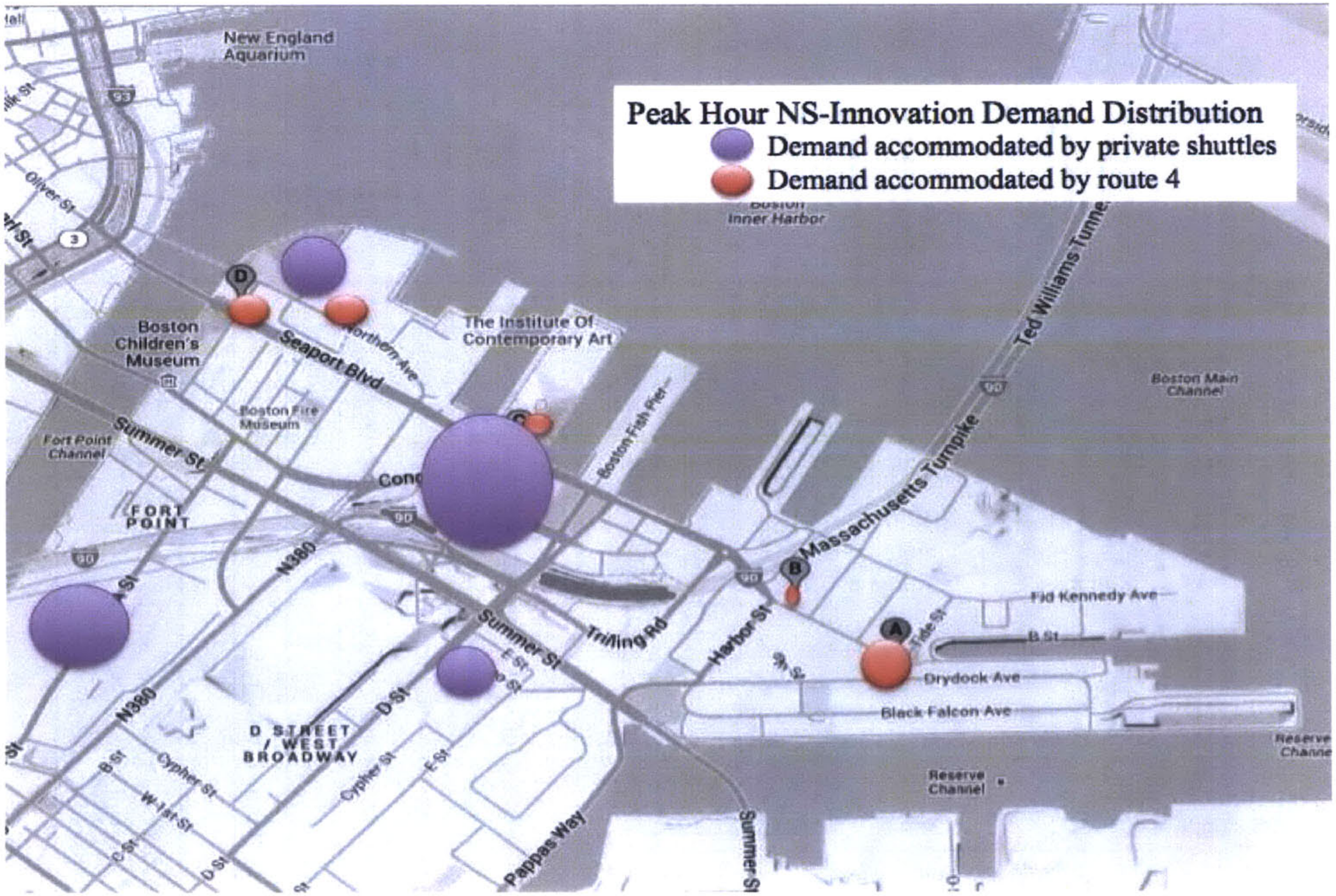


Figure 3-38: North Station –Seaport District peak hour demand distribution

	Route 4	Private Shuttles
Peak hour ridership	55	216
Coverage	Seaport Boulevard	Seaport Boulevard A Street Corridor D Street Corridor
Vehicles per Hour	4	22
Headway	15 min	10 min – 40 min
Travel Time	10 min – 15 min*	12 min**

*As a public bus route, No. 4 bus serves stops within the district sequentially. Thus the travel time ranges from 10 min to 15 min, according to the MBTA schedule.

**Since the private shuttles provide point-to-point service, linking North Station to different places in the district, the travel time is determined by the average travel time for different private shuttles, whose travel time ranges from 9 min to 14 min.

Table 3-19: Comparison between Route 4 and private Shuttles

Light-Duty Small Bus *Typical Uses:* Demand Response service and low demand fixed-route services *Length:* 16 to 28 ft *Seats:* 10 to 22	
Medium-Duty Small Bus *Typical Uses:* Demand Response and low demand regional express fixed-route services *Length:* 25 to 35 ft *Seats:* 20 to 30	
Heavy-Duty Small Bus *Typical Uses:* Low demand fixed-route services *Length:* 30 ft *Seats:* 22 to 30	

Figure 3-39: Common bus types [21]

[21] From City of Madison, WI, Bus Study

As for the bus types in use, currently, most shuttles employ the first two types, light- and medium-duty buses, with only one route (to WTC) using a heavy-duty small bus. However, when the shuttles are consolidated, a larger bus would probably be needed, since it offers increased capacity to most routes and, coupled with the headway reduction, should provide enough capacity to meet the demand. More details of this analysis can be found in the short-term strategies section.

Conclusion

- Most private shuttle services and demand are concentrated at North Station.
- Along the Seaport Boulevard and Congress Street Corridors, few shuttles connect to South Station, reflecting the fact that the Silver Line provides good South Station access, whereas areas south of Congress Street are all provided with private shuttles to both North and South Stations, indicating public transport gaps.
- Most private shuttles are contracted to shuttle operators, such as A&A Metro, MBT Worldwide, Boston Coach, etc.
- The fleet composition includes 14-seat vans and 25- and 30-seat buses.
- Most of the shuttles are free for employees, although some require proof to board and have a coordinator to supervise.
- Some of shuttles now serve several companies, such as World Trade Center, Seaport Hotel, Fidelity and West/East Building, a sign of the trend toward private shuttle consolidation.

3.2 ROAD NETWORK

This section describes the results of the traffic assessment for the base year. Two matters should be noted for the results of this assessment:

- We considered 2009 as the base year of our analyses because this is the most recent year with available traffic data.
- Only weekday peak hour conditions were examined in our analyses. The peak hours were chosen based on counts conducted for the Seaport Square study and are as follows:
  - The morning peak hour (08.00 – 09.00)
  - The evening peak hour (16.45 – 17.45)

3.2.1 AM Peak Hour

Aggregate trip statistics

The aggregate indicators in Table 3-20 show that the network in the AM peak period has acceptable performance, meaning that the vehicles have acceptable travel speeds for an urban network and that the network accommodates many originating, terminating, and through vehicle trips without significant aggregate delays. In terms of trip distribution, we note that most trips either terminate or pass through the District.

Indicator	Value
Average speed (mph)	17
Average delay (min)	2.8
Total number of trips	14,200

Table 3-20: Aggregate statistics in the AM peak hour

Intersections

As can be seen in Table 3-21, even in the base year there are two intersections operating at capacity (LOS E) and three intersections operating over capacity (LOS F), as illustrated by the yellow-highlighted and red-highlighted rows respectively.

Mapping the results from Table 3-21, we obtain Figure 3-40. There are six major points to note in this figure.

1. The intersection of Drydock Avenue and Summer Street is a significant bottleneck. Summer Street is an important corridor that connects the residential areas of South Boston with the CBD. Alternative options provide limited connectivity to the financial district since they involve the use of urban streets and Dorchester Avenue in the southwest.
2. The interaction between the two intersections (Congress and D, and Transit Way and D) is not fully captured, since these are very close and spillover is highly probable.
3. Two highway off-ramps intersect with Congress Street, leading to a LOS F at that intersection.
4. There is a clear interaction between the LOS F at the off-ramps and the LOS F at Seaport; it appears that one is spilling over to the other.
5. Congress Street is problematic as two of its intersections are encountering significant delays.
6. Seaport Boulevard is also showing difficulty in handling the base year's vehicle demand since two of its intersections are experiencing significant delays.

Intersection	Average Stops (stops/veh)	Control Delay (sec/veh)	LOS	Signalized
A St & Melcher St	0.4	17	C	No
A St & W 2nd St	0.6	18	B	Yes
A St & W Broadway	0.8	29	C	Yes
B St, Congress St, I90 Off-Ramp WB & I93 On-Ramp	1	46	D	Yes
Boston Wharf Rd & Seaport Blvd	1.1	69	E	Yes
Congress St & D St	1.2	69	E	Yes
Congress St, A St & Thompson Place	1.1	41	D	Yes
Congress St, W Service Rd & Boston Wharf Rd	1	48	D	Yes
D St & Summer St	1	45	D	Yes
D St, Transit Way & D St.	0.3	12	B	Yes
Dorchester Ave, Broadway Bridge & W Broadway	1	35	D	Yes
Drydock Ave, Summer St & Pappas Way	1.8	103	F	Yes
Haul Road & W Service Rd	0.3	20	C	No
I90 Off-Ramp EB, I93 Off-Ramp, Congress St	1.5	87	F	Yes
Northern Ave & B St	0.7	28	C	Yes
Northern Ave & Congress St	0.3	18	C	No
Northern Ave & D St (1)	0.6	24	C	Yes
Northern Ave & D St (2)	0.9	44	D	Yes
Northern Ave, Old Northern Ave & Seaport Blvd	1.3	81	F	Yes
Pump House Road & Summer St	0.1	0.3	A	No
Sleeper St & Seaport Blvd	0.6	12	B	Yes
Summer St & Melcher St	0.8	23	C	Yes
Summer St & WTC Ave	0.5	20	C	Yes

Table 3-21: Intersection statistics (AM peak hour)

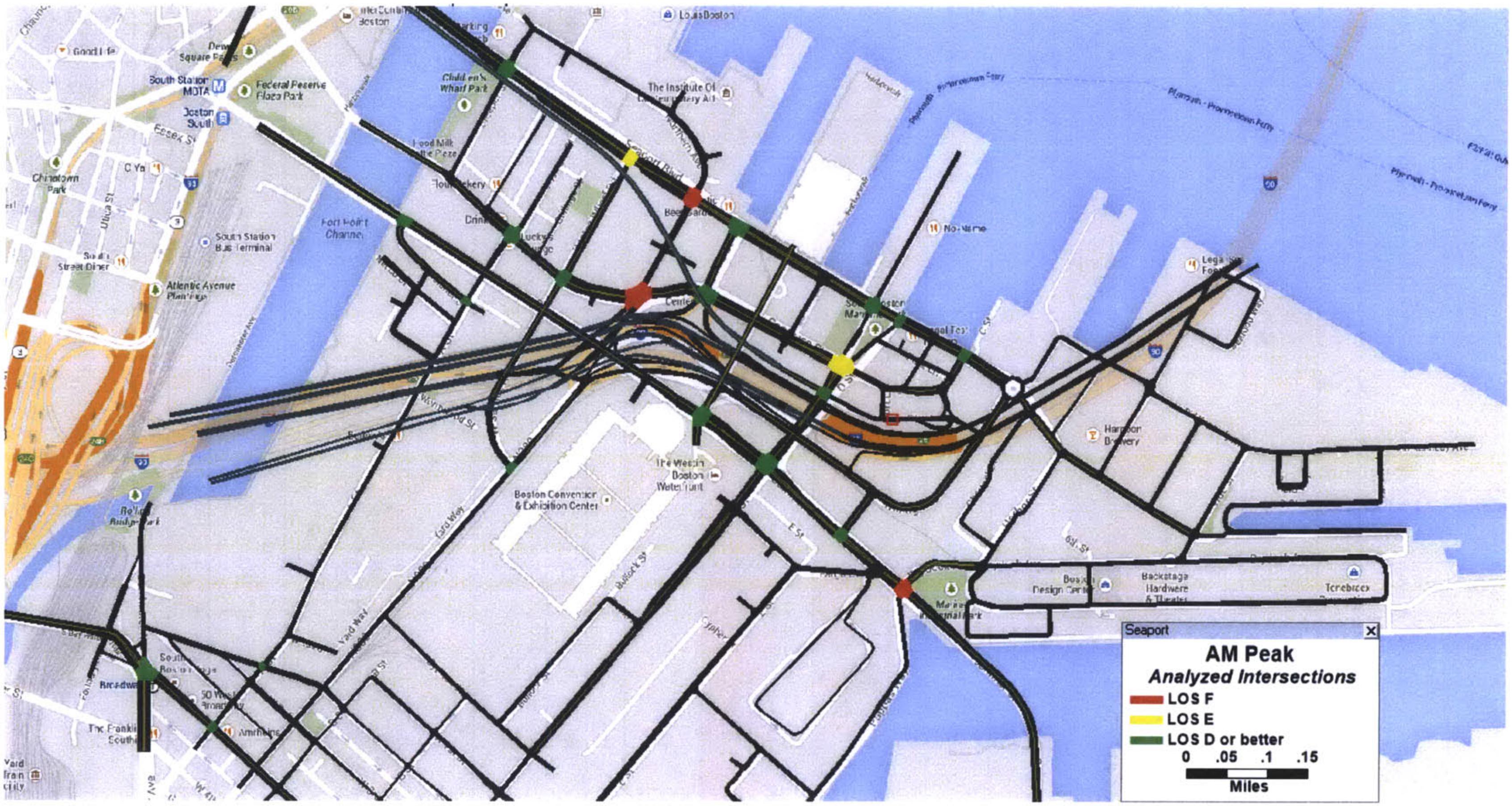


Figure 3-40: LOS of key intersections (AM peak hour)

Links

The link performance indicator results are shown in Table 3-22. These results indicate that the five most heavily used roads in the District are Haul Road, Summer Street, Drydock Ave, Seaport Blvd/Northern Ave and Congress Street respectively. Note that Haul Road has a strikingly high VMT, which because of its length.

Of the 40 links studied, the five links that have the highest delays are Congress Street, Seaport Blvd/Northern Ave, Haul Road, D Street and Drydock Avenue respectively. In light of the intersection analysis, perhaps the only surprising result is the delay on Haul Road, because the other four roads all have intersections that operate over capacity (i.e. LOS F). The high delay on Haul Road is probably due to its intersection with West Service Road and its intersection with I-90 off-ramp, as well as the high VMT rates.

Street	Delay (min/mile)	Street	VMT (veh-mi)
A St	2.5	**A St**	349
B St	9.1	**B St**	85
Boston Wharf Rd	7.6	**Boston Wharf Rd**	41
Broadway Bridge	0.5	**Broadway Bridge**	12
C St	0.0	**C St**	3
Congress St	9.5	**Congress St**	352
Cypher St	2.8	**Cypher St**	24
D St	5.3	**D St**	236
Design Center Pl	30.0	**Design Center Pl**	2
Dorchester Ave	9.4	**Dorchester Ave**	70
Drydock Ave	2.8	**Drydock Ave**	432
E 1st St	0.0	**E 1st St**	28
E St	1.3	**E St**	185
F St	15.4	**F St**	7
Fargo St	7.1	**Fargo St**	140
Farnsworth St	0.0	**Farnsworth St**	98
Garage Access Rd	0.0	**Garage Access Rd**	25
Harbor St	0.0	**Harbor St**	51
Haul Road	2.2	**Haul Road**	899
HOV line	0.0	**HOV line**	401
I90 Off-Ramp EB	0.0	**I90 Off-Ramp EB**	57
I90 Off-Ramp WB	10.4	**I90 Off-Ramp WB**	22
I93 Off-Ramp	0.0	**I93 Off-Ramp**	136
I93 On-Ramp	0.8	**I93 On-Ramp**	22
Mass Pike	0.1	**Mass Pike**	848
Melcher St	2.2	**Melcher St**	41
Old Northern Ave	0.2	**Old Northern Ave**	98
Pump House Road	0	**Pump House Road**	0
Seaport Blvd/ Northern Ave	8.4	**Seaport Blvd/Northern Ave**	398
Summer St	0.4	**Summer St**	448
Sleeper St	5.3	**Sleeper St**	34
Thompson Place	30.0	**Thompson Place**	10
Tide St	12.0	**Tide St**	4
W 1st St	0.1	**W 1st St**	175
W 2nd St	4.2	**W 2nd St**	26
W 3rd St	1.5	**W 3rd St**	12
W Broadway	1.6	**W Broadway**	211
W Service Rd	3.9	**W Service Rd**	98
WTC Ave	0.7	**WTC Ave**	27

Table 3-22: Link statistics (AM peak hour)

3.2.2 PM Peak Hour

Aggregate trip statistics

Overall, the network performs better in the PM peak than in the AM peak since the average speed is higher, even though the total number of trips is higher. As for the average delay, the PM peak hour has a slightly higher value, which can be explained by the increase in number of trips. In general, the spreading of trips in different directions and among different District exits is probably the main contributor to the better network performance in the evening peak.

The increase in total trips is probably because a considerable number of the PM peak hour trips could be for leisure purposes, as opposed to the AM peak hour trips which are mostly commuting trips. In terms of trip distribution, it can be noted from Table 3-23 that the origins and destinations are generally (and as expected) reversed in the PM peak hour. This means that the trips originating and the trips terminating in the District in the PM peak hour reflect closely the trips terminating and the trips originating in the AM peak hour.

Indicator	Value
Average speed (mph)	18
Average delay (min)	2.9
Total number of trips	16,200

Table 3-23: Aggregate statistics (PM peak hour)

Intersections

The intersections analysis in the PM peak reveals that the intersections perform much better in the PM peak than the in the AM peak. Table 3-24 lists detailed intersections statistics for the PM peak hour. The following conclusions can drown from this table:

- There are no intersections operating over capacity (i.e. LOS F).
- Only two intersections operate at capacity (i.e. LOS E), as shown by the yellow-highlighted rows.
- The intersection of Congress Street and D Street is operating at LOS E in both the PM peak hour and the AM peak hour.

Figure 3-41 maps the results shown in Table 3-24.

Intersection	Average Stops (stops/veh)	Control Delay (sec/veh)	LOS	Signalized
A St & Melcher St	0.4	16	**C**	No
A St & W 2nd St	0.3	17	**B**	Yes
A St & W Broadway	0.7	27	**C**	Yes
B St, Congress St, I90 Off-Ramp WB & I93 On-Ramp	1.1	39	**D**	Yes
Boston Wharf Rd & Seaport Blvd	1	42	**D**	Yes
Congress St & D St	1.1	57	**E**	Yes
Congress St, A St & Thompson Place	1.3	74	**E**	Yes
Congress St, W Service Rd & Boston Wharf Rd	0.9	38	**D**	Yes
D St & Summer St	0.8	33	**C**	Yes
D St, Transit Way & D St.	0.6	18	**B**	Yes
Dorchester Ave, Broadway Bridge & W Broadway	1.1	44	**D**	Yes
Drydock Ave, Summer St & Pappas Way	0.8	37	**D**	Yes
Haul Road & W Service Rd	0.4	25	**D**	No
I90 Off-Ramp EB, I93 Off-Ramp, Congress St	0.7	22	**C**	Yes
Northern Ave & B St	0.7	20	**B**	Yes
Northern Ave & Congress St	0.3	20	**C**	No
Northern Ave & D St (1)	0.4	12	**B**	Yes
Northern Ave & D St (2)	0.5	12	**B**	Yes
Northern Ave, Old Northern Ave & Seaport Blvd	0.6	21	**C**	Yes
Pump House Road & Summer St	0.1	0	**A**	No
Sleeper St & Seaport Blvd	0.7	15	**B**	Yes
Summer St & Melcher St	0.8	25	**C**	Yes
Summer St & WTC Ave	0.4	15	**B**	Yes

Table 3-24: Intersection statistics (PM peak hour)

Two main observations can be made from Figure 3-41. First, similar to the AM peak hour assessment, we recognize that the model is probably missing the important interaction between the intersection of Congress Street and D Street and the intersection of Transit Way and D Street. In reality, we expect that spillover effects will have an impact on the operation of both intersections. Second, the two intersections that face considerable delays are both on Congress Street, showing that Congress Street is problematic even in the evening peak hour.

Links

The link statistics for the PM peak hour are shown in Table 3-25. In the PM peak hour, the five most heavily used roads in the District are Summer Street, Seaport Blvd/Northern Ave, West Broadway, Congress Street and D Street. It is interesting that in the evening peak hour, the five roads that face the highest delays are the same five roads that have the highest VMT (this was not the case in the morning peak hour). We note that Summer Street has a VMT significantly higher than the other roads, indicating its importance as a major route for South Boston residents.

As for delay, the five links that have the highest delays are Congress Street, Seaport Blvd/Northern Ave, D Street, Summer Street and West Broadway respectively. The results are not surprising since all are major roads that are heavily used. The important thing to note is that Congress Street faces high delays in both the PM and the AM peak hours.

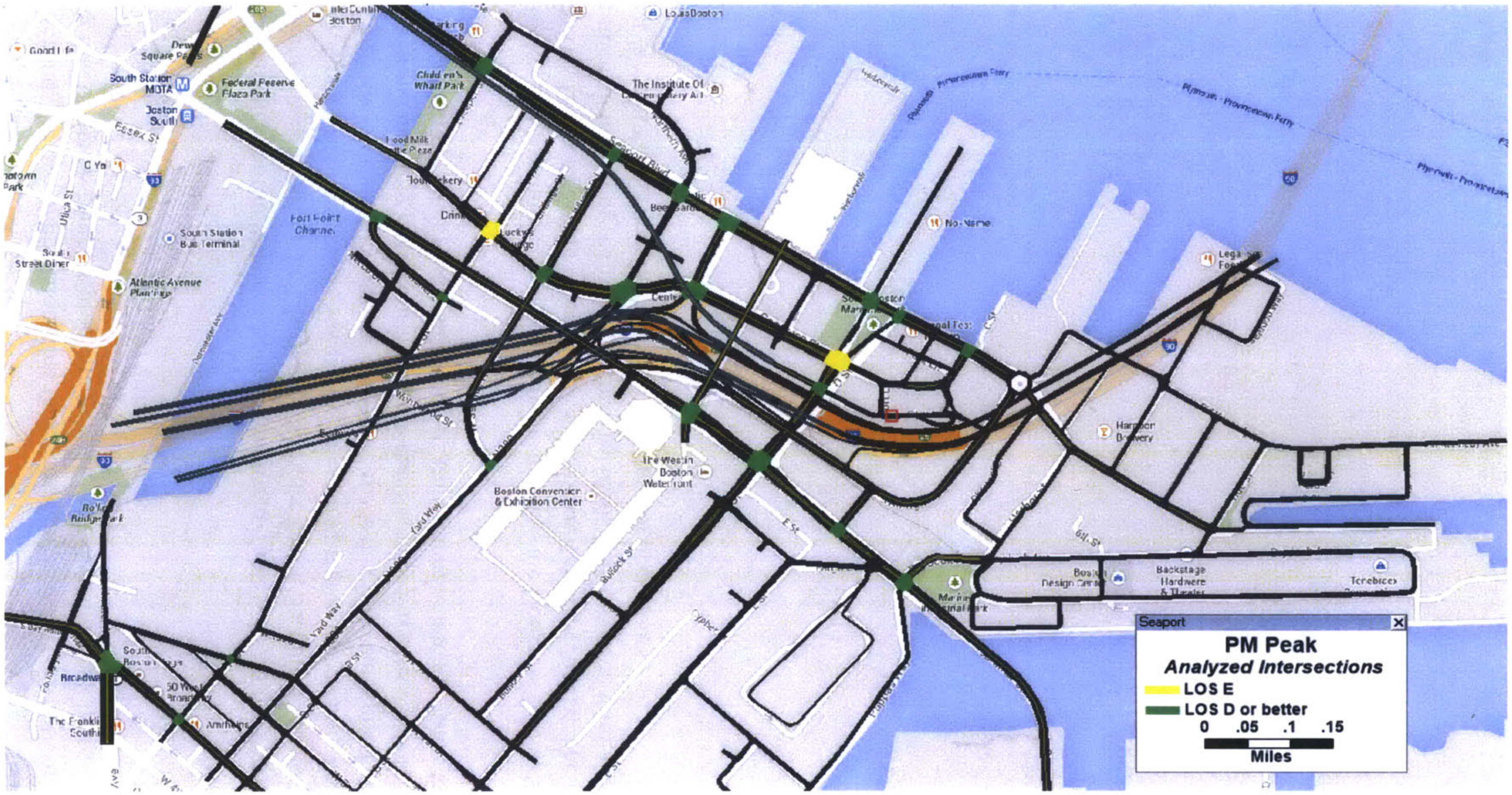


Figure 3-41: LOS of key intersections (PM peak hour)

Street	Delay (min/mile)	Street	VMT (veh-mi)
A St	1.2	A St	302
B St	7.0	B St	87
Boston Wharf Rd	5.6	Boston Wharf Rd	31
Broadway Bridge	6.9	Broadway Bridge	14
C St	2.0	C St	15
Congress St	9.0	Congress St	427
Cypher St	1.2	Cypher St	15
D St	5.1	D St	393
Design Center Pl	1.5	Design Center Pl	8
Dorchester Ave	2.5	Dorchester Ave	173
Drydock Ave	5.1	Drydock Ave	87
E 1st St	0.3	E 1st St	18
E St	3.1	E St	118
F St	2.0	F St	3
Fargo St	1.5	Fargo St	8
Farnsworth St	0.0	Farnsworth St	1
Garage Access Rd	0	Garage Access Rd	0
Harbor St	1.8	Harbor St	24
Haul Road	0.2	Haul Road	285
HOV line	0.0	HOV line	140
I90 Off-Ramp EB	2.8	I90 Off-Ramp EB	28
I90 Off-Ramp WB	18.6	I90 Off-Ramp WB	19
I93 Off-Ramp	2.6	I93 Off-Ramp	35
I93 On-Ramp	1.0	I93 On-Ramp	23
Mass Pike	0.1	Mass Pike	5234
Melcher St	4.9	Melcher St	33
Old Northern Ave	0.0	Old Northern Ave	1
Pump House Road	3.8	Pump House Road	8
Seaport Blvd/Northern Ave	3.1	Seaport Blvd/Northern Ave	808
Sleeper St	7.6	Sleeper St	33
Summer St	1.4	Summer St	1212
Thompson Place	0	Thompson Place	0
Tide St	2.0	Tide St	3
W 1st St	0.6	W 1st St	276
W 2nd St	9.6	W 2nd St	48
W 3rd St	2.0	W 3rd St	3
W Broadway	2.9	W Broadway	503
W Service Rd	1.2	W Service Rd	53
WTC Ave	0.9	WTC Ave	7

Table 3-25: Link statistics (PM peak hour)

3.3 PARKING

This section describes the current parking conditions in the District. It provides information about the number of existing parking spaces, parking policies, and the locations of major parking facilities. The section is divided in three parts: parking freeze, off-street parking and on-street parking.

3.3.1 Parking freeze

The Massachusetts State Implementation Plan (SIP) implemented an off-street parking freeze in Downtown, East, and South Boston as a measure of reducing vehicle emissions, encouraging public transport use, and stimulating transit oriented development in those three areas. On March 15, 1993 the Massachusetts Department of Environmental Protection adopted the South Boston Parking Freeze regulation. The regulation became effective in the area on April 9, 1993. The Freeze established three zones in South Boston: (a) Piers, (b) Industrial/Commercial and (c) Residential. The zones were separated geographically as shown in Figure 3-42. The Seaport District covers the entire Piers Zone and part of the Industrial/Commercial Zone.[22]

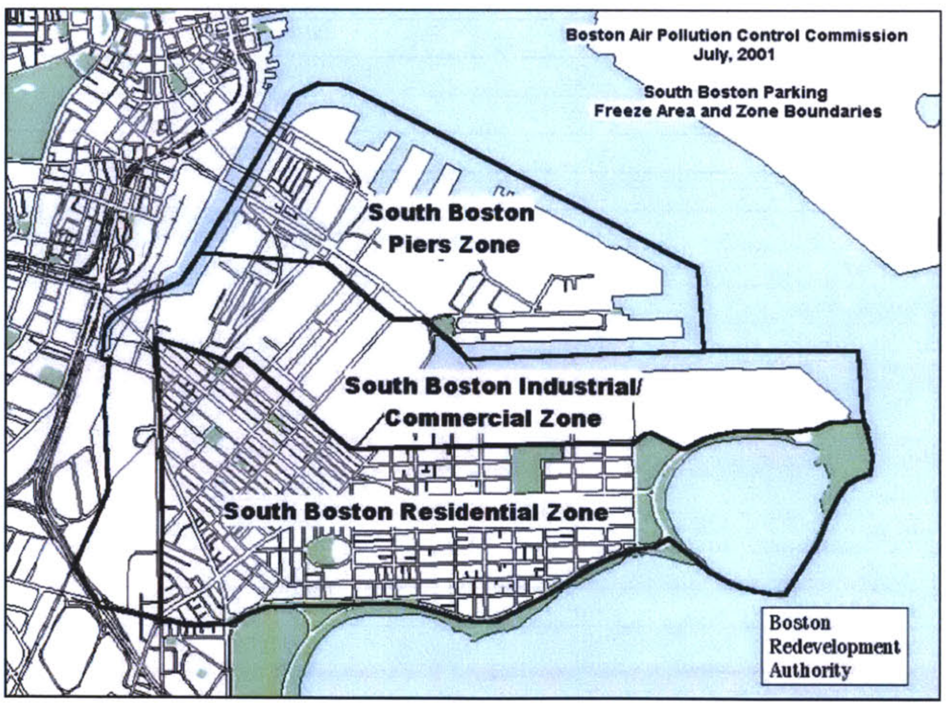


Figure 3-42: South Boston parking freeze zoning system[23]

[22] Commonwealth of Massachusetts – Department of Environmental Protection (July 2001)
[23] Boston Redevelopment Authority

The Boston Air Pollution Control Commission (APCC) is responsible for the operation, maintenance and enforcement of the South Boston Parking Freeze. APCC issued initial parking permits to all owners of property with motor vehicle parking spaces. APCC has the authority to modify initial parking permits as well as to issue new permits. However, to discourage automobile commuting, the Commission initially required that during the morning peak (07:30 – 09:30) all parking facilities in the South Boston Piers Zone are permitted to utilize only 90% of their off-street parking spaces. The percentage was reduced to 80% after the South Boston Transit Way started servicing the area.

In terms of on-street parking, as illustrated in Figure 3-43, curb parking is restricted in the western part of the District. Residents can park their vehicles only if they have a parking permit, while visitors must pay an hourly fee. For the rest of the Seaport District, on-street parking is not strictly regulated; residents and visitors alike can park their vehicles by paying an hourly fee.

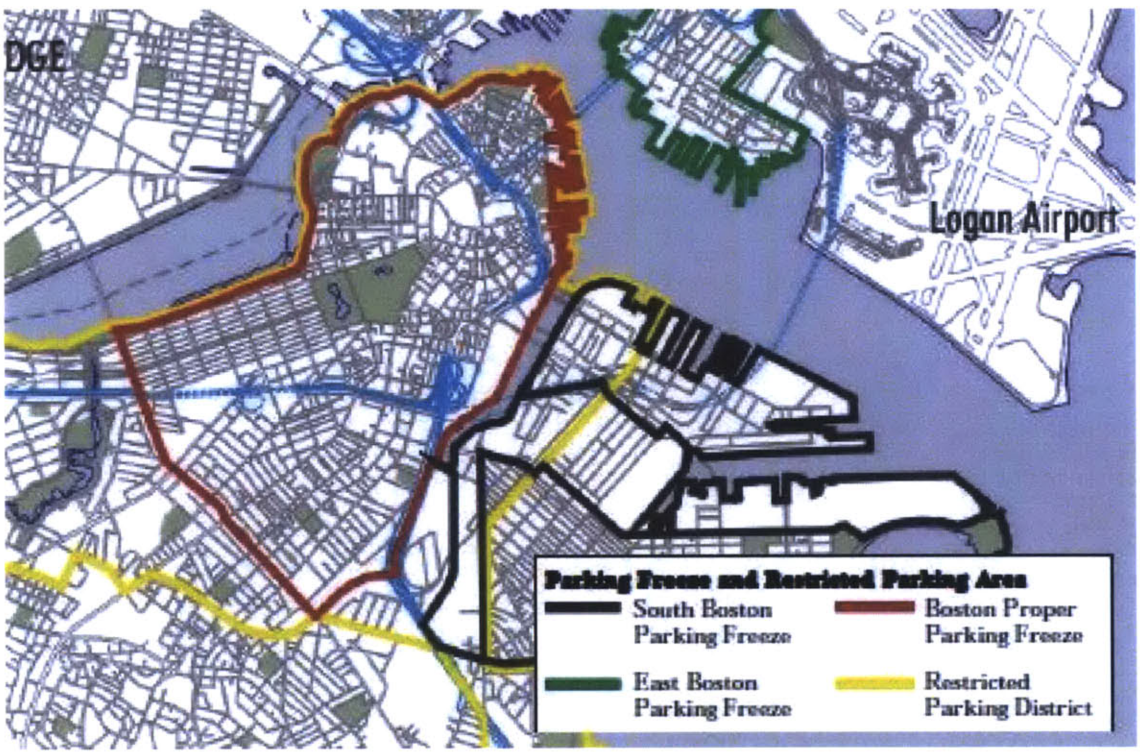


Figure 3-43: Map of restricted parking in the area[24]

[24] City of Boston – Department of Transportation (2001), Map from Access Boston 2000-2010.

3.3.2 Off-street parking

The number of off-street parking spots in South Boston cannot exceed 30,389[25]. In the Seaport District today, 19,509 parking are assigned and are classified either as Pier or Industrial/Commercial, depending on their location and usage (refer to Appendix A2 for the detailed off-street parking inventory). However, of the 19,509 permitted parking spots, only a limited number (roughly 60% or 12,000) are currently provided in parking lots and garages. It should be noted that the Boston Convention and Exhibition Center currently has an additional 2,204 parking spots that do not count in the "bank" established by the Freeze. Figure 3-44 illustrates the number and location of off-street parking spaces and other details about the transportation network in the District. Note two things about the off-street parking numbers in Figure 3-44. First, they represent the total permitted spaces, which means that not all the spaces necessary exist today. Second, since they represent the total permitted spaces per parcel, some of the adjacent values are "0" as these have already been accounted for in the respective parcel. Detailed information about the inventory of off-street parking spaces in the District is shown in Appendix A2.

[25] City of Boston http://www.cityofboston.gov/environment/AirPollution/southboston.asp (last visit 5/19/2014)

Figure 3-44: Off-street and on-street parking spaces in the Seaport District[26]

[26] City of Boston Environment Department (2014)

3.3.3 On-street parking

The number and location of on-street parking spaces is shown in Figure 3-44 above. Note from Figure 3-44 that there are around 429 parking meters in the area, most of which are double-meters, which sum to approximately 800 on-street spaces. Those spaces are concentrated in the following road segments:

- Seaport Boulevard. Metered parking is available east of Sleeper Street to D Street, on both sides of the Boulevard. Parking is also allowed for residential use east of B Street.
- Sleeper Street. Residential parking is allowed only east of the Street and south of Seaport Boulevard.
- Boston Wharf Road/W Service Road. Parking is allowed north of Congress Street.
- East Service Road. Some parking spots are available between Congress Street and Seaport Boulevard on both sides of the road.
- D Street. Curb parking is permitted south of Congress. A limited number of spots are also available between Congress Street and Northern Avenue, on the west side of D Street.
- Congress Street. Parking is allowed west of Boston Wharf Road on both sides.
- Thomson Place. Access is limited by barriers; however, some perpendicular and very few parallel parking spots exist near Congress Street, securing access to the nearby buildings.
- Summer Street. Parking is allowed west of D Street on both sides. However, on-street parking is not allowed in front of the Convention Center and on that side of the road.
- Melcher Street. Parking is allowed on both sides.
- World Trade Center Avenue. This is an elevated ramp with a limited number of parking spots north of Congress Street.
- Drydock Avenue. Parking is allowed only on the north side from Harbor Street to the end of Drydock Avenue.
- A Street. Parking is allowed south of Necco Street, but only on the side of the road (east in the beginning and west later on). Between Congress and Necco, curb parking is available on both sides.

3.3.4 Utilization

As discussed in section 2.1.1, our analysis indicates that in the base year, the AM peak hour (08:00 – 09:00) attracts about 5,200 vehicle trips. Considering that during the rest of the morning peak (i.e. from 07:30 – 08:00 and 09:00 to 09:30) demand is not as significant as in the peak hour, we assumed that the rest of the morning peak carries the equivalent of 70% of the peak hour demand, or 3,600 vehicle trips. Therefore, the total demand for parking during the morning peak is estimated at 8,800 vehicles.

From the supply side, we assumed that the parking facilities in the District adhere to the 80% utilization regulation for the morning peak, which means that 9,600 (12,000*0.8) off-street parking spaces are available in the morning peak. Additional parking supply is available from the on-street parking spots. By including the 800 on-street parking spots with the 9,600 off-street spots, we end up with a total parking supply of 10,400 spots. Subtracting the 8,800 vehicles from the existing 10,400 parking spots, we get 1,600 unutilized parking spaces. Therefore, the current parking supply adequately serves the AM peak demand for vehicle trips.

In terms of the PM peak hour, generally parking is not an issue since most people are exiting the District. However, there are two issues to note. First, in terms of off-street parking, the 2010 US Census reports that there are about 1,500 vehicles for the 2,100 residents in the District, which means that usually the available off-street parking spaces for non-residents is around 10,500. Second, in terms of on-street parking, 800 spaces are probably low given that the District has numerous high quality restaurants and a lively night-life. In fact, during our visits to the area, we had difficulty finding on-street parking spaces and noted that some restaurants offered valet services at high rates even on weekday evenings, indicating that indeed there is a shortage of on-street parking spaces.

The current parking situation can be summarized as follows:

- The current supply exceeds the base year demand for vehicle trips. Even with the 80% restriction during the AM peak, there is still a significant number of spots that remain unutilized.
- The current off-street parking supply is enough to accommodate the base year demand. Therefore, a reduction in on-parking spots can be considered, providing extra lanes to public transport, if necessary. Visitors will be significantly affected by this policy, however they will gain by having better public transport access in the area.
- The threshold of permitted off-street parking spots set from the South Boston Parking Freeze is significantly higher than the base year demand (by a factor of three).

3.4 SENSITIVITY ANALYSIS

This section describes the sensitivity analysis conducted of the road network performance for both the AM and the PM peak hours. The purpose of this analysis is:

a) To estimate the impacts of different demand levels on the road network.
b) To assess the capacity of the road network, if no changes were made.
c) To evaluate if the South Boston Parking Freeze is consistent with the road network capacity.

Two things should be noted about the sensitivity analysis. First, this analysis considers the capacity of the network to be constant and deterministic since it considers that no significant changes to the network will occur. In reality, it is possible to increase the capacity of the network by introducing small improvements; however, it is reasonable to assume that any increase will not be significant and the sensitivity analysis can adequately address that by providing range estimates. Second, sensitivity analysis was preferred since the ITE Trip Generation Manual, which was used to estimate future demand, fails to estimate changes in trip trends (such as shifts in mode choice and/or peak spreading) that may occur when demand for trips in the area increase significantly.

In the following sections, we will first discuss the setup of the sensitivity analysis, which is a description of why we chose to increase base demand by certain percentages. We will then present a summary of the results of our sensitivity analysis and discuss their implications. Finally, we will give our conclusions regarding the three main purposes of this analysis.

3.4.1 Setup

For the purpose of this analysis, demand was separated into three categories: (a) trips attracted to the District, (b) trips generated from the District and (c) trips through the District, the majority of which use the Interstate highway system. As described in section 2.1, attracted trips are important during the AM peak hour, while generated trips are important during the PM peak hour. Increase in demand was based on the following criteria:

- For the AM peak hour:
    - Attracted trips were increased by 10%, 20%, 30%, 40% and 50%.
    - Generated trips were increased by 9%, 16%, 22%, 27% and 30%.
    - Through trips were increased by 5.7%, 9.2%, 12.9%, 18.1% and 23.5%.

- For the PM peak hour:
    - Attracted trips were increased by 9%, 16%, 22%, 27% and 30%.
    - Generated trips were increased by 10%, 20%, 30%, 40% and 50%.

- Through trips were increased by 5.7%, 9.2%, 12.9%, 18.1% and 23.5%.

The ratio between the increase of attracted trips and the increase of generated trips was estimated based on the ratio of expected future residential developments and future jobs. For example, in the AM peak hour, a 20% increase in generated trips is consistent with the forecast increase in residential units, and a 16% increase in attracted trips is consistent with the increase in jobs. For through trips the increase was based on the MassDOT Traffic and Revenue study for 2010. For more detail regarding demand increase and forecasts, refer to Chapter 2.

3.4.2 Results

The results of the conducted sensitivity analysis are illustrated and discussed for the AM and PM peak hours. The results were based on the following five sensitivity sets for the AM peak hour (note that the percentages of attracted and generated trips were reversed for the PM peak hour):

- Scenario 1: Increase attracted trips by 10%, generated trips by 9%, and through trips by 5.7%
- Scenario 2: Increase attracted trips by 20%, generated trips by 16%, and through trips by 9.2%
- Scenario 3: Increase attracted trips by 30%, generated trips by 22%, and through trips by 12.9%
- Scenario 4: Increase attracted trips by 40%, generated trips by 27%, and through trips by 18.1%
- Scenario 5: Increase attracted trips by 50%, generated trips by 30%, and through trips by 23.5%

Average Speed

During both the AM and the PM peak, average speed is reduced as demand increases. As can be seen in Figure 3-45, for every scenario in the sensitivity analysis, the average speed recorded for the AM peak hour is lower than the average speed in the PM peak hour. This trend is consistent with the baseline scenario (year 2009), and is likely due to the fact that trips during the AM peak hour are more concentrated in the Northwestern part of the District, whereas during the PM peak hour the trips are distributed in the network in a more homogenous way. It should also be noted that the average speed in the AM peak hour reduces significantly until scenario 4, but remains practically unchanged between scenarios 4 and 5. For the PM peak hour however, the average speed reduces slightly until scenario 4, but a sudden drop is recorded for scenario 5.

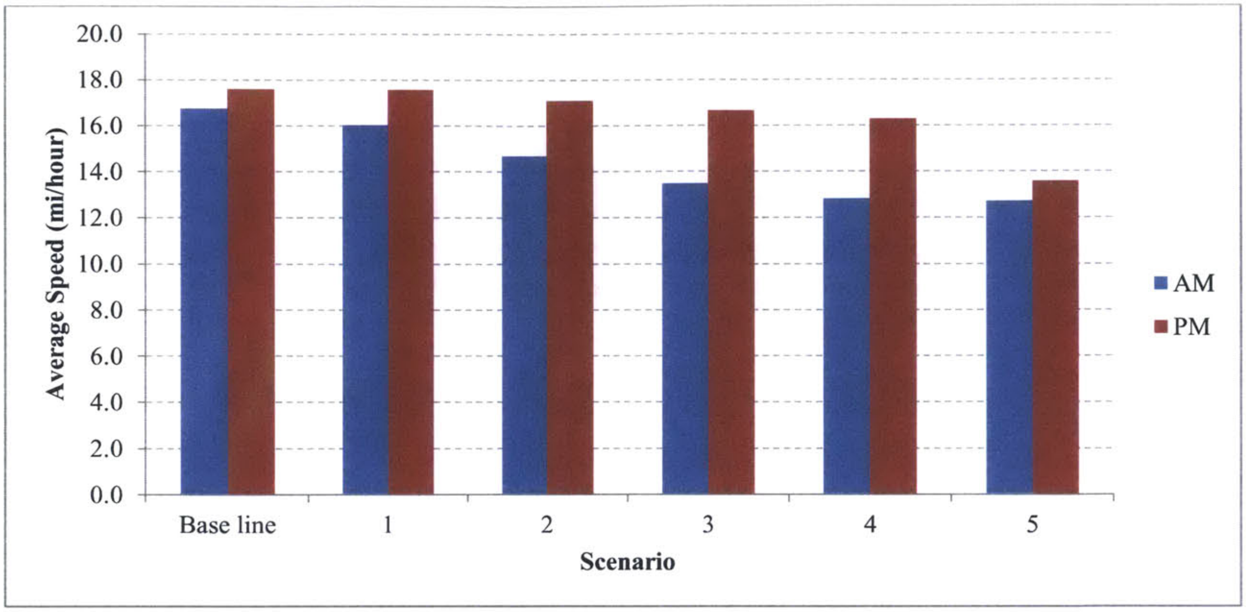


Figure 3-45: Average speed

Average Delay

As expected, average delay increases with demand. For the AM peak hour, the increase is more severe than in the PM peak hour. However, for both periods, delay per vehicle more than doubles between the 2009 and scenario 5 conditions. The results for the AM and the PM peak hours are shown in Figure 3-46.

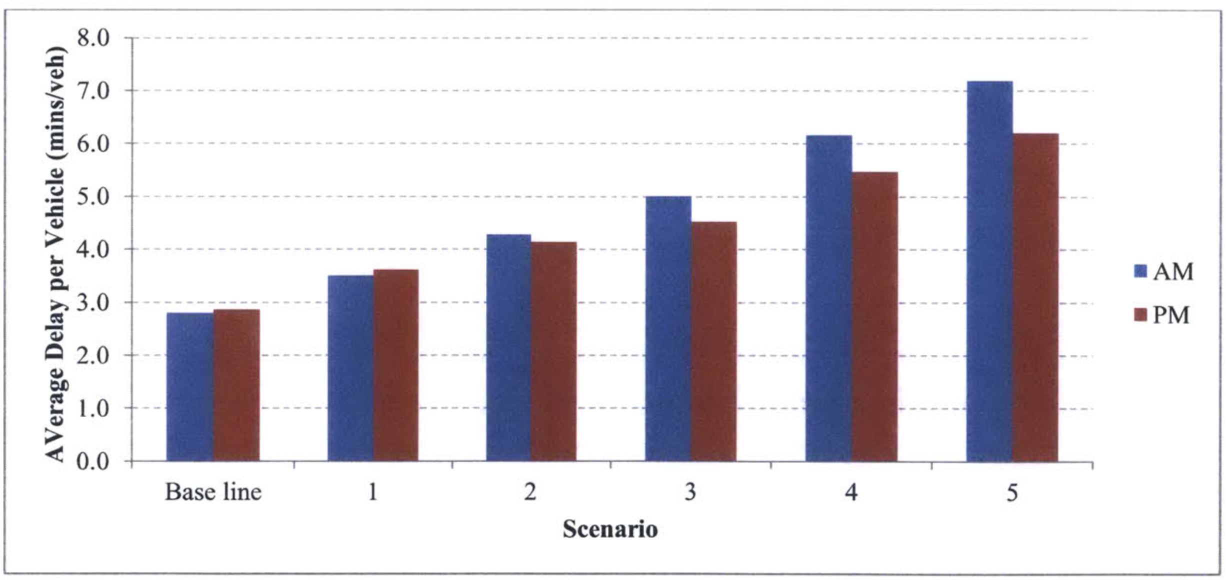


Figure 3-46: Average delay per vehicle

Intersection LOS

In the intersection analysis, the AM peak hour faces significant problems as demand increases, as shown in Figure 3-47. Note three things. First, even in the baseline case, five intersections experience problematic conditions. Second, the number of intersections that operate above capacity (LOS F) is stable between the baseline and scenario 4, whereas the number of intersections that operate at capacity (LOS E) continually increases across scenarios. Third, the results of scenario 5 suggest that more than half of the analyzed intersections experience significant problems.

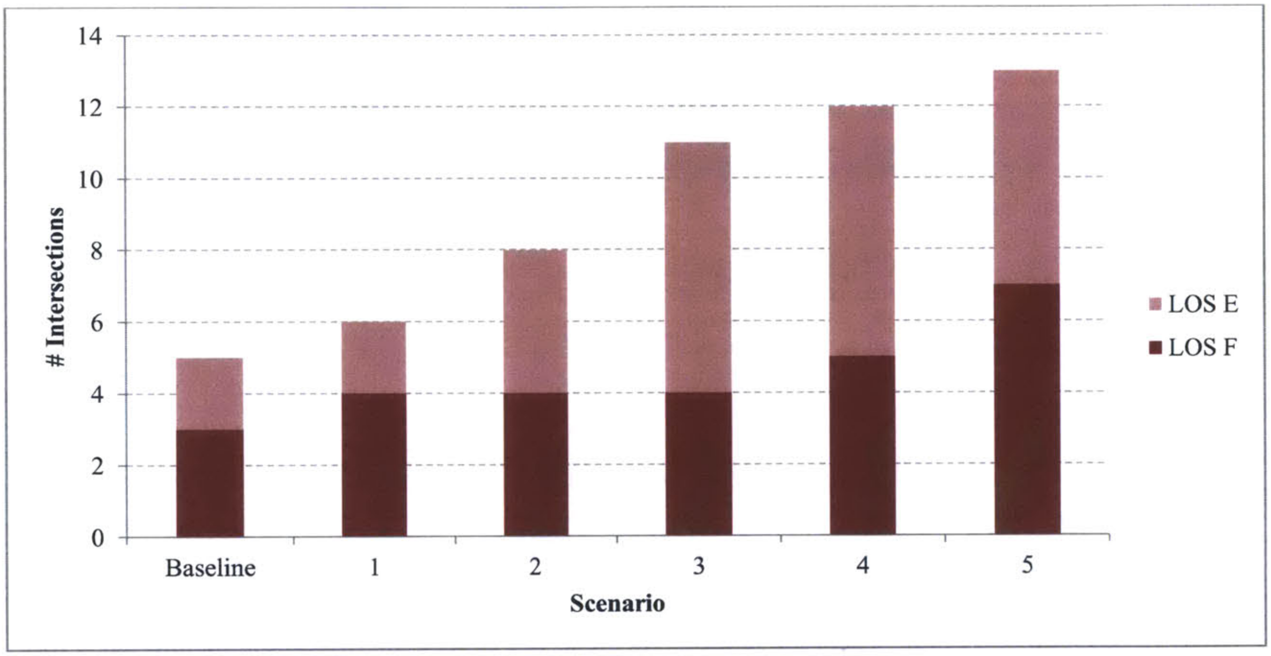


Figure 3-47: Intersections operating at LOS E and LOS F (AM peak hour)

The results for the PM peak hour reveal few bottlenecks in the area, especially for low or moderate increase in demand, as illustrated in Figure 3-48. Note that even in scenarios 4 and 5, only four intersections operate above capacity and two operate at capacity. Even though such intersection performance is not acceptable, it should be noted that, when comparing the AM and PM peak hour intersection results, the road network operates much better during the PM peak. This conclusion is confirmed by the aggregate statistics for each peak hour.

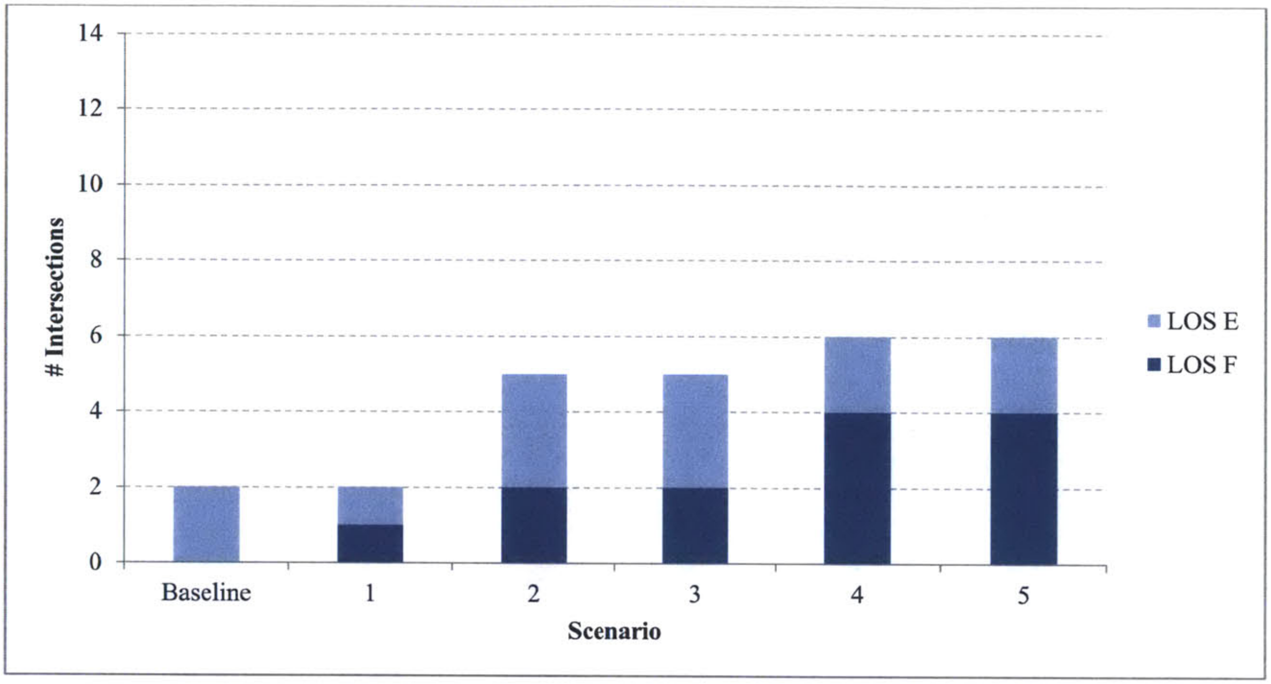


Figure 3-48: Intersections operating at LOS E and LOS F (PM peak hour)

Results from all off-ramps that connect the highway system to the Seaport District reveal significant increases in maximum queue lengths as demand for vehicle trips in the network increases (see Figure 3-49, Figure 3-50, and Figure 3-51). In particular, the demand that corresponds to scenario 2 seems to be the turning point since queues are spilling into the regional highway system and results record a sudden and steep increase in maximum queue lengths. From that point, the maximum queue lengths increase significantly from one scenario to the next. Therefore, based on these results, it is estimated that without any changes in the road network, an increase in demand of between 10% and 20% is enough to cause significant problems that will affect both the accessibility of the District, as well as the stability of the regional network. However, it is important to note the caveat that the results illustrate the maximum queue lengths recorded during the peak hour, meaning that the high queue lengths in scenario 2 (for instance) are not necessarily regularly experienced during the entire peak hour. Nevertheless, we note that even if such high queue lengths existed for only 20% of the peak hour, the significant effects on the regional highway system could not be ignored and would have to be addressed.

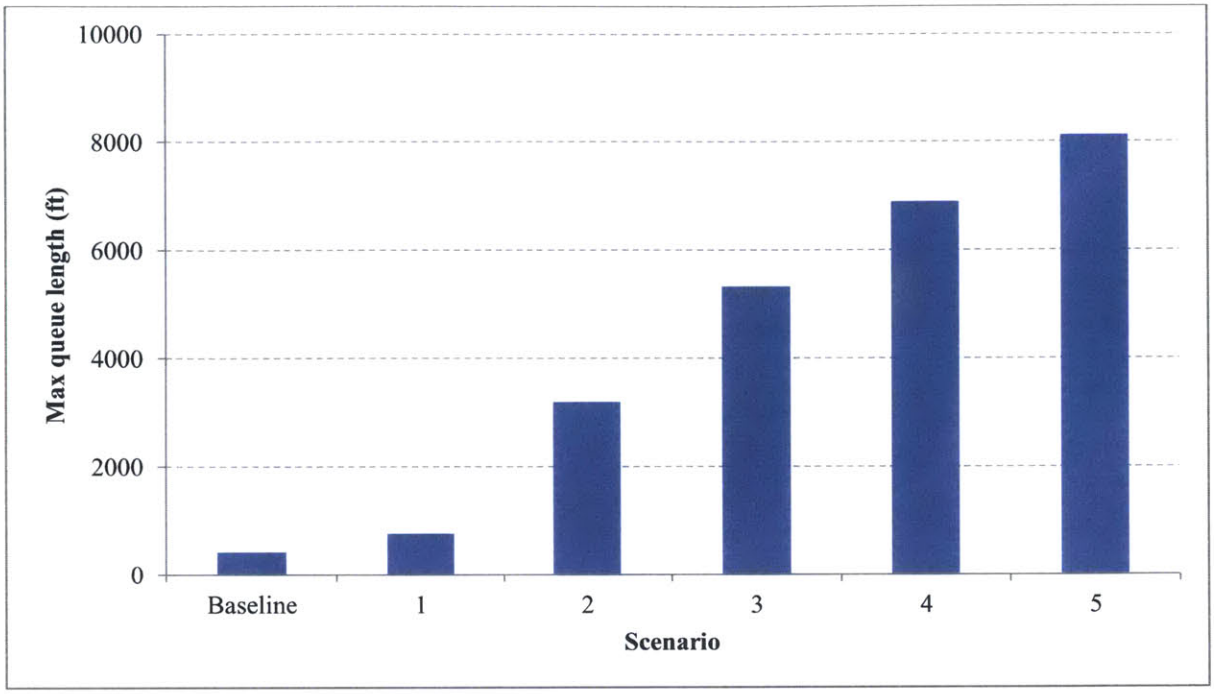


Figure 3-49: Maximum queue length at I-90 off-ramp WB (AM peak hour)

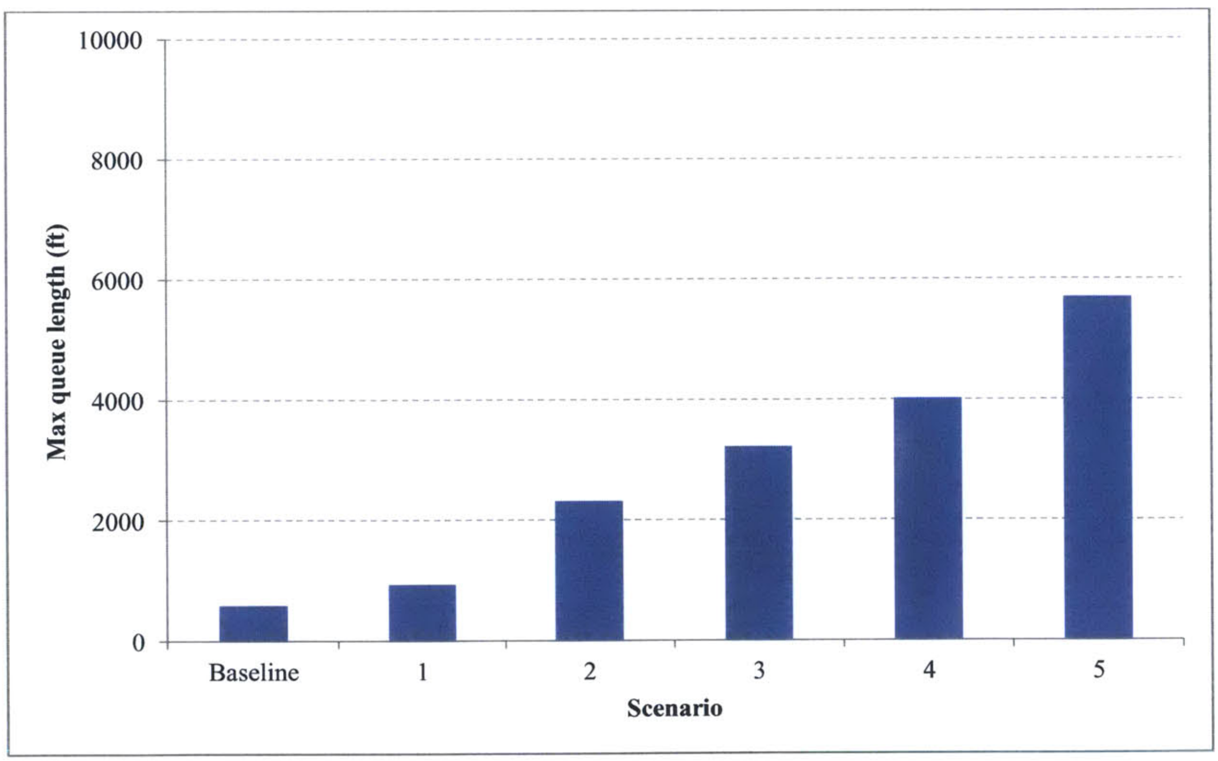


Figure 3-50: Maximum queue length at I-90 off-ramp EB (AM peak hour)

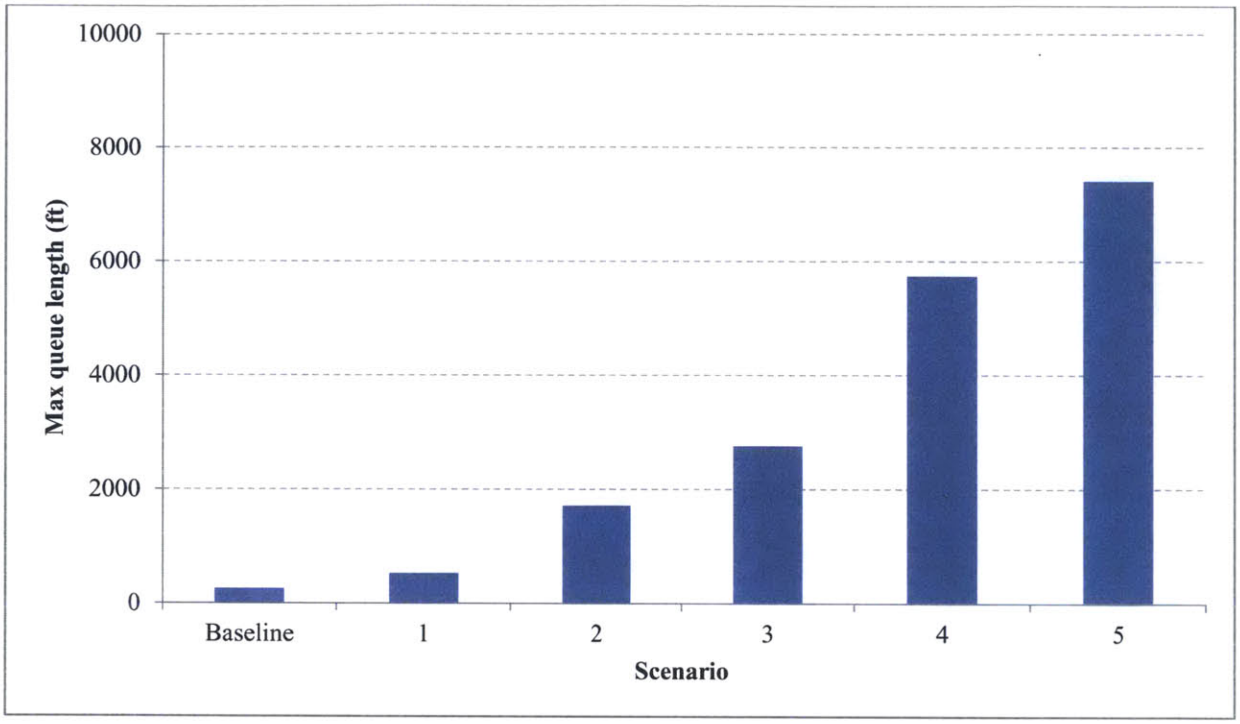


Figure 3-51: Maximum queue length at I-93 off-Ramp EB (AM peak hour)

4 SHORT-TERM ANALYSIS

This chapter focuses on the short-term analysis, corresponding to the year 2017. Under this scenario, development projects that are currently under construction will be completed, increasing the demand for public transport and vehicle trips in the District. This chapter provides an estimate of the future demand, investigates the expected impacts if no improvements are made to the transportation network, and proposes alternatives to tackle the expected future problems. Note that in this chapter, "no-build" means that the existing (i.e. 2009) transportation network has not been modified, whereas "build" means that the existing transportation network has been modified.

4.1 ESTIMATED DEMAND

Future demand was estimated based on the ITE Trip Generation Manual and ABC's estimates (adjusted based on the recent growth experienced in the Seaport District). A detailed description of the methodology is provided in Chapter 2. The forecast demand for 2017 is shown in Table 4-1.

		Person Trips					
		AM Peak Hour			PM Peak Hour		
Year	Zone Type	Total	Attracted	Generated	Total	Attracted	Generated
2017	Office	7409	6520	889	8791	1494	7297
	Industrial	2078	1808	270	2040	592	1449
	Hotel	1037	591	446	931	270	661
	Retail	4076	2814	1262	6237	3544	2693
	Residential	1088	316	773	1248	761	487
	Total	**15687**	**12048**	**3639**	**19247**	**6661**	**12586**

Table 4-1: Demand forecast for the short-term analysis

Scenario 2 of the sensitivity analysis corresponds to a roughly 20% increase in vehicle trips attracted to the District during the AM peak hour[27], which is consistent with the increase in demand of person trips as calculated from the ITE manual for 2017. However, the assumption that the proportional increase in person trips will be reflected in vehicle trips implies that the mode split remains constant during peak hours. For trips originating and trips terminating in the area, a decisive factor that affects mode split is parking supply. As discussed in Chapter 3, the

[27] For the PM peak hour, the 20% increase was an increase in vehicle trips generated from the District.

parking capacity in the District today is estimated to be 10,400 parking spots during the AM peak period. Assuming that this number will remain constant until 2017, we estimated whether the parking supply will effectively constrain the vehicle trips in the area. The estimation was made as follows:

> From the O-D matrix of Scenario 2 in the sensitivity analysis, we estimated 6,100 vehicle trips attracted to the District during the AM peak hour. Assuming an additional 70% of vehicle trips for the rest of the AM peak period (based on current peak hour to peak period demand ratios), the total number of vehicle trips attracted to the District is estimated to be 10,400. Given that there are 10,400 existing parking spaces available during the AM peak period, we can conclude that the parking supply can meet the estimated 2017 demand and therefore, there is a strong likelihood that the mode share will remain constant. However, as development occurs, it is highly likely that the parking supply will increase because the South Boston Parking Freeze permits a total of approximately 19,500 spaces in the area.

In terms of public transport, the estimated short-term demand per route (see Table 4-2) was based on three assumptions:

- Attracted ridership (to District) increases by 20% and generated ridership (from District) increases by 16%.
- Current public transport origin-destination patterns will be maintained.
- Current mode share remains constant.

Note that SL2 and SLW are combined since much of the demand to the District is only within the trunk route, with considerably less ridership to the Design Center, as discussed in Chapter 3. Separating the two overstates SL2 demand since in the future, SLW will have lower headway, so the ridership share will undoubtedly change in favor of whichever route has the best service within the trunk. This will be applied for medium- and long-term demand as well.

	AM peak hour direction	PM peak hour direction
SL1	379	478
SL2 & SLW	1396	1351
Route 4	44	55
Route 7	233	63

Table 4-2: Short-term future public transport demand

4.2 NO-BUILD SCENARIO

The no-build scenario describes the performance of the public transport and road network in the District in the short-term, if no changes are made.

4.2.1 Public Transport

	AM peak hour direction	PM peak hour direction	Current peak hour capacity
SL1	379	478	318
SL2 & SLW	1396	1351	1560
Route 4	44	55	216
Route 7	233	63	702

Table 4-3: Short term peak hour District demand and capacity

The increased demand in the short-term scenario, which is estimated at 20% proportional growth, will exceed the current capacity of SL1 and SL2 during the peak hour, as shown in Table 4-3. All the other MBTA surface bus routes currently provide enough capacity for the 2017 no-build scenario. However, note that since a large proportion of SL2 riders use stops that are shared with SLW (as discussed in the current assessment), some of the SL2 demand can be split into the SLW, so there is likely to be enough capacity overall. As for SL1, all the stops within the District are shared with SL2/SLW, so the demand can be easily transferred. However, if we sum the demand on all SL routes, which is 1,829 for PM peak, and compare it with the current total capacity of 1,878, we find that the current operations can only just accommodate the short-run scenario, leaving very little margin of safety if demand increases faster than expected. Thus, the level of service on SL can easily deteriorate due to over-crowding. Perhaps more significantly, this high demand, close to capacity, within the District means that any airport passengers with luggage will find it extremely difficult to use SL, which of course is undesirable. So, a more effective way to separate Seaport and Logan demand, as well as provide added capacity will be examined in the Strategies section.

A point to note with the data here is that the demand represents total ridership (i.e. boardings), which is not directly comparable to the capacity values since they were obtained through calculating the maximum load on the bus. However, the bottleneck of the Silver Line is in the South Station to World Trade Center section where most demand is concentrated, and the load on this section is very similar to the total ridership on SL because passengers to the airport and Design Center as well as WTC will mainly board at South Station for outbound trips. Similarly, for inbound trips the loading on the WTC to South Station section is close to the total inbound ridership. Thus, we can use the total ridership to indicate the load at the bottleneck section. Note that the demand here only contains the District's generated and attracted passengers, and hence it cannot represent the load on local bus routes, especially Route 7. Since the district's demand only consist of a small share of the total ridership on Route 7, the capacity issue of this route relies more on the City Point's demand rather than Seaport District's demand. For Route 4, the low ridership in the baseline scenario makes the short-run capacity enough, even when considering the whole route's ridership.

For the private shuttles, the capacity on the individual shuttles can be treated as a soft constraint since the capacity of private shuttles is adaptable and evolves according to the demand. Moreover, the current boarding for each private shuttle is less than 20 and the 20% increase will provide an estimated 4 more riders on each vehicle, which for most routes will not result in capacity issues, assuming random arrival of passengers during peak hour. Thus, the level of service of private shuttles will not become an issue in the short run. Yet, from a system point of view, the current system of individual shuttles is not very cost efficient and can likely be improved by initiating consolidated routes that provide better frequency and service span.

4.2.2 Traffic

As noted earlier, the no-build short-term scenario corresponds to Scenario 2 of the sensitivity analysis, in which attracted trips were increased by 20%, generated trips were increased by 16% and through trips were increased by 9.2% (the attracted and generated trip increase percentages were reversed for the PM Peak Hour). The road system performance results of the baseline and Scenario 2 are shown in Table 4-4.

	Average Delay		Average Speed		
		AM Peak Hour			
Scenario	Mins/veh	Change	Miles/hour	Change	# Trips
Base line	2.8		16.7		14,158
2	4.3	53%	14.7	-12%	15,936
		PM Peak Hour			
Base line	2.9		17.6		16,203
2	4.1	44.4%	17.1	-2.8%	18,143

Table 4-4: Aggregate statistics (short-term no-build)

For the AM peak hour, there are eight intersections operating under capacitated conditions. It should be noted that the intersections operating at LOS F have very high control delays (larger than 200 seconds). These high delays affect neighboring intersections such as the Congress Street, West Service Road and Boston Wharf Road intersection (which is now at LOS E) probably due to spillover effects.

For the PM peak hour, two intersections are operating over capacity (i.e., LOS F) and two intersections operating at capacity (i.e., LOS E). The bottlenecks in the District in this scenario are significantly increased in comparison to the base case. Control delay and average number of stops also increase to every intersection. Table 4-5 shows the statistics regarding the bottlenecks in the area for both the AM and the PM peak hours.

Intersection	Control Delay (sec/veh)	Average Stops (stops/veh)	LOS
	AM Peak Hour		
B St, Congress St, I90 Off-Ramp WB & I93 On-Ramp	59.2	1.1	**E**
Congress St & D St	72.9	1.3	**E**
Congress St, W Service Rd & Boston Wharf Rd	57.2	1.2	**E**
Northern Ave & D St	60.4	1.3	**E**
Drydock Ave, Summer St	220.1	3.7	**F**
I90 Off-Ramp EB, I93 Off-Ramp, Congress St	124.7	2.0	**F**
Northern Ave, Old Northern Ave, Seaport Blvd	108.2	1.7	**F**
Boston Wharf Rd & Seaport Blvd	145.7	1.9	**F**
	PM Peak Hour		
Congress St, A St & Thompson Place	95.7	1.6	**F**
Dorchester Ave, Broadway Brg & W Broadway	94.2	1.9	**F**
Congress St & D St	66.4	1.1	**E**
Summer St & WTC Ave	54.2	0.9	**E**

Table 4-5: Intersection statistics (short-term no-build)

Regarding the off-ramp queues in the AM and PM peak hours, Table 4-6 shows the maximum length of the queues at the three major off-ramps from the Interstate system. For the AM peak hour, Figure 4-1 displays the maximum queues on the street network. Note that in this scenario, all three off-ramp queues disrupt the mainline Interstate flow and delay the vehicles that are not going to the District. For the PM peak hour, the I-90 and I-93 off-ramps maximum queue lengths increase significantly compared with the base line scenario. However, no spillover effect is recorded.

Ramp	Max Queue Length (feet)
AM Peak Hour	
I-90 Off-Ramp (WB)	3,206
I-90 Off-Ramp (EB)	2,317
I-93 Off-Ramp	1,715
PM Peak Hour	
I-90 Off-Ramp (WB)	215.6
I-90 Off-Ramp (EB)	119.3
I-93 Off-Ramp	98.5

Table 4-6: Off-ramp statistics (short-term no-build)

In terms of link performance during the AM and PM peak hours, Table 4-7 shows the delay and VMT statistics of the worst five links in each period. The major entry/exit streets in the District encounter high delays but are still heavily used. Thus, the network is facing considerable difficulties accommodating the high flows on Seaport Boulevard, Congress Street, and Summer Street. In this scenario, D Street also experiences significant delays in both the morning and the evening peak hours.

a) I-90 WB

b) I-90 EB

c) I-93

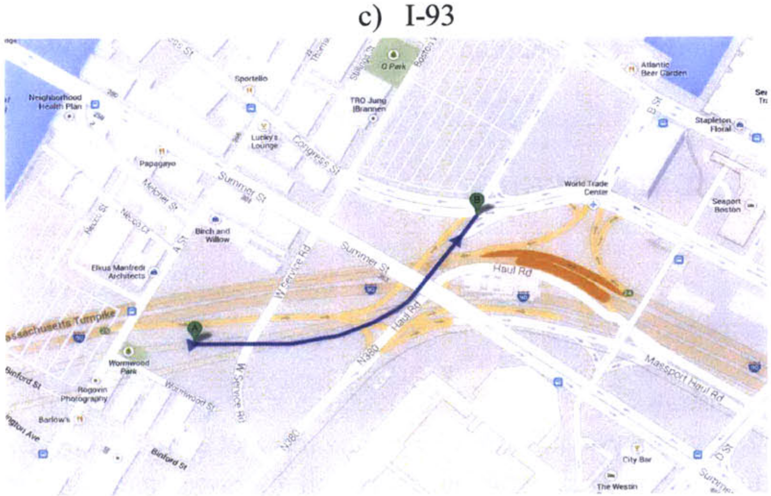


Figure 4-1: Maximum queue lengths at Interstate off-ramps (AM peak hour)

Street	Delay (veh-hrs)	Street	VMT (veh-mi)
AM Peak Hour			
Seaport Blvd/Northern Ave	158.9	Summer St	2,004
Summer St	143.7	Seaport Blvd/Northern Ave	1,193
Congress St	95.8	W Broadway	657
D St	31.3	Congress St	607
Dorchester Ave	22.4	D St	439
PM Peak Hour			
Congress St	83.6	Summer St	2,120.8
Seaport Blvd/Northern Ave	53.2	Seaport Blvd/Northern Ave	1139.6
D St	51.0	W Broadway	608.4
Summer St	50.0	Congress St	605.9
W Broadway	43.1	Dorchester Ave	441.8

Table 4-7: Link statistics (short-term no-build)

Overall, there are high delays per vehicle, many intersections operate at, or over, capacity, off-ramp queues are too long and interfere with the Interstate system, and major links experience high delays. In other words, it does not appear that the traffic network is able to handle this scenario in its current condition.

4.3 IMPROVEMENT STRATEGIES

4.3.1 Public Transport

The short-term strategies analyzed in this section aim to address the problems that will occur in the public transport system in 2017, in which the total demand for the system will increase by approximately 20%. The strategies focus on improving the public transport system without requiring major capital investments. The aim is to:

- Improve the Silver Line's capacity by optimizing the use of the current fleet and infrastructure.
- Propose shuttle consolidation alternatives.

The analyzed potential solutions include the following:

- Silver Line platooning, schedule improvement and using the State police ramp to access the Ted Williams Tunnel.
- Signal priority for the Silver Line at the D Street intersection.
- Express routes connecting the District to North Station, Green Line, Orange Line and Blue Line.

It should be noted that the peak hour demand is the bottleneck for the public transport system and the imbalance of the ridership during peak hour for trips into and from the District is evident from previous analyses. Therefore, the peak hour peak direction is the main concern for our analyses.

Figure 4-2 and Figure 4-3 show the current public transport system within the District, for the reader's reference.

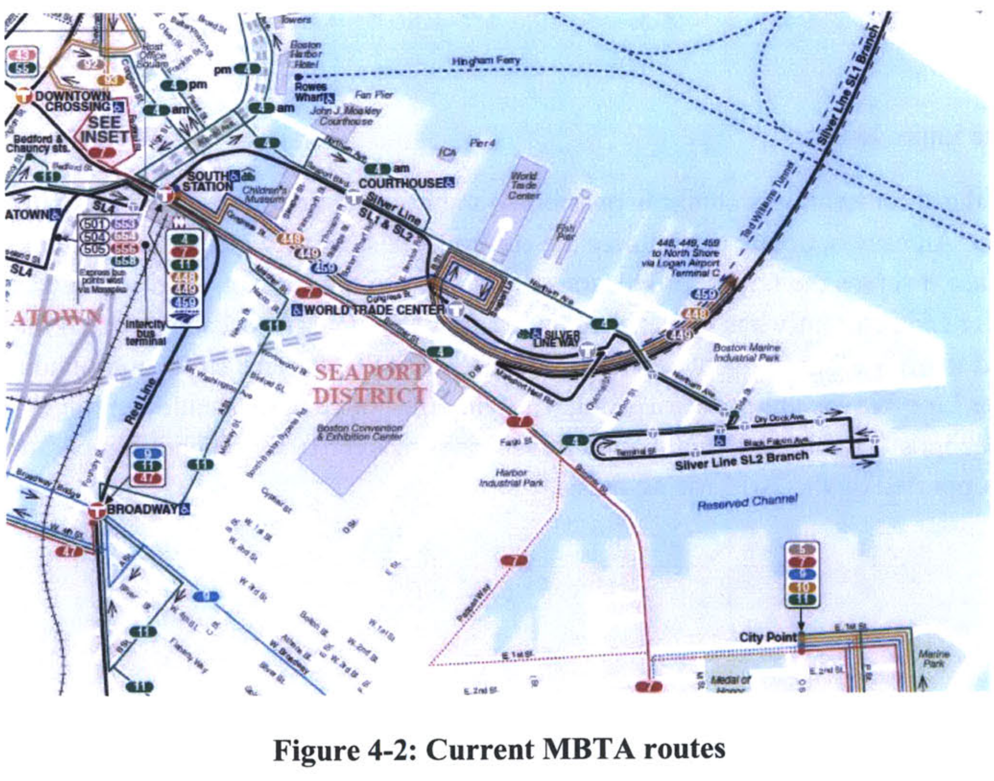


Figure 4-2: Current MBTA routes

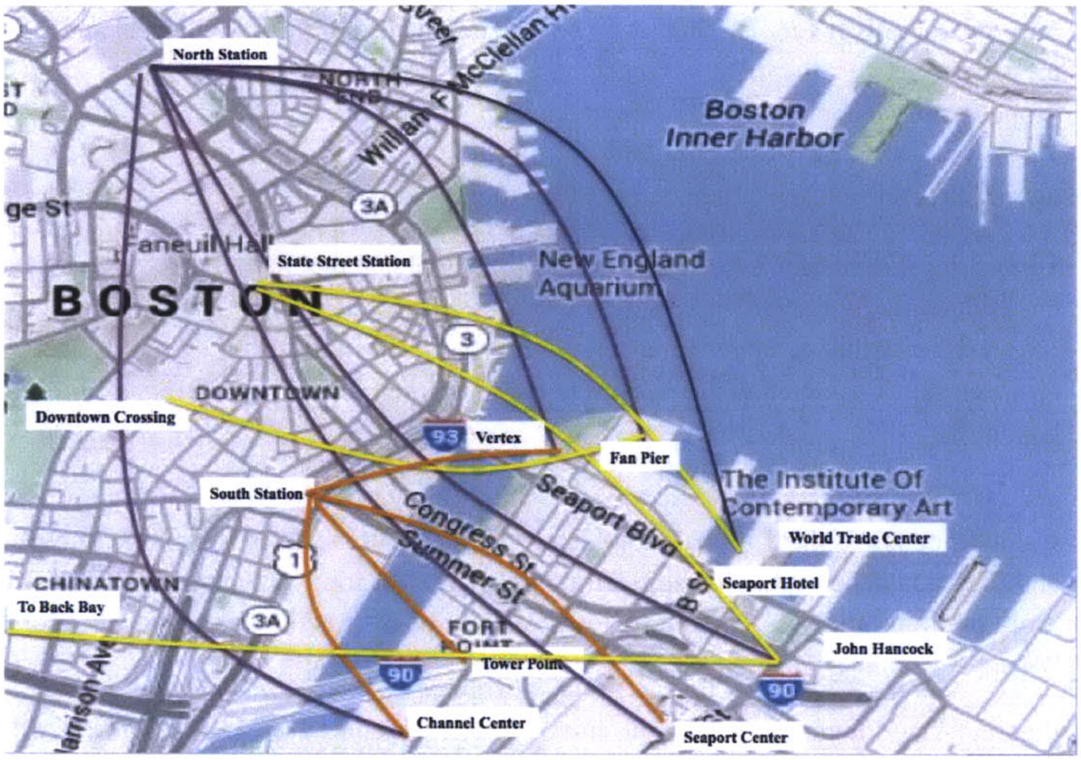


Figure 4-3: Current private shuttle routes (from field observations)

Silver Line Improvements

In the short term, it is certainly possible to improve public transport service in and around the District. An easy option is to optimize the currently existing service, particularly the Silver Line because it serves the largest proportions of travelers to the District. As discussed in Chapter 3, the Silver Line currently has higher than necessary cycle times (see Table 4-8), so these could be reduced to offer more frequent service. In addition, the SL1 surface street outbound route after Silver Line Way is unnecessarily long. Utilizing the police ramp should cut travel times by 100-120 seconds[28], reducing the outbound travel times by over 10%, which is a recommendation strongly supported by the 2013 MEng thesis[29].

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28 Conservative estimate – data collected on Sunday (off-peak) in March 2014. Time savings during peak will be higher.

29 Cao, O'Connor, and Were "Improving Public Transportation to Boston Logan International Airport" MIT MEng Transportation thesis (2013).

SL1	Duration	SL2	Duration
Cycle time (percentile)	50 (99.2%)	Cycle time (percentile)	30 (95.8%)
Actual 95^{th} percentile travel time	45	**Actual 95^{th} percentile travel time**	30
SLW			
Cycle time (percentile)		20 (99.9%)	
Actual 95^{th} percentile travel time		13	

Table 4-8: Scheduled vs. actual cycle times for Silver Line[30]

Another useful option is to use transit signal priority (TSP) at the D Street intersection, which could significantly reduce delays for buses especially during peak hours, thereby saving time for passengers as well as improving reliability/schedule adherence. This is shown in Table 4-9, where the reductions in average stop time for Silver Line is very large when compared to the base (non-TSP) case. Implementing TSP consistently reduces delays for Silver Line at the D Street intersection by 80% or more, at only a modest cost to autos (only around 10-15% increase in network delay). Therefore, TSP provides a very clear benefit that can significantly improve Silver Line performance.

Scenario	Existing Conditions	Existing with TSP	High travel growth (20%) without TSP	High travel growth (20%) with TSP	High travel growth (20%) with TSP and more buses
Buses per hour on Silver Line	30	30	48	48	60
Total Network Delay (hours)	64.5	66.0	123	136	137
Average Stop Time on Transit Way at D Street (seconds), both directions	48.4	5.65	43.6	8.25	9.5

Note: Travel growth percentages are for overall traffic (including auto) volumes.
"Network" = All intersections along D Street, from Summer Street to Seaport Boulevard inclusive.

Table 4-9: Effects of TSP

[30] MBTA schedule and AVL data 2013

Finally, perhaps the most significant operational change that could be implemented without incurring large capital costs is to use bus platooning, specifically on the SLW-SL1 routes. Bus platoons are two buses traveling in pairs, essentially acting as 'one' bus; this is achieved by having both buses departing as close to one another as possible at the originating station, and maintaining this configuration throughout the common portion of the route. So, both buses can be grouped as one unit for the purposes of headway calculations (although there will be a slight 10-15 seconds delay from one arrival to the next in real life, which is reflected in the sample schedule shown in Table 4-10) and thus is very useful in situations where there is a constraint on the headway, which is the case for Silver Line because of D Street. Note that this at-grade crossing means that the other (non-platooned) headways cannot be too low, otherwise severe congestion might occur.

Currently, there is a combined Silver Line headway on the main section (Silver Line Way to South Station) of 120 seconds during the peak hour. This could in fact be lowered further but, based on the analysis of last year's MEng thesis, 90 seconds seems to be the limit – even at this point, their thesis states that there will be growing congestion and moderate traffic delays, but it should still be bearable. In fact, as Table 4-9 shows, high travel growth combined with a high bus frequency at 48 buses per hour generates 123+ hours of network delay, a very large number. Although part of the delay can be attributed to the 20% increase in traffic volumes, the high frequency of buses also plays a significant role, hence capping this frequency at 40 buses per hour (i.e. 90 seconds headway) should help reduce congestion. With this in mind, Table 4-10 shows the schedule at a combined headway of 90 seconds, with an increase in frequency of the SL1 to 7.5 minutes, SLW to around 2 minutes, and SL2 constant at 5 minutes (on average).

Note that the current fleet of 32 buses can easily handle the requirements. The rows in yellow highlight the platoons, with SLW leading the platoon from South Station so that passengers who are only going to the Seaport District will naturally board it, since the SLW bus arrives first, and passengers who need to go to the airport can then have more room on the SL1, which departs 10 seconds later. In this way, there is additional capacity without lowering the combined headway further, plus better passenger differentiation at South Station, increasing comfort for airport travelers with luggage.

In the schedule shown in Table 4-10, the capacity within the District increases to 2,600 passengers per hour (and an additional 454 passengers/hour to the airport, due to market differentiation as a result of platooning), which is a substantial increase over the current capacity of 1,878

	Outbound		Inbound	
Bus ID No.	**South Station**	**Silver Line Way**	**Silver Line Way**	**South Station**
D1	8:00:00	SL2 trip time = 28 mins		8:28:00
1	8:01:30	8:07:30	8:08:30	8:13:30
A1	8:01:40	SL1 trip time = 38 mins		8:39:40
2	8:03:00	8:09:00	8:10:00	8:15:00
D2	8:04:30			8:32:30
3	8:06:00	8:12:00	8:13:00	8:18:00
4	8:07:30	8:13:30	8:14:30	8:19:30
5	8:09:00	8:15:00	8:16:00	8:21:00
A2	8:09:10			8:47:10
D3	8:10:30			8:38:30
6	8:12:00	8:18:00	8:19:00	8:24:00
7	8:13:30	8:19:30	8:20:30	8:25:30
D4	8:15:00			8:43:00
1	8:16:30	8:22:30	8:23:30	8:28:30
A3	8:16:40			8:54:40
2	8:18:00	8:24:00	8:25:00	8:30:00
D5	8:19:30			8:47:30
3	8:21:00	8:27:00	8:28:00	8:33:00
4	8:22:30	8:28:30	8:29:30	8:34:30
5	8:24:00	8:30:00	8:31:00	8:36:00
A4	8:24:10			9:02:10
D6	8:25:30			8:53:30
6	8:27:00	8:33:00	8:34:00	8:39:00

Bus ID Key
"D-" prefix = to Design Center (SL2)
"A-" prefix = to Airport (SL1)
Without prefix = SLW
Highlighted = SLW/SL1 platoon

Table 4-10: Sample schedule at 90s combined headway

Table 4-11 shows the capacities available with different configurations of the Silver Line (detail calculations can be found in Appendix A4). At this point, it is important to introduce the "SLG" (Silver Line Gateway) which is the MBTA's name for the new service to Chelsea, as shown in Figure 4-4. Projected to be in service by 2016, SLG travels in a combination of mixed traffic and its own busway from downtown Chelsea (with connection to the Commuter Rail station) to the District via the Ted Williams Tunnel. From our estimate, based on MassDOT and other published data, the cycle time should be around 70 minutes (55 minutes travel, 15 minutes layover), so the route is relatively long.

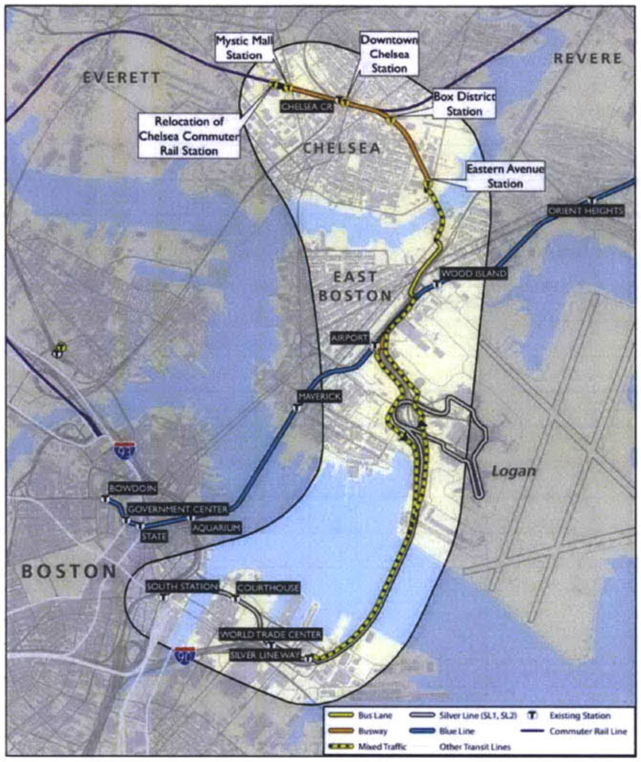


Figure 4-4: Proposed SLG route[31]

Turning to the table itself, note that apart from Scenario 1, SL1 capacity is separated from the District total due to platooning and customer differentiation, e.g. 2,600 passengers per hour is capacity within the District only. Scenario 4 is the same scenario shown on the sample schedule in Table 4-10 and is the recommended one since it offers high capacity while maintaining all 3 Silver Line services. The capacity is limited to 2,600 due to the headway limitation of 90 seconds from the D Street intersection, as mentioned earlier; the bus fleet is large enough at this stage to accommodate all services, so is not a concern here. Scenarios 2 and 3 show services only with SLW; this was done in an attempt to increase District capacity due to the shorter cycle times of SLW, however as can be seen, the headway constraint renders this useless.

Another key point is that although theoretically it is possible that SLG be included in the main tunnel section and form part of the trunk service, as shown in Scenario 5, this is likely to cause reliability issues in practice since the route is long and mixed with traffic, so has an increased potential of bunching during peak hour, particularly because the Ted Williams Tunnel is often congested during both peaks, thereby disrupting headways within the trunk section of the Silver Line. An additional concern is the at-grade crossing at D Street, which has the potential to further compound any delays the SLG may already face. Hence, it is preferable that the Silver

[31] MassDOT website

Line to Chelsea be operated on the surface in the District during the short-term to allow better performance in the trunk section, and although SLG will face slightly longer cycle times, the route should still offer fast service to the District relative to the current public transport options in Chelsea. Plus, SLG surface operations make it considerably easier when the time comes for the D Street grade separation project, since the riders of SLG will not have to be displaced out of the tunnel (because the route is already on the surface) – politically, this is much less controversial than instituting a new service for a few years and then having to provide a more inconvenient substitute a few years later.

	Scenario	1 (Current)	2	3	4	5
SL1	Headway	10 mins	7 mins	7 mins	7 mins	7 mins
	# of buses	5 buses	7 buses	7 buses	7 buses	7 buses
	Capacity	318	454	454	454	454
SL2	Headway	5 mins	N/A	N/A	5 mins	5 mins
	# of buses	6 buses			6 buses	6 buses
	Capacity	780			780	780
SLG	Headway	N/A	N/A	N/A	N/A	10 mins
	# of buses					7 buses
	Capacity					390
SLW	Headway	5 mins	1.5 mins	2 mins	2:10 mins	2:45 mins
	# of buses	4 buses	9 buses	6 buses	6 buses	5 buses
	Capacity	780	2,600	1,950	1,820	1,430
	Total capacity for the District (i.e. excludes SL1, except Scenario 1)	1,878	2,600	1,950	2,600	2,600
	Platooning	No	Yes	Yes	Yes	Yes
	Combined Headway for the District (excludes SL1, except Scenario 1)	2 minutes	1.5 minutes	2 minutes	1.5 minutes	1.5 minutes

Table 4-11: Silver Line potential capacity

Private Shuttle Consolidation

Based on the current assessment in section 3.1.5, the ridership share, especially during peak hour, carried by MBTA surface bus routes is low compared with the share carried by private shuttles. In the peak hour, peak direction, 25% of the AM ridership to the District and 29% of the PM ridership from the District are accommodated by employer shuttles while the surface bus routes, including Routes 4, 7 and 11 combined, only carry 13% and 6% during the AM and PM peak hours respectively. This reflects the fact that a sizeable proportion of the current non-auto demand in the Seaport District, especially during the peak hour, has not been well served by public transport services and some of the gaps have had to be filled by the employers, obtaining the services from a variety of private operators. In fact, this action even facilitates the ridership share decrease of MBTA bus services. Although the existing private shuttle routes help to serve the non-auto demand, it is more a reflection of an economically-feasible solution (for an employer) to an area lacking key public transport connections and is thus not the optimal method. Indeed, this is supported by the Shuttle Efficiency Study by VHB (2003) for the Seaport TMA and ABC, which was conducted before the introduction of the Silver Line: there were numerous shuttles from South Station linking the Courthouse and WTC areas which no longer exist since the demand is now well served by the Silver Line. Furthermore, operating the shuttles themselves is costly, when including all the routes provided, as analyzed in section 3.1. Thus, the idea of private shuttle consolidation makes sense, not only to better serve the current and future increasing public transport demand in the District, but also to reduce the financial burden of employers through a more cost-effective and coordinated system. The strategies introduced in the following pages aim to provide a more comprehensive service with higher levels of service and coverage, while at the same time offering a lower cost for employers.

Since it is necessary to combine private shuttles and complement the surface bus routes, we need to estimate the potential demand. The future District, as mentioned in the earlier chapters, will largely be a commercial area, offering a combination of entertainment/leisure and office spaces, with a smaller number of high-end residential units. It is projected that most jobs will be highly skilled, white-collar professionals, so the workers that commute into the District will most likely need to have high levels of education. Figure 4-5 below illustrates this, showing areas where the population has a bachelor's degree or higher. It is clear that downtown Boston and Back Bay, the northwestern (Cambridge out to Lexington and beyond) and western (Brookline-Newton-Wellesley, etc.) corridors offer the most highly-educated workforce, so will likely form a sizeable proportion of future commuters to the District. It should be noted that other areas with lower educational attainment levels could have significant numbers of commuters to the Seaport District, particularly areas close by, but nevertheless, the workforce requirements of the new employers will necessitate that highly educated areas provide large shares of commuters.

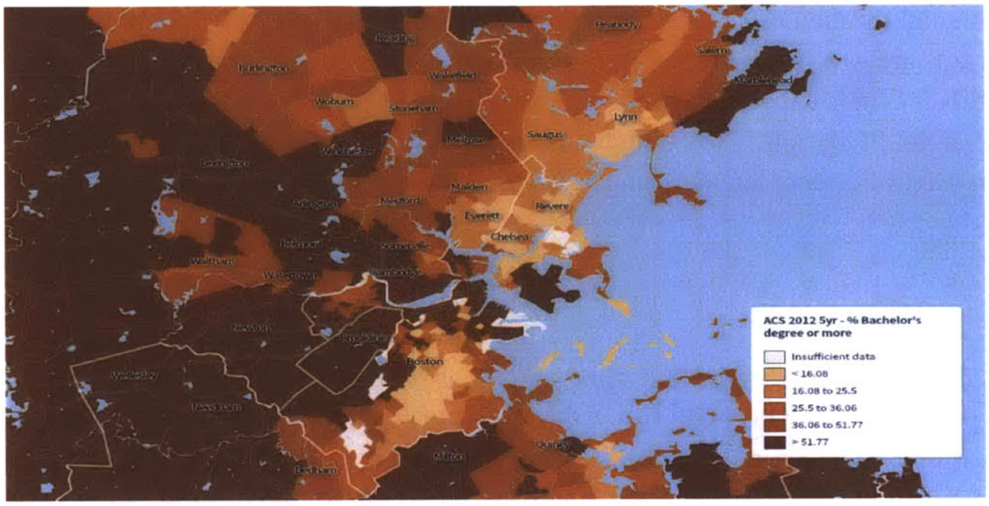


Figure 4-5: Educational attainment by census tract map[32]

From this, we can then examine transport links to these areas to find ways to better improve connectivity to the District. Table 4-12 highlights this:

Area	Public Transport Connections
Downtown Boston	Extensive
Back Bay	Green Line/local buses
Western corridor	Green Line (Brookline/Newton) Worcester commuter rail line (Wellesley and beyond)
Northwestern corridor	Red Line Express buses to Alewife (Lexington) Fitchburg commuter rail line (Concord and beyond)

Table 4-12: Key links to the Seaport District

It is apparent that the Red, Green and Commuter Rail Lines should play a significant role in providing access to the Seaport District. In fact, the Red Line is – this cannot be stressed

[32] www.socialexplorer.com

enough – crucial for the District's accessibility, because around 90% of all boardings/alightings within the area are as a result of the Silver Line, which has a direct connection to South Station. So, if the Silver Line's capacity is improved, the Red Line should too, in order to avoid congestion at South Station. Providing better linkages to these routes will thus enable a more efficient transfer of commuters to/from the District.

Connection Selection

As discussed in the in the preceding section, it is the connections to rapid transit that are the key to public transport accessibility in the Seaport District. Since the area does not have direct access to various rapid transit lines that exist in downtown Boston, it is desirable that each MBTA rapid transit line be easily accessible by private shuttles directly or at most via one transfer, because the role that the consolidated routes or the current private shuttles play is to fill the gap between downtown Boston and Seaport District for those who would like to use public transport with a quick one-bus transfer to the District (as opposed to having to make multiple transfers). The combined private shuttle routes aim to provide good public transport access to downtown Boston and Commuter Rail for workers as well as visitors to the District, and to complement the existing and future surface public transport system. It is assumed that most of the riders would have easy access to downtown Boston in the first place through the heavy rail and Commuter Rail networks.

In order to serve the riders to the T and Commuter Rail most efficiently, stations that the consolidated routes connect to are of the utmost concern when during route design. Direction of travel, branch of the line, proximity to the district, feasibility of the route, and redundancy of the connection will be the main considerations when determining what stations to serve. South Station and North Station provide services to Commuter Rail and therefore these two stations are inevitably included in the combined shuttle network. In addition, South Station provides a connection to the Red Line and North Station to the Orange Line north and Green Line north. Broadway could also be another possible Red Line connection since it is located at the edge of the Seaport District, thereby making it easier to circulate within the district. For the Blue Line, Aquarium and State are candidates.

Connection to	Candidate Stops
Red Line	South Station or Broadway
Commuter Rail (south)	South Station
Orange Line (north)	North Station or State
Green Line (northwest)	North Station
Commuter Rail (north)	North Station
Blue Line	State or Aquarium
Orange Line (south)	State or Back Bay
Green Line (southwest)	State or Copley

Table 4-13: Potential connection and stop selection

The main concerns of the combined routes are as follows:

- High frequency. Currently, most of the private shuttles provide services to public transport hubs every 10 to 15 minutes during the peak, without any interim stops between the trip ends. Lower headways for the coordinated system would be expected to compensate for the disutility of additional stops on the route, if there were none previously.
- One-seat ride. According to field observations, each of the private shuttles linking the District to the public transport system and commuter rail of Boston provides enough seats for employees and visitors. From the employers' and employees' perspective, it is desirable to make sure that each employee has a comfortable and convenient travel experience by taking the combined bus or shuttle.
- Longer time span. Currently, some of the shuttles provide continuous service to riders while others only provide services during the AM and PM peak hour when most of the commuter trips take place. However, it is recommended that the combined services have a longer time span than the individual shuttle routes, thereby not only covering the various demands but also attracting more ridership so that riders can enjoy a higher level of flexibility.
- Better coverage of services. Currently the private shuttles are available for commuters of certain companies which have recognized the need of the services and are willing to pay the costs. The lack of services between some parts of the District and downtown Boston does not necessarily mean that there is no current or near future demand. Rather, with a consolidated network, the routes can cover areas which were not previously accessible by public transport to date.
- Free rides for employees and integrated fare payment. Since the private shuttles are mainly serving commuters, future combined service will still need funding from companies and new developers who receive benefits from the new system. Funds from the City of Boston and Massport are also a possibility. For employees of contributing

companies, free rides will be provided. In addition to this, Charlie Card readers should be installed to allow the shuttles to be integrated into the regular public transport network and give more passengers access to the service. The fares can then be recouped by the operator, reducing costs further.

- Lower operating cost. The consolidation will be appealing to employees if the operating cost assumed by each employer could be reduced, lower than the cost when they provide individual private shuttles. This could be achieved, given the economies of scale and density, and if the cost can be equitably divided.
- Real-time arrival information. For the current shuttle services, the on-time performance is good and the shuttles often wait for riders who are slightly late so that employees do not need to worry about missing the shuttle. However, with a consolidated shuttle service, it may not be possible to perform quite so well in terms of schedule-adherence, due to the added stops and longer route. In addition, high demand takes place during peak hours when the surface streets are congested and large variations in travel time can occur. Thus, accurate real-time information about the new combined service, deployed through apps or websites, will be important.

Route Alternatives

The connection to rapid transit matters more than the specific route because the consolidated routes mainly target commuters to and from the District, though the externality of integrated shuttles will definitely benefit the potential riders along the route within a short walking radius. As discussed briefly in the previous parts of this section, several possible alternatives with logical purpose and actionable route choice are presented and assessed. Note that in all the following maps, the blue line represents the route into the District and the red line represents the route out of the District.

North Station Connections:

Alternative A1

The route shown in Figure 4-6 uses the Congress Bridge to exit the District, turns right onto the Greenway, loops around North Station and returns to the District on the same path; the whole route runs express, with an optional stop at Aquarium station if there is enough demand. The main purpose of this route is to provide a fast connection to North Station's Commuter Rail and at the same time serve passengers to the northern branches of the Orange and Green Lines as well as the Blue Line. Note that though this route goes through Haymarket Station, there is no stop there since North Station already serves the Orange and Green Lines. Considering the commuter-oriented and express nature of this route, the travel time should be as short as possible. The route does not detour to serve South Station, because it is already well served by the Silver Line, especially for the northern part of the District and thus it is assumed that there is little additional demand in the short run. Nevertheless, the southern part of the District still lacks an efficient connection to South Station, so it is possible to add a stop since the shuttle route is only one block away from the station. A summary of this alternative is:

- Stops: North Station, Aquarium and South Station
- Estimated Average Travel Time (roundtrip – this applies to all the subsequent alternatives shown)
  - Off peak: 12 minutes running time + dwell time
  - Peak: 18 minutes running time + dwell time
- Limitation: No good connection to Green Line southwest and Orange Line south.

Figure 4-6: Alternative A1 (North Station connection)

Alternative A2

This alternative is also designed to serve the North Station demand. The only difference is that this alternative uses Congress Street instead of the Greenway for trips to the District. The main advantage of this route is that it provides more options for passengers to board and alight. The connection to State provides linkage to Orange Line and Blue Line, which are served by two existing shuttles. However, these additional connections to heavy rail are redundant, since the Orange Line connection has already been covered by the North Station stop and the Blue Line connection by the Aquarium stop. Furthermore, although A2 is estimated to be slightly faster by 1 minute, this is more than counteracted by the fact that there is greater unreliability in travel time, since Congress Street travels through the downtown core and is often more prone to traffic variability. A summary of this alternative is:

- Stops: South Station, Aquarium, North Station and State
- Estimated Average Travel Time
    - Off peak: 11 minute running time + dwell time
    - Peak: 17 minute running time +dwell time
- Limitation: No good connection to Green Line southwest and Orange Line south; redundant connection to State, since Orange Line can already be accessed at North Station.

Figure 4-7: Alternative A2 (North Station connection)

Green/Orange Line and South Station Connection Strategy:

Alternative B1

This route provides a way to connect Green and Orange Lines as well as South Station Commuter Rail. The route is longer, relative to other alternatives, which is a disadvantage: the connections to Copley and Hynes are redundant, from the perspective of quick connection to rapid transit, since the Chinatown stop and Boylston stop already provide quick access to the southern parts of the Orange and Green Lines respectively. Nevertheless, the benefit is that the route can serve the demand from the District to Hynes Convention Center and the entire Back Bay area with a one-seat ride. In order to serve the peak hour commuters and maintain the high frequency of the shuttle service, the longer distance of this route would require a larger fleet. If this can be done, then the route would be a good complement to the North Station express. A summary of this alternative is:

- Stops: South Station, Chinatown, Copley, Hynes Convention Center, Boylston
- Estimated Average Travel Time:
    - Off peak: 17 minutes running time + dwell time
    - Peak: 30 minutes running time + dwell time
- Limitation: No connection to North Station commuter rail or to Blue Line.

Figure 4-8: Alternative B1(Green/Orange Line south)

Alternative B2

The shuttle also exits the district by Congress Street, and uses Dorchester Avenue and Summer Street, turning left onto the John F Fitzgerald Surface Road, then turns right into Kneeland Street and Stuart Street, and then goes back using Boylston Street and Essex Street. This route provides connections to the Red Line via South Station, Green Line south via Boylston Station and Orange Line via Chinatown. The benefit of this route is that it connects to public transport routes from the southern part of Boston. This route is also very short and can reduce travel time. Though the route is neither straight nor direct enough due to Downtown

Boston's street layout, this route only has three left turns, which is not bad. Moreover, there is a bus lane on Essex Street, indicating a good travel environment for the shuttles during the peak hour; indeed, if this lane could be extended further, travel times can be improved even more. A summary of this alternative is:

- Stops: South Station, Boylston, Chinatown
- Estimated Average Travel Time:
  - Off-peak: 10 minutes running time + dwell time
  - Peak: 18 minute running time + dwell time
- Limitations: Congestion might be a concern during peak hour.

Alternative B3

This alternative plays the same role as B1 and connects to the same public transport stations: Copley and Back Bay. However, it serves Broadway station instead of South Station and offers more access to the areas immediately south of downtown. This alternative suggests:

- Stops: Broadway , Copley, Back Bay
- Estimated Average Travel Time:
  - Off peak: 16 minutes running time + dwell time
  - Peak: 24 minutes running time + dwell time
- Limitation: No connection to Blue Line, to Orange Line north

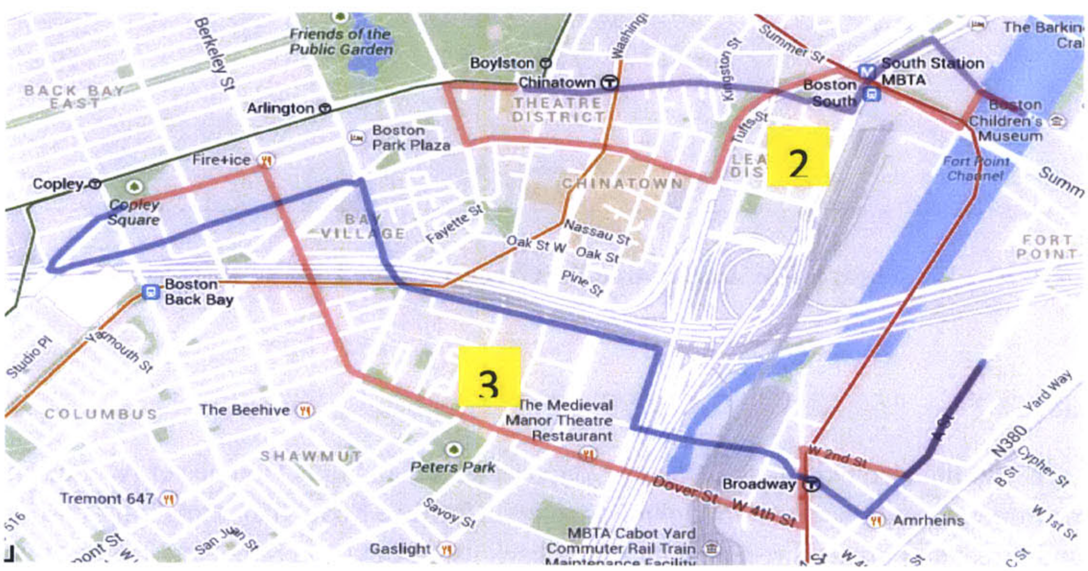


Figure 4-9: Alternatives B2 and B3 (Green/Orange Line south)

Alternative B4

This route is quite different from B1 since the route exits the district via Broadway station, instead of Congress Street. Since there is not too much traffic congestion on Haul Road and A Street during peak and off-peak. In addition to the Red Line access at Broadway, Copley and Back Bay stations provide a direct link to the Green and Orange Lines south, and complement the North Station express route which lacks these links. The route design is not perfect in that the route is not direct and straight-forward, due to the one-way streets. The benefit is that the level of service of surface traffic in this part of downtown Boston is better than in the Chinatown and Boylston area. Another advantage of this route, when compared with alternative B2, is that it provides direct access to the Back Bay area and Hynes Convention Center. A summary of this alternative is:

- Stops: Broadway, Copley, Back Bay
- Estimated Average Travel Time:
  - Off peak: 13 minutes running time + dwell time
  - Peak: 20 minutes running time + dwell time
- Limitation: No connection to Blue Line, and inbound shuttle does not connect to Orange Line.

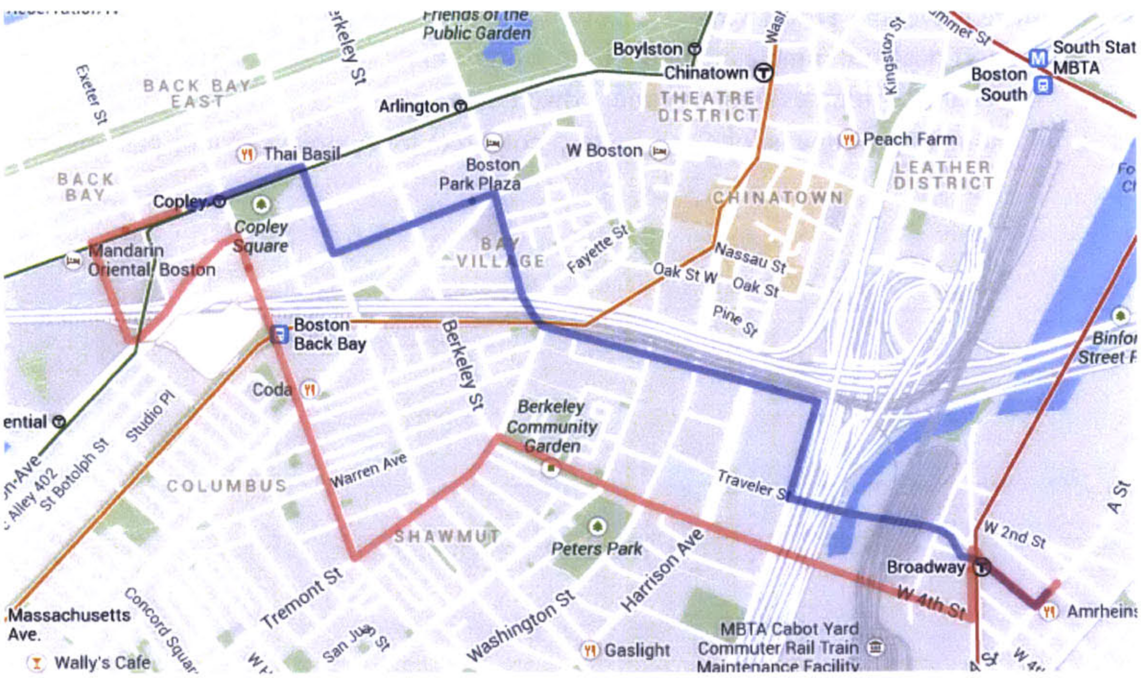


Figure 4-10: Alternative B4 (Green/Orange Line south)

District Inner Loop Strategy:

Alternative C1

This shuttle would enter the District by the Congress Street Bridge, use Seaport Boulevard, loop around the Design Center and Seaport Center before turning back onto Congress Street. Before it exits the district, the shuttle also turns left into A Street and turns back at Channel Center. For the PM peak trips, the route will reverse so that the World Trade Center demand will be served first, due to its large demand. The current development is concentrated in the northern part of the district and future development will continue in that region as well as the A Street corridor. Therefore, the route within the district is designed in a way that the current and potential demand can be met as much as possible and thus the number of stops increases, compared with the segment in downtown Boston. The stop selection is consistent with the demand analysis from private shuttles as well as Routes 4 and 7. Though it is better for employers and commuters to set the stops just in front of the companies, this cannot always be the case. The benefit of this route design is that it covers most of the existing and near future surface public transport demand. The downside is that the running time is long, especially for passengers in the A Street corridor. A summary of this alternative is:

- Stops: Vertex, World Trade Center, Design Center, John Hancock, Point Channel, Channel Center
- Estimated Average Travel Time
    - Off peak: 20 minutes running time + dwell time
    - Peak: 28 minutes running time + dwell time
- Limitation: Travel time is long and route is not direct for A street corridor passengers.

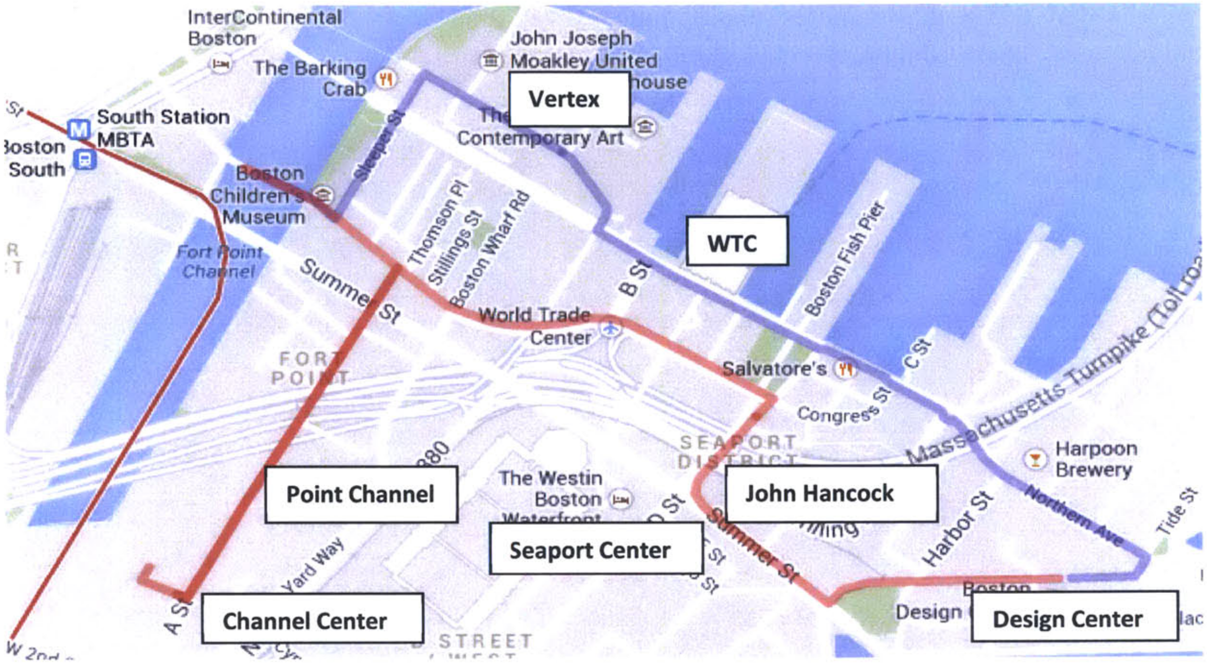


Figure 4-11: Alternative C1 (District inner loop)

Alternative C2

Alternative C2 splits C1 into two separate routes. One serves only Seaport Boulevard and Congress Street and the other serves the A Street corridor directly. The benefit of this route is that passengers both in the northern part of the district and southern part of the district are able to receive fast and direct connections to downtown Boston. Although at first glance, C2 might seem more expensive, since there are two routes instead of one, the annual cost is similar to C1 because of the reduced cycle times and the fact that the headways can be increased due to separated demand in each route (but headways are still capped at 15 minutes or less during the peak). Note also that the A Street corridor bus stops at South Station, before running express to North Station, to provide easy public transport access since the Silver Line does not travel into the southern part of the District. A summary of this alternative is:

- Stops: Vertex, World Trade Center, Design Center, John Hancock
- Stops: Point Channel, Channel Center
- Estimated Average Travel Time
  For north sub-area loop
    - Off peak: 12 minutes running time + dwell time
    - Peak: 18 minutes running time + dwell time
  For A Street sub-area loop

- Off peak: 8 minutes running time + dwell time
- Peak: 10 minutes running time + dwell time

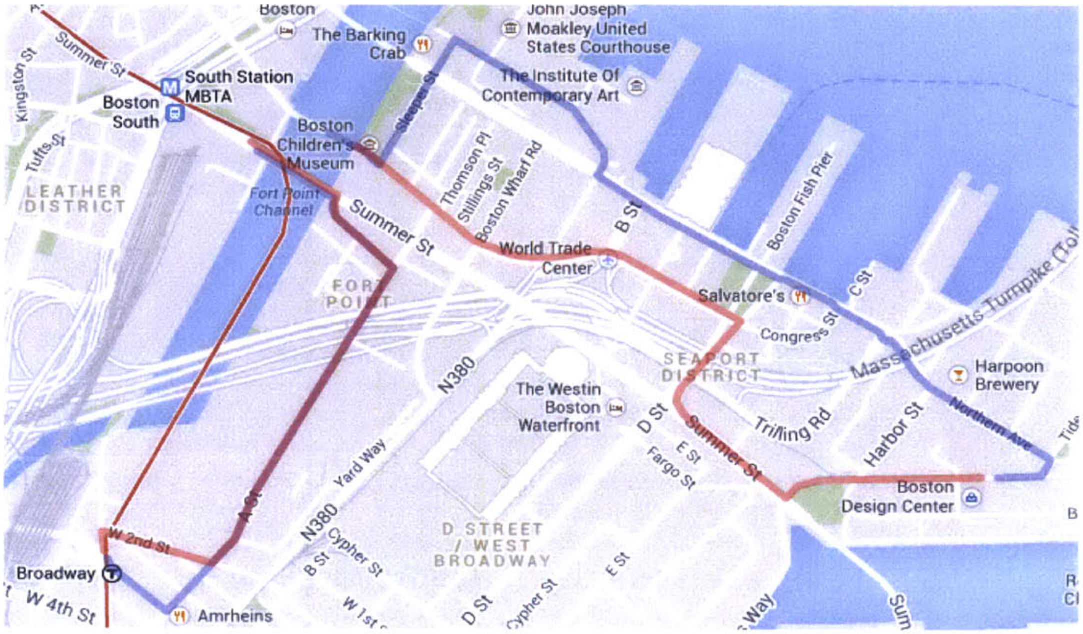


Figure 4-12: Alternative C2 (District inner loop)

The various downtown and District alternatives are combined and characterized in Table 4-14 with the following notes and findings:

- The cycle time estimated for each alternative is for the peak hour with layover time assumed to be 20% of running time. The running time is calculated as the peak hour travel time plus 5-minute dwell time.
- With the suggested headway and projected demand, which reaches 500 riders for the consolidated route, a regular 40' bus will be optimal with a design capacity of 53 people (35 seated capacity + 18 standing capacity).
- Demand projected for A1+C1 shuttle is based on the current demand of North Station private shuttles, State Street shuttles as well as part of South Station shuttles, multiplying by a coefficient of 1.2 to reflect growth for the near future.
- Demand projected for Orange Line and Green Line is based on the Seaport TMA commuter assignment of each public transport line, which shows the Orange and Green Line demand is similar to the sum of North Station Commuter Rail and Blue Line. The proposed North Station shuttle routes should mainly cover passengers from the Green Line north and Orange Line north, with a smaller ridership for commuters approaching

from the south on the Green and Orange Lines, particularly since the alternative B2 shuttle already handles those riders.

- Note that the demand for the two services in alternative C2 simply adds up to the projected demand for the C1 route. Though it is highly likely that alternative C1 will encourage intra-district trips, which is not possible in alternative C2 since the routes are split, for peak hour trips which are more likely to be home-based work trips, those intra-district trips will be only a very small share. Thus, it is reasonable to assume that intra-district travel is limited during the peak, this is not necessarily true for the off-peak.

Annual Operating Cost

For the North Station connection route, as is shown in Table 4-14, the peak hour cost for the full loop (Alternative A1+C1) is slightly higher than two separate loops (Alternative A1+C2 with northern loop and A Street loop). The same is true for the Boylston-Chinatown route. Yet the two separate loops can provide more capacity and separate the demand. Therefore, it is preferable to have two separate routes during peak hour to serve northern part of District demand and A Street corridor demand when ridership is high. For off-peak periods and evening services, the full loop within the District is more attractive, not only to reduce the operating cost but also to enable better intra-district flows.

Thus, A1+C2 and B2+C2 will be chosen from 07:00-09:00 and 17:00-19:00 while A1+C1 and B2+C1 will be adopted from 09:00-17:00 and evening service. Assuming the consolidated shuttles operate only on weekdays (250 days per year), and with a cost of $145/hour, the total annual cost for the North Station and Boylston-Chinatown is about $4,200,000 - $4,600,000, lower than the current estimated private shuttle operation cost.

Alternatives	Service Area	Public transport Access	Stops	Cycle Time	Headway	Fleet size	Projected Demand	Capacity
			North Station Connection					
A1+C1	Full seaport area	North Station, South Station Commuter Rails, Blue Line, Orange Line north and Green Line north	North Station, Aquarium, South Station, Vertex, WTC, Design Center, John Hancock, Channel Center	60 min	5 min	12	533	636
A1+C2 (Northern loop)	North Sub-area		North Station, Aquarium, South Station, Vertex, WTC, Design Center, John Hancock	50 min	7.5 min	7	368	424
A1+C2 (A Street loop)	A Street Corridor		North Station, Aquarium, South Station, Channel Center, Point Channel	40 min	10 min	4	165	318
			Back Bay & Copley Connection					
B3+C1	Full seaport area	Red Line, Green Line south, Orange Line south, Back Bay area	Broadway, Copley, Back Bay, Channel Center, Point Channel, John Hancock, Design Center, WTC, Vertex	70 min	7 min	10	400	454
			Boylston-Chinatown Connection					
B2+C1	Full seaport area	Red Line, Green Line south, Orange Line south	Boylston, Chinatown, South Station, Vertex, WTC, Design Center, John Hancock, Channel Center	60 min	6 min	10	400	530
B2+C2 (Northern loop)	North Sub-area		Boylston, Chinatown, South Station,Vertex, WTC, Design Center, John Hancock, Channel Center	50 min	8 min	7	300	398
B2+C2 (A Street loop)	A Street Corridor		Boylston, Chinatown, South Station, Channel Center, Point Channel	40 min	15 min	3	100	212

Table 4-14: Alternatives analysis

4.3.2 Traffic

Approach

The strategies examined for traffic analysis targeted problems that were identified during the no-build scenario. The strategies considered operational changes that required little if any capital investment. The noted problems in the no–build scenario correspond to bottleneck intersections located in the center of the Seaport District and at specific entry points to the District. The analysis focused on:

- Improving the performance of each problematic intersection.
- Ensuring that other points in the network (such as intersections located downstream) maintain a good operational level
- Ensuring pedestrian access that will be respected by through traffic.

To attain the above, the considered solutions implemented either one or a combination of the following:

- Signal optimization in traffic corridors.
- Signal optimization at isolated traffic signals.
- Changes in lane configuration.
- Prohibition of left or right turns.
- Addition of exclusive turning lanes. This was considered only when the existing road infrastructure could accommodate such changes.
- Changes in the type of the control method at intersecting roads (for instance, from yield to signalized).

Strategy 1 – Green Waves

Description:

This strategy focuses on providing a green wave to vehicles entering the Seaport District road network from the I-90 EB off-ramp and I-93 off-ramp. The green wave will direct the flow of the two off-ramps' through Congress Street to Northern Avenue and up to D Street, as illustrated in Figure 4-13. This green wave provides the incoming vehicles consecutive green time from the starting intersection of Congress Street and East Service Road, to the intersections of Northern Avenue and East Service Road, Northern Avenue and B Street, and Northern Avenue and D Street. As the vehicles move within the green wave from intersection to intersection, they spread to various directions (for instance, some of them turn left to Seaport

Boulevard travelling towards the financial center), resulting in only a limited number of cars traveling after the intersection of Northern Avenue and D Street.

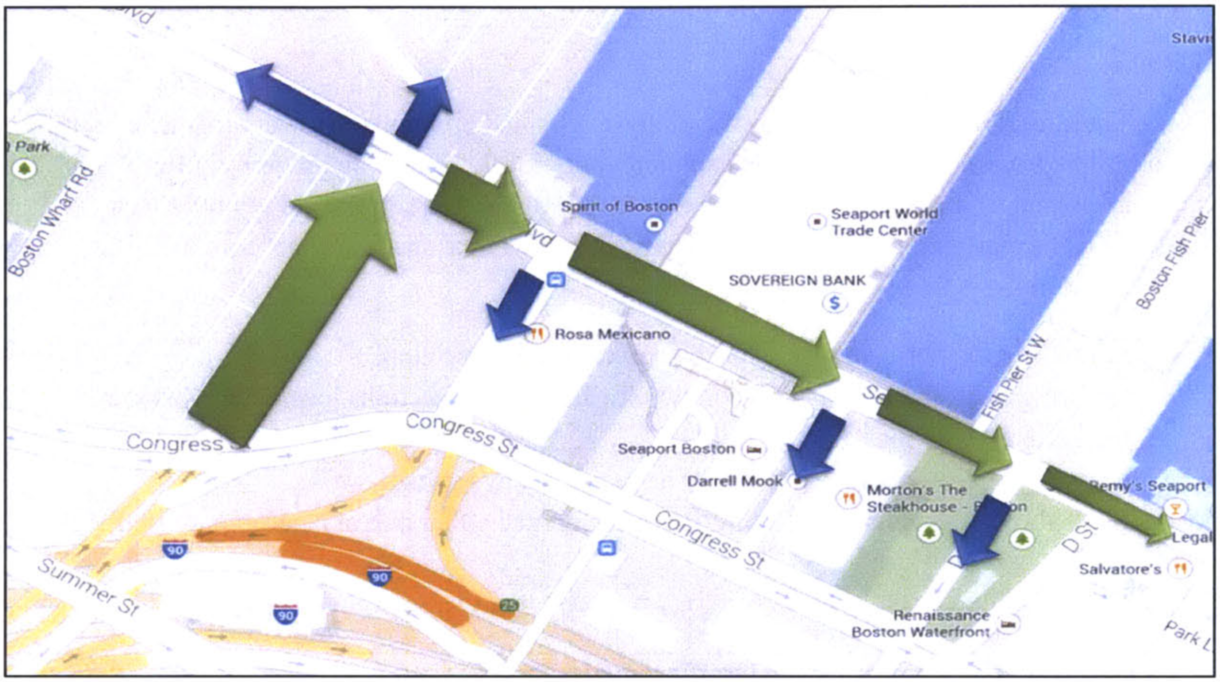


Figure 4-13: Green wave for vehicles coming from I-90 EB and I-93

The same strategy was followed for the traffic volumes entering the Seaport District from I-90 WB. In this case however, the main stream of the vehicles coming from the I-90 off-ramp turns left on Congress Street. Therefore, as part of this strategy, the green time of the I-90 WB off-ramp in the intersection of Congress and B Street was coordinated with the green time of the inbound direction (i.e. towards downtown) of Congress Street at the intersection with East Service Road, as shown in Figure 4-14.

It should be noted that Strategy 1 was implemented only during the AM peak hour, where significant traffic flows enter the Seaport District from the Interstate system. This strategy was not implemented during the PM peak hour because, during this evening peak, a limited number of vehicles enter the District from the Interstates and the intersection can therefore accommodate the flows without the need for a green wave.

Figure 4-14: Green wave for vehicles coming from I-90 WB

Complications:

Green waves today are serving the inbound directions of Congress Street and Seaport Boulevard. The proposed strategy conflicts with the current conditions since it shifts priority to vehicles coming from the highway system. Therefore, with no changes in the signalized intersections upstream, the proposed strategy would negatively affect the traffic conditions on Congress Street and Seaport Boulevard, unless the following is also implemented:

- Adjust the intersection of Congress and Boston Wharf Road to create a new green wave for the inbound direction.
- Adjust the phase configuration at the intersection of Seaport Boulevard and East Service Road such that all movements from East Service Road share green time with all movements from Old Northern Avenue. This results in reducing the number of phases from four to three, which provides more green time to Seaport Boulevard movements. The additional green time helps in accommodating the increased number of vehicles that accumulate during red time due to the lack of the green wave on Seaport Boulevard.

Results:

The effectiveness of this strategy can be evaluated based on intersection delays and queue spillovers. The results show that the network in the Seaport District can operate significantly better during the AM peak hour with this strategy. All intersections affected by this strategy operate better, except for the intersection of Congress Street and B Street. This intersection faces an increase in average control delay since it is not served by a green wave. However, since all other intersections operate better after the implementation of this strategy and queue spillovers do not affect the regional highway system, this strategy is effective. Results are summarized in Table 4-15.

Intersection	Existing green waves			New green waves		
	Control Delay (sec/veh)	Average Stops (stops/veh)	LOS	Control Delay (sec/veh)	Average Stops (stops/veh)	LOS
Boston Wharf Rd & Seaport Blvd	145.7	1.9	F	47.1	0.9	D
I90 Off-Ramp EB, I93 Off-Ramp, Congress St & East Service Road	124.7	2	F	52.7	1.2	D
Northern Ave, Old Northern Ave, Seaport Blvd & East Service Road	108.2	1.7	F	49.1	1.1	D
Northern Ave & D St (Southbound)	60.4	1.3	E	36.8	0.8	D
B St, Congress St, I90 Off-Ramp WB & I93 On-Ramp	59.2	1.1	E	79.2	1.4	E
Congress St, W Service Rd & Boston Wharf Rd	57.2	1.2	E	40	1	D
Northern Ave & D St (Northbound)	25.5	0.6	C	19.6	0.4	B

Max Queue Length (feet)			
Ramp	I-93	I-90 EB	I-90 WB
Existing	1,715	2,317	3,206
Strategy 1	257	563	699
Difference	-1,458	-1,754	-2,507

Table 4-15: Results under Strategy 1

Strategy 2 – Lane Configuration

Description:

Changes in lane configuration can assist in cases where the distribution of lanes does not correspond to the distribution of flows. This strategy could be implemented at the intersection of West Broadway and Dorchester Avenue, located in the southwest part of the District. Demand at this intersection is high. During the PM peak hour, roughly 500 vehicles in the outbound direction of West Broadway turn right on Dorchester Avenue in order to continue their trip to South Boston. Currently, the intersection serves high volumes, which limits the green time for each phase; only one lane is dedicated to the right turning volumes even though the right turning movement has a significant demand, and the left and straight movements are served by separate lanes as well. The recommended strategy changes the lane configuration by providing two dedicated right turn lanes and one shared lane for vehicles wanting to travel straight and/or turn left, as shown in Figure 4-15.

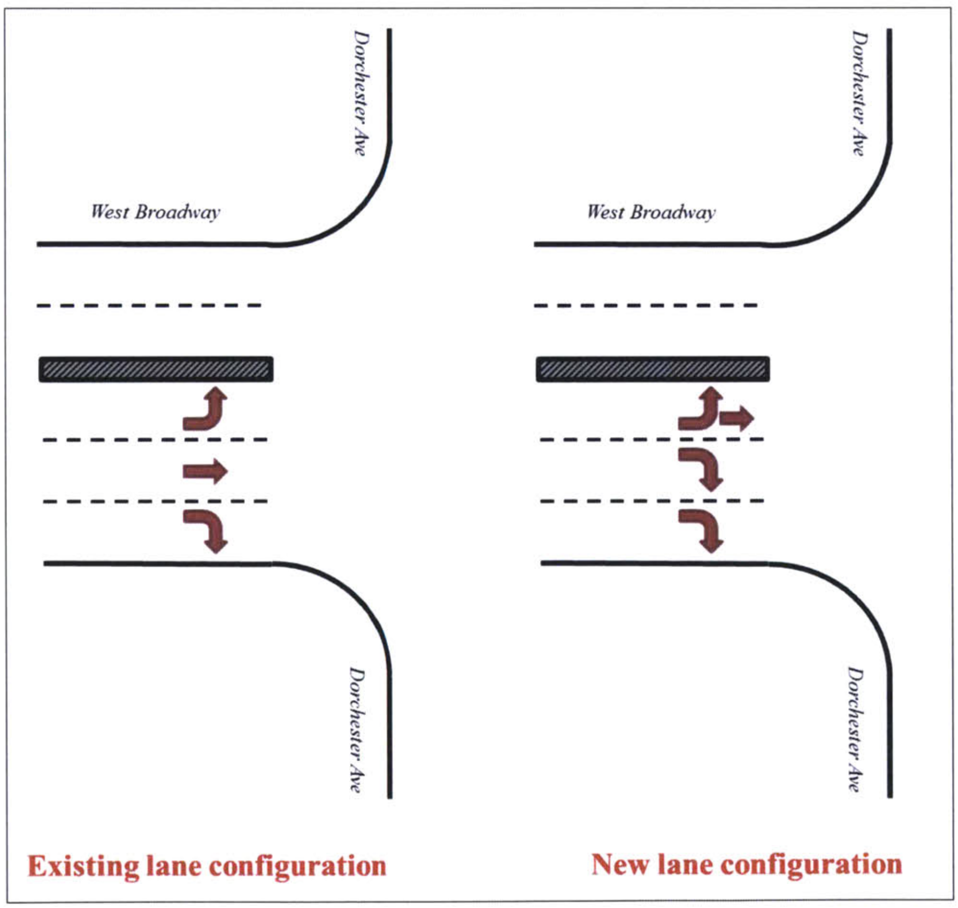


Figure 4-15: Lane configuration at West Broadway and Dorchester Avenue intersection

Complications:

The new lane configuration will increase the capacity of the right turn, but reduce the capacity of the straight and left turns. Note that, in contrast to the flows in the PM peak hour, the straight and left turns during the AM peak hour serve more traffic than the right turns. This complication can be solved by optimizing the traffic signal based on the new lane configuration. It is also important to note that this intersection is close to the Broadway "T" station and therefore pedestrian flows during peak hours are also increased. Hence, it is necessary to ensure that the signal plan of the intersection includes an exclusive pedestrian phase.

Results:

The results in Table 4-16 show that the new configuration can adequately serve the PM peak hour traffic as well as slightly improve the operations of the intersection during the AM peak hour. The significant delays in the PM peak have been reduced to acceptable levels, while the LOS improved from F to D.

Time of Day	Existing lane configuration			New lane configuration		
	Control Delay (sec/veh)	Average Stops (stops/veh)	LOS	Control Delay (sec/veh)	Average Stops (stops/veh)	LOS
AM peak hour	54.1	1.4	D	48	1.1	D
PM peak hour	94.2	1.9	F	46.9	1.0	D

Table 4-16: Performance of West Broadway and Dorchester Avenue intersection

Strategy 3 – Turn Prohibition

Description:

Turn prohibition can reduce the friction between straight and turning movements in cases of shared lanes and can serve as a traffic mitigation tool since it may detour vehicles to other routes that serve the same origin-destination pair. This strategy could be implemented at the intersection of Congress Street and D Street. The intersection already faces the problem of being close to the intersection of D Street and the Silver Line Way, hence is important to maintain good operations, at least until the grade separation of D Street and the Silver Line Way is completed. However, during both the AM and PM peak hours, the intersection operates at capacity (i.e. LOS E). Implementing prohibition of the right turn in the outbound direction of Congress Street, as illustrated in Figure 4-16 can reduce the traffic going through the intersection and provide more capacity for the other movements. The turn prohibition can be particularly effective during the PM peak hour, when many vehicles go through the intersection in order to reach the on-ramp of I-90 on D Street to enter the highway system.

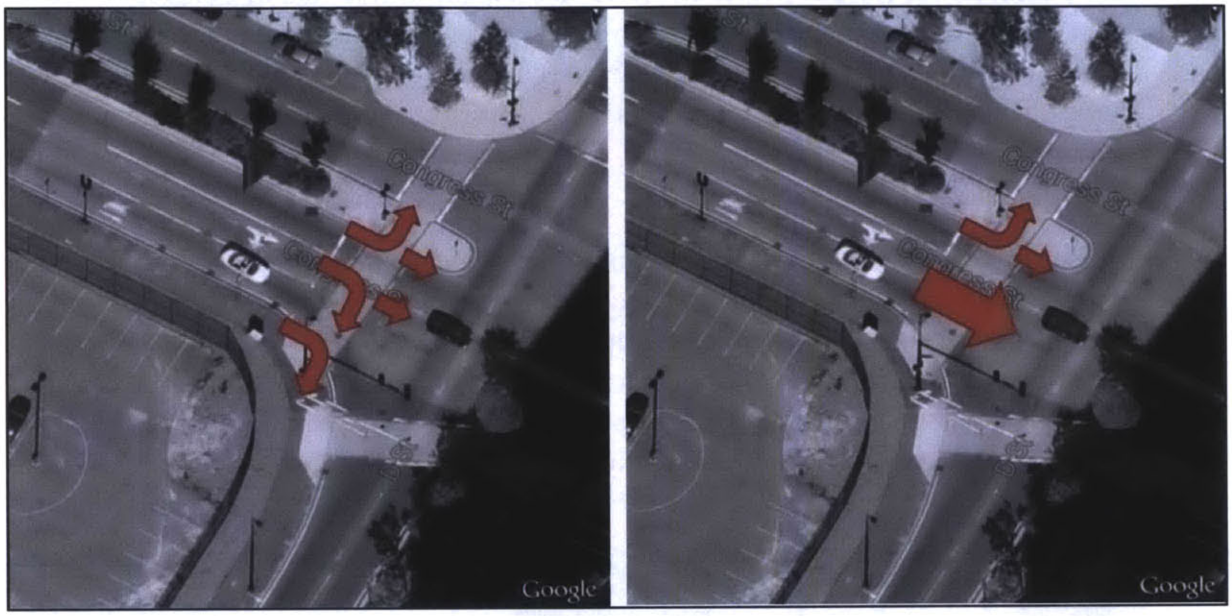


Figure 4-16: Right turn prohibition at the Congress Street and D Street intersection

Complications:

With the prohibition of the right turn, a significant number of vehicles (roughly 500 per hour during the PM peak hour) have to reroute in order to reach their destination. Two main detour options arise:

- Many vehicles continue straight on Congress, turn right on Northern Avenue, take the Haul Road and enter the highway system directly from there. This is the dominant detour and leads to an increase in conflicting moves at the intersection of Congress Street and Northern Avenue. In this intersection today, vehicles traveling outbound on Congress Street have to yield to vehicles passing through in either direction on Northern Avenue. The increase in traffic volume (which resulted from implementing the right turn prohibition at Congress Street & D Street intersection) creates queues on Congress Street at the intersection of Congress Street and Northern Avenue. In order to tackle that, a traffic signal was introduced. The signal provides priority to vehicles travelling along Northern Avenue and includes an exclusive pedestrian phase. In addition, the parking lane on the right of Congress Street was turned into a traffic lane. Five parking spots were affected by this change, which is considered insignificant. It should be noted that the operation of this signal is not required during the AM peak hour, since traffic flows are low and the existing control system (yield priority) adequately serves the intersection.

- Some vehicles use Northern Avenue before reaching the intersection of Congress Street and D Street. These vehicles follow the green wave described in Strategy 1 and then turn right onto D Street and pass through the intersection of Congress and D Street perpendicular to their original route. This route was selected by a small proportion of the detouring traffic.

Results:

The traffic conditions at the intersection of Congress and D Street have improved for both the AM and the PM peak hours. As expected, the turn prohibition had a stronger impact during the PM peak hour, since many vehicles want to enter the highway system through the I-90 on-ramp. The results of the intersection of Congress Street and Northern Avenue during the PM peak hour show that the change in the control type (from yield to signal) can address the detouring traffic adequately. The impacts of the implementation of this strategy are summarized in Table 4-17.

Intersection	Existing			With right turn prohibition		
	Control Delay (sec/veh)	Average Stops (stops/veh)	LOS	Control Delay (sec/veh)	Average Stops (stops/veh)	LOS
AM peak hour						
Congress St & D St	72.9	1.3	**E**	62.5	1.0	**E**
Northern Ave & Congress St	21.9	0.3	**C**	22.9	0.6	**C**
PM peak hour						
Congress St & D St	66.4	1.1	**E**	45.7	0.9	**D**
Northern Ave & Congress St	17.5	0.3	**C**	29.3	0.5	**D**

Table 4-17: Performance of Congress Street and D Street intersection

Strategy 4 – Improve Traffic Signal Plans

Description:

The intersection of Summer Street and Drydock Avenue is facing significant delays and queues during the AM peak hour. The main reason is that the inbound Summer Street approach has to serve volumes that exceed 1,000 vehicles per hour. Today, one phase serves both directions of Summer Street and another phase provides separate green time only to the outbound direction of Summer Street. In order to increase the saturation flow of this approach, the two phases that serve Summer Street were consolidated.

Complications:

Today, the two green phases are separated because vehicles from the outbound direction of Summer Street turn left onto Drydock Avenue. The consolidation of the two green phases leads to significant delays and queues in the left turning bay of Summer Street because the large number of conflicting vehicle movements minimizes the time of acceptable gaps. In order to address that issue, it is recommended to accommodate the left turn during the exclusive pedestrian phase. While this is not desirable as it conflicts with pedestrian flows, it is acceptable since vehicle flows are not particularly high. In addition, with the consolidation of the Summer Street phase, the time of the pedestrian phase can be increased, providing more green time to pedestrians.

Results:

As can be seen from Table 4-18, the implementation of this strategy can significantly improve the performance of this intersection. Results correspond only to the AM peak hour, since no changes were introduced in the PM peak hour.

Intersection	With the existing signal plan			With consolidated phases		
	Control Delay (sec/veh)	Average Stops (stops/veh)	LOS	Control Delay (sec/veh)	Average Stops (stops/veh)	LOS
Drydock Ave & Summer St	220.1	3.7	F	34.9	0.9	C

Table 4-18: Performance of Summer Street and Drydock Avenue intersection

4.4 RECOMMENDATIONS

Based on our analyses for both the public transport and the traffic networks, we summarize our recommendations that aim to accommodate the expected demand and maintain the transportation network at a good operational level in 2017.

Public Transport

In the short-term, a two-fold strategy should be adopted with regard to public transport in the District: improving Silver Line services and creating consolidated shuttle routes.

With respect to the Silver Line, the optimization of the schedule, through new cycle times and use of platooning, should enable more efficient and effective services. The use of TSP and the State police ramp to I-90 is also strongly recommended since it saves considerable travel time as well as improving reliability. However, a caveat is that combined headways should not be lower than 90 seconds because of traffic congestion concerns. Thus, the total capacity available through Silver Line in the District should be 2,600 passengers per hour, enough to accommodate short-term demand; in the longer term, the "T under D" project will be needed, as discussed in the following chapters.

As for the shuttles, through the identification and short-term assessment of possible alternatives, two integrated routes are recommended for peak hour commuter service, namely: North Station – Seaport District route and Boylston/Chinatown – Seaport District route. The Back Bay/Copley route is a good potential for short-term work-based trips for the Seaport District which may not be optimal for the peak hour because of its longer travel time and lack of South Station link. Considering the similar operating cost for whole area services and sub-area services, Alternatives A1+C2 and B2+C2 are recommended for the short-run, which saves passengers travel time.

In addition to the selection of route alternatives, there are a number of key tactics to supplement the private shuttle consolidation strategy:

- In order to facilitate the process of shuttle consolidation, a management and operational committee should be first established by a significant organization in the area, with the Seaport TMA being a good candidate. Cost distribution mechanisms should be negotiated and determined based on a number of criteria, including number of employees, size of company, square feet of real estate, parking spots, etc., with a goal of each paying a fair share, which is crucial for employers to buy-in the service.
- The committee, after establishment, also needs to get funding from other sources to accelerate the consolidation process.

- With an organized consolidated shuttle service, the physical station amenities should improve for passengers.
- Route 4 can be replaced by the North Station express shuttle since it has the same function but with improved frequency; this can allow the MBTA to save cost, while also providing some funding for the private shuttles.
- The consolidated shuttle service, though geared to accommodate most of the commuter trip demands, should still allow employers to operate their own independent services to other destinations if necessary.

Traffic

- Implement Strategy 1 to disperse the high vehicle flows at the Interstate off-ramps, Strategy 2 to accommodate the high flows at the Dorchester and West Broadway bottleneck, Strategy 3 to lessen the severity of the Congress and D bottleneck, and Strategy 4 to accommodate the large volume of vehicles travelling on Summer Street
- Maintain the current off-street parking restriction policy during the AM peak hour

Employing the above traffic recommendations allows the network to perform much better than its performance in the 2017 no-build scenario, as illustrated by the aggregate statistics shown in Table 4-19. In fact, the network performs even better than its performance in the baseline (2009) scenario (compare Table 4-19 to Table 3-20 and Table 3-23). More importantly, the improvements in the traffic network fully resolve the issue of queue spillovers at the three major Interstate off-ramps in the District because the resulting queues are short and do not disrupt the vehicle flows on the Interstates in the post-build 2017 scenario, as shown in Table 4-20.

	Average Delay		Average Speed		
		AM Peak Hour			
Scenario	Mins/veh	Change	Miles/hour	Change	# Trips
2017 no-build	4.3		14.7		15,936
2017 build	2.8	-35%	20	36%	15,934
		PM Peak Hour			
2017 no-build	4.1		17.1		18,143
2017 build	3.1	-24%	20	17%	18,166

Table 4-19: Comparison of 2017 no-build and build

Max Queue Length (feet)			
	Ramp		
Scenario	I-93	I-90 EB	I-90 WB
2017 no-build	1,715	2,317	3,206
2017 build	257	563	699
Change	-1,458	-1,754	-2,507

Table 4-20: Highway off-ramp queue lengths in 2017 no-build and build

Along with the above, based on our visits to the Seaport District, we believe that some additional changes in the regional street network are likely to be needed because the current network causes unnecessary delays and backups in the District and the changes will help in successfully operating important future public transport routes. These changes include:

- For automobiles only: Prohibiting the left turn from Seaport Boulevard onto Purchase Street.
- For automobiles only: Prohibiting the right turn from both Summer Street and Congress Street onto Atlantic Avenue.

However, because our model does not encompass these streets, we recommend further analysis and modeling of the above changes.

5 MEDIUM-TERM ANALYSIS

This chapter focuses on the medium-term analysis, corresponding to the year 2025. According to our predictions, more than 60% of the total expected development will have occurred by then, meaning that the demand for trips to the District would be considerably higher than the current demand. In this chapter, we will present our estimates of the 2025 demand, investigate the expected impacts if no improvements are made to the transportation network, and propose alternatives to tackle the anticipated problems. Note that in this chapter, the "no-build" scenario means that the recommended short-term "build" scenario transportation network already exists and has not been modified, whereas "build" scenario here means that the recommended 2017 "build" scenario transportation network already exists and has been modified further by the recommended strategies that are proposed in this chapter.

5.1 ESTIMATED DEMAND

Future demand was estimated based on the ITE Trip Generation Manual and ABC's estimates (adjusted based on the growth experienced today in the Seaport District). A detailed description of the methodology is provided in Chapter 2. The forecast demand for 2025 is shown in Table 5-1.

Person Trips							
		AM Peak Hour			PM Peak Hour		
Year	Zone Type	Total	Attracted	Generated	Total	Attracted	Generated
2025	Office	8,906	7,837	1,069	10,873	1,848	9,024
	Industrial	2,083	1,812	271	2,046	593	1,453
	Hotel	1,448	825	623	1,166	338	828
	Retail	5,644	3,896	1,747	8,811	4,994	3,816
	Residential	1,505	437	1,069	1,720	1,049	671
	Total	**19,586**	**14,807**	**4,778**	**24,615**	**8,823**	**15,792**

Table 5-1: Demand forecast for the medium-term analysis

Scenario 5 of the sensitivity analysis corresponds to a roughly 50% increase in vehicle trips attracted to the District during the AM peak hour[33], which is consistent with the increase in the demand of person trips as calculated from the ITE manual for 2025. Similar to the short-term

[33] For the PM peak hour, the 50% increase was an increase in vehicle trips generated from the District.

demand estimation, an important assumption here is that the proportional increase in person trips will be reflected in vehicle trips, meaning that the mode split will remain constant during the peak hours. For trips originating and trips terminating in the area, a decisive factor that affects mode split is parking supply. As discussed in Chapter 3, the parking capacity in the District today is estimated to be 10,400 parking spots during the AM peak period. Assuming that this number will remain constant until 2025, we estimated whether the parking supply will constrain the vehicle trips in the area, as explained below:

> From the O-D matrix of Scenario 5 in the sensitivity analysis, we estimated 7,800 vehicle trips attracted to the District during the AM peak hour. Assuming an additional 70% of vehicle trips for the rest of the AM peak period (based on current peak hour to peak period demand ratios), the total number of vehicle trips attracted to the District is estimated to be 13,300. Given that there are 10,400 existing parking spaces available during the AM peak period, we conclude that the parking supply cannot meet the 2025 demand. However, as development occurs, it is highly likely that the parking supply will increase because the South Boston Parking Freeze permits a total of approximately 19,500 spaces in the area. Therefore, similar to the short-term conditions, it is highly likely that the mode split will remain constant. This implies that approximately 3,000 additional parking spaces will have to be built to accommodate the traffic demand during the morning peak period in 2025. Given that approximately 7,500 additional parking spaces are permitted, and taking into consideration the morning peak period off-street parking restriction policy of 80% utilization, the construction of 4,000 new parking spaces by 2025 is a reasonable assumption.

For the medium-term scenario for public transport, the demand increases by around 50% from the 2008 scenario. Therefore, for the no-build mid-term scenario, the following assumptions are made:

- The mode split is assumed to remain the same as the current mode split.
- Current public transport origin-destination patterns will be maintained.

Thus, the demand for public transport under the no-build scenario can be summarized in Table 5-2.

	Medium-term Peak hour Demand	
	AM peak direction	**PM peak direction**
Silver Line 1	270	347
SL2 & SLW	1,949	1,939
North Station Route (northern loop)	460	460
North Station Route (A Street loop)	206	206
Boylston-Chinatown Route (northern loop)	375	375
Boylston-Chinatown Route (A Street loop)	125	125

Table 5-2: Medium-term peak hour demand by route

5.2 NO-BUILD SCENARIO

This section will describe the impacts that the 2025 demand will have on the transportation network in the District and the performance of the network if no improvements are made to the network. Before discussing the details of our results, it is important to clarify that for the public transport network, the results described in this section assume that the short-term strategies have already been implemented and remain in place. Similarly, for the traffic network, the short-term traffic strategies proved to be successful in improving the conditions of the traffic network and were therefore adopted. Subsequently, the 2025 demand was introduced to the already improved network. Therefore, the results in this section assume that the short-term traffic strategies have already been implemented. In addition, note that for the traffic network, the results also assume that one specific medium-term alternative proposed here is indeed approved and implemented by 2025—that being the grade separation ("T under D") at the Transit Way and D Street intersection (otherwise the network simply cannot accommodate the increased demand on both the road and public transport networks by 2025). This means that during the construction of "T under D", the traffic strategies discussed here would likely be less effective because of construction-induced congestion on D Street.

5.2.1 Public Transport

The demand and capacity for public transport under the no-build scenario is summarized in Table 5-3. For the no-build scenario, we assume the demand between the Airport and Seaport District is well separated because of the platooning of SL1 and SLW. The demand distribution of passengers from South Station to Silver Line Way section on SL2 and SLW is based on their frequency. Thus, the proportional 50% increase will make the public transport system near capacity, especially the surface bus routes. Note that since a sizeable proportion of SL2 riders are not going to the Design Center, the ridership is essentially shared with SLW – as mentioned in Chapter 4's demand discussions.

	Mid-term Peak hour Demand		
	AM peak direction	PM peak direction	Peak hour Capacity
SL1	270	347	454
SL2 & SLW	1,949	1,939	2,600
North Station Route (northern loop)	460	460	424
North Station Route (A Street loop)	206	206	212
Boylston-Chinatown Route (northern loop)	375	375	371
Boylston-Chinatown Route (A Street loop)	125	125	159

Table 5-3: Medium-term peak hour demand

Furthermore, it is possible that the demand could be considerably more than in Table 5-3; 50% increase from baseline scenario is a fairly conservative estimate and it is certainly feasible that the increase be much higher. This is because of the nature of new developments, which are closely tied to the economic climate and the market's volatility, so in essence if there was a big recovery in the economy, there will likely be a spurt of new construction projects. In the past 6-7 years, due to the Great Recession, growth was stagnant, and although the economy is now slowly recovering, it is still unclear how rapid the future growth will be, hence the conservative estimate and thus the distinct possibility of much higher growth. A further point to note is that, by a basic comparison of the District to downtown Boston, it is clear that if the District were to become densely developed, the requisite transport network is still sorely lacking – downtown Boston requires numerous subway lines with high capacity to sustain its high-density developments yet the District has nowhere near that much capacity, e.g. the Red Line's maximum capacity of around 13,000 passengers per hour in each direction during the AM peak hour dwarfs the Silver Line's by a considerable magnitude. Improving the capacity is possible since theoretically, BRTs can run with headways as low as 20 seconds, but unfortunately, this is impossible to achieve due to the D Street constraint – it would cause traffic chaos if the traffic lights had to change frequently to accommodate such heavy bus traffic, as well as negatively impacting Silver Line operations, especially travel times. Hence, the crux of the matter is that the Silver Line and other local public transport routes will have to be improved considerably to meet future demands. Furthermore, the longer the delay in making these improvements, the higher the costs will be, both for the transport operators, its users and the drivers in the District, as will be made clear in the following section.

5.2.2 Traffic

The aggregate statistics for 2025 are shown in Table 5-4. These results show that in both the morning and evening peak hours, both the average delay and the average speed worsen with increasing demand, as expected. It is interesting to note that the significant increase in demand between 2017 and 2025 impacts the PM peak hour traffic more strongly than the AM peak hour traffic (this pattern was not observed in most of the earlier scenarios).

	Average Delay		Average Speed		
		AM Peak Hour			
Scenario	**Mins/veh**	**Change**	**Miles/hour**	**Change**	**# Trips**
2017 build	2.8		20		15,934
2025	3.7	24%	16.3	-19%	18,194
		PM Peak Hour			
2017 build	3.1		20		18,166
2025	4.8	55%	16	-20%	20,830

Table 5-4: Aggregate statistics (medium-term no-build)

At the intersection level, Table 5-5 shows the intersections that operate either at or above capacity. During the AM peak hour, the network experiences difficulties at five bottlenecks, of which perhaps the three most important locations are (1) the intersection of Congress Street and the I-90 and I93 off-ramps, (2) the intersection of Drydock Avenue and Summer Street and (3) the intersection of Dorchester Avenue and West Broadway. These three bottlenecks are especially important because they are major entry points to the District. As for the PM peak hour, we note that five intersections operate under difficult conditions. In this case however, the intersection of Summer Street and World Trade Center Avenue is the only intersection that operates over capacity as it encounters rather significant delays. In addition, we note that the intersection of Dorchester Avenue and West Broadway experiences high delays, indicating that this intersection is a key location since it operates at capacity during both the morning and evening peak hours.

Intersection	Control Delay (sec/veh)	Average Stops (stops/veh)	LOS
AM Peak Hour			
Congress St, W Service Rd & Boston Wharf Rd	57.0	1.1	E
Dorchester Ave, Broadway Brg & W Broadway	76.1	1.4	E
Boston Wharf Rd & Seaport Blvd	90.7	1.5	F
Drydock Ave, Summer St	105.7	2.2	F
I90 Off-Ramp EB, I93 Off-Ramp, Congress St	90.8	1.6	F
PM Peak Hour			
D St & Summer St	71.5	1.3	E
Dorchester Ave, Broadway Brg & W Broadway	79.0	1.4	E
Haul Road & W Service Rd	38.5	0.5	E
Summer St & Melcher St	58.4	1.6	E
Summer St, WTC Ave	240.3	3.5	F

Table 5-5: Intersection statistics (medium-term no-build)

In terms of queue spillovers, the only major problem occurs at the westbound I-90 off-ramp during the AM peak hour, as shown in Table 5-6 and in Figure 5-1. The queues spillover to the Interstate and disrupt the traffic flows in the Ted Williams Tunnel. The eastbound I-90 off-ramp also experiences queues that almost interfere with the flows in the Interstate system. However, even though the long queues on this ramp are an important problem, we note that these queues do not cause consistent disruptions to the Interstate flows because the recorded queues are the maximum queues that occur during the peak hour (i.e. they represent the peak of the peak). The I-93 off-ramp does not see considerable spillovers, and neither does the PM peak hour in general.

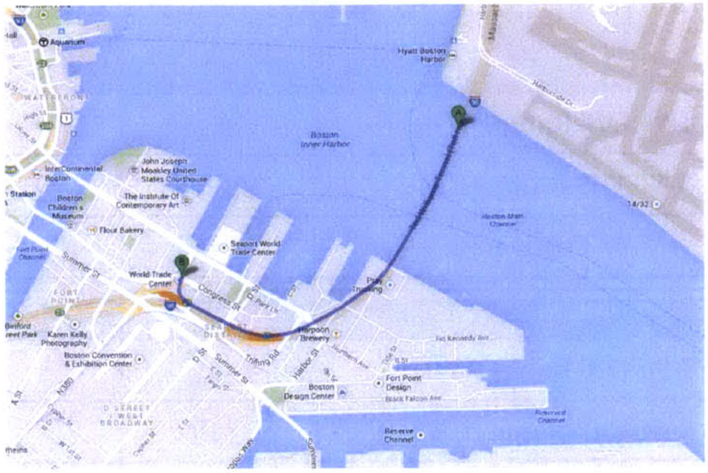
Ramp	Max Queue Length (feet)
AM Peak Hour	
I-90 Off-Ramp (WB)	6,796
I-90 Off-Ramp (EB)	918
I-93 Off-Ramp	419
PM Peak Hour	
I-90 Off-Ramp (WB)	398
I-90 Off-Ramp (EB)	194
I-93 Off-Ramp	137

Table 5-6: Off-ramp statistics (medium-term no-build)

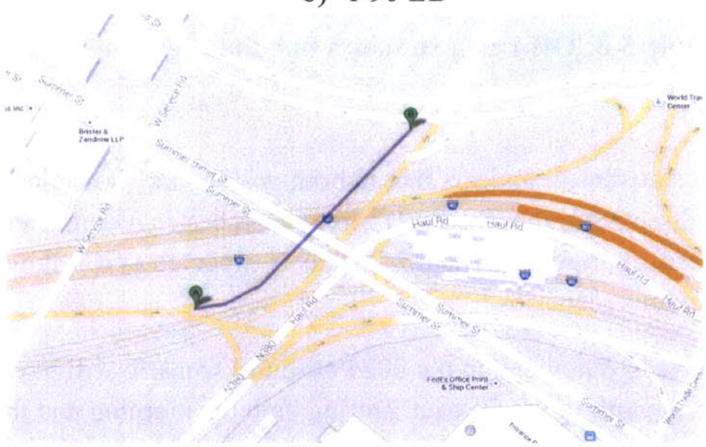
As for the link statistics, it appears that in both peak hours, the main streets (i.e. Seaport Boulevard, Congress Street, Summer Street, D Street, Dorchester Avenue, and West Broadway) are considerably utilized, as shown in Table 5-7. This is expected as it follows the general trends observed in all the previous scenarios.

Overall, the increased demand in the 2025 no-build scenario will have considerable impacts on the traffic network in the District. During both the morning and the evening peak hours, multiple intersections operate either at or above capacity. In addition, and perhaps most importantly, during the AM peak hour, long queues at the I-90 westbound off-ramp will form and will continuously disrupt and delay traffic flow in the Ted Williams Tunnel.

a) I-90 WB



b) I-90 EB



c) I-93

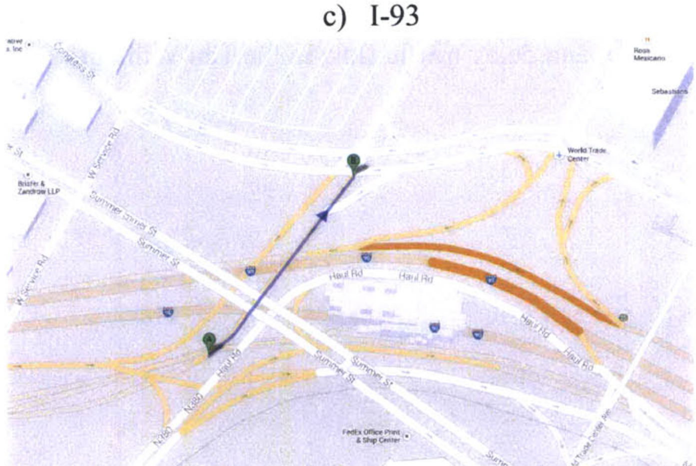


Figure 5-1: Maximum queue lengths at Interstate off-ramps (AM peak hour)

Street	Delay (min/mile)	Street	VMT (veh-mi)
AM Peak Hour			
Seaport Blvd/Northern Ave	4.8	**Summer St**	2,454
Summer St	2.2	**Seaport Blvd/Northern Ave**	1,303
Congress St	6.1	**W Broadway**	723
D St	5.3	**Congress St**	571
Dorchester Ave	3.9	**Dorchester Ave**	457
PM Peak Hour			
Summer St	3.5	**Summer St**	2,121
Seaport Blvd/Northern Ave	3.4	**Seaport Blvd/Northern Ave**	1,304
D St	7.5	**W Broadway**	649
Congress St	3.9	**Congress St**	581
W Broadway	2.9	**Dorchester Ave**	492

Table 5-7: Link statistics (medium-term no-build)

5.3 IMPROVEMENT STRATEGIES

5.3.1 Public Transport

The mid-term strategies analyzed in this section aim to address the problems that will occur in the public transport system by 2025, by when the total demand for the public transport system will increase by approximately 50%. The strategies focus on improving the system so that the medium-term demand can be well served and prepare to adjust to the long-term economic development.

The potential solutions to be analyzed include the following:

- Greatly improve the Silver Line's capacity by constructing "T under D"
- Propose alternative Silver Line routes during construction
- Modify the consolidated surface bus routes to satisfy the new demand
- Initiate Congress Street bus lanes
- Propose new ferry routes from the Seaport District to East Boston, Chelsea and Charlestown

Note that, although every effort has been made to ensure as detailed an analysis as possible, due to the limited resources and time available, these strategies have not been examined to the same depth as in the short-term analysis section. Nevertheless, the strategies discussed here should provide a good framework for further study, particularly for the D Street Grade Separation project, where considerable time has been spent on the operational issues surrounding it.

D Street Grade Separation

As section 5.2 demonstrated, the Silver Line's ridership, although accommodated with a 50% demand increase, has a good chance of being higher than the capacity provided in the short-term solution of 2,600 passengers per hour (District only), as shown in Scenario 4 from Table 5-8. Furthermore, another key issue is that the maximum capacity available during the construction of "T under D" through substitute buses is not enough to handle the medium-term peak District demand of 1,949 passengers per hour, as will be discussed later in this section. Thus, it is imperative the D Street intersection be grade separated as soon as possible, thereby allowing the Silver Line to have its own right-of-way from South Station all the way to Silver Line Way (the main section in the District and where most future growth is projected) and provide enough capacity for the future, as well as averting the capacity crisis of substitute busing. Without this, there is a very real risk that workers will be unable to easily access the area, dampening economic growth, which would negatively impact the District.

Table 5-8 shows the capacities available with different configurations of the Silver Line. It should be noted that SL1 capacity is separated from SL2 and SLW capacity due to platooning and customer differentiation. Scenario 5 to Scenario 8 assumes that the "T under D" is constructed in the medium term. Note that, unlike in the short-term, the constraint is now the fleet size, which is currently 32, as opposed to the headway. It is assumed that a 20% reserve ratio will be used, which seems high but bear in mind that in 2025, the buses will be over 20 years old, so major rehabilitation will be needed, with more buses taken out for repairs. Thus, 25 buses should be available, 7 for SL1 (1 in reserve) and 18 for non-SL1 (6 in reserve). With this in mind, a commentary of Table 5-8 is presented:

- Scenario 4, which is recommended for the short-run without "T under D", provides a maximum 2,600 capacity during peak hour with 5-minute headway for SL2 and 2:10-minute headway for SLW.
- Scenario 6 assumes that SL2 will not be operated. Rather surface buses will replace SL2 to provide connections from South Station to the Design Center. This applies to the Chelsea route (SLG) as well. Thus, the tunnel serves only the airport and South Station-Silver Line Way demand, resulting in a maximum capacity of 5,850 for the District, which is the highest among all the scenarios, due to the lowest headway of 40 seconds.
- Scenario 7 includes SL2 and in this scenario the SLG is assumed to use surface roads. The 5-minute headway of SL2 and 1-minute headway of SLW in total provide a capacity of 4,680 for the district during peak hour.
- Scenario 8 assumes no SL2 while including the SLG running in the tunnel. The headway for SLW increases slightly to 1:10 minutes and thus a capacity of 3,730 can be achieved. Notice that platooning for Chelsea route and SLW is not conducted and therefore the capacity for the District increases; otherwise capacity for the District will be reduced to 3,340.
- Scenario 9 includes both SL2 and Chelsea route. Headway for SL2 still remains 5 minutes, 10 minutes for Chelsea one and 2:30 minutes for SLW. In this scenario, the total capacity for the district will be 2,730.

Scenario 6 represents the maximum possible capacity with grade-separation, which can accommodate the medium-term demand for the area. But for the medium run, Scenario 8 will be preferable since it allows SLG to use the tunnel and improve travel times for passengers from Chelsea. Although SL2 will now be on the surface, due to the limited ridership to the Design Center as seen in Chapter 3, relatively few passengers should be affected. Furthermore, the Congress Street bus lanes should help to reduce the increase in travel time.

Scenario		4 (selected short term)	6	7	8	9
SL1	Headway	7 mins	6 mins	6 mins	6 mins	6 mins
	# of buses	7 buses	7 buses	7 buses	7 buses	7 buses
	Capacity	454	530	530	530	530
SL2	Headway	5 mins	N/A	5 mins	N/A	5 mins
	# of buses	6 buses		6 buses		6 buses
	Capacity	780		780		780
SLG	Headway	N/A	N/A	N/A	10 mins	10 mins
	# of buses				7 buses	7 buses
	Capacity				390	390
SLW	Headway	2:10 mins	40 seconds	1 minute	1:10 mins	2:30 mins
	# of buses	6 buses	18 buses	12 buses	11 buses	5 buses
	Capacity	1,820	5,850	3,900	3,340	1,560
	Total capacity for the district	2,600	5,850	4,680	3,730	2,730
	T under D	No	Yes	Yes	Yes	Yes
	Platooning	Yes	Yes	Yes	Yes	Yes
	Combined Headway for SL2/SLW (also include SL1 if no platooning)	1.5 minutes	40 seconds	50 seconds	1:03 mins	1:26 mins

Table 5-8: Potential capacities of Silver Line (short and medium terms)

Figure 5-2 shows how the area might look once construction is completed. In the outbound direction, all the buses will now pass under D Street, before rising up and emerging after the Manulife Building. There will then be a surface stop for both SL1 and SLW, the latter of which can then use the loop to turn back for inbound travel. Note that the holding bays will also be provided for the SLW to recover and layover for the next trip, as well as to provide operational flexibility. SL1 will then continue onwards, turning right onto the Haul Road and then looping round using the ramp. In Scenarios 7 and 9 where Silver Line 2 still operates, SL2 buses will continue on Trilling Road, Northern Avenue and then loop around the Design Center and head back to the tunnel. In the inbound direction, SL1 can travel, utilizing a single-lane tunnel, directly from I-90 into the main tunnel under D Street, via an underground Silver Line Way stop. This is projected to save 2-3 minutes (conservative), since buses will no longer have to drive all the way to B Street and come back along Congress, saving time for passengers and reducing traffic congestion. "T under D" and the route reconfiguration will thus save around 5-6 minutes (see Table 5-9), which is nearly 20% of the SL1's current off-peak running time. The time savings shown is very conservative, since it is measured during current off-peak conditions; by 2025, the demand is estimated to increase by 50% or more, so the travel time reduction will be considerable. This will increase even more during the peak since the new SL1 route interacts with considerably less road traffic in the District. Furthermore, the benefit gained through "T under D" is also shared with car drivers: since there are fewer buses running in mixed traffic, there will be reduced congestion, increasing capacity and reducing travel times. So, "T under D" enables the two major transport modes within the District to be improved considerably.

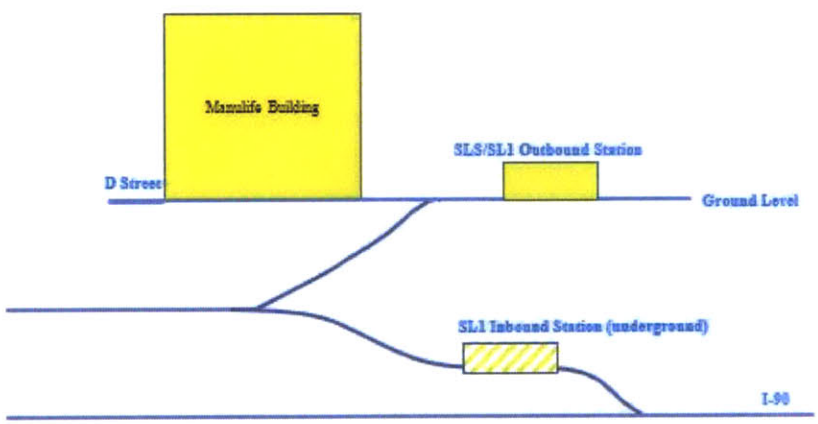


Figure 5-2: T under D proposed layout

Changes	Off-Peak SL1 Time Savings
No D Street Intersection	30 seconds each way (1 minute roundtrip)
Police Ramp (SL1 Outbound)	Around 2 minutes
SL1 Outbound direct tunnel from I-90	2-3 minutes
Total	**5-6 minutes (roundtrip)**

* Note that the savings estimates are conservative, i.e. with minimal traffic interference; during congested conditions, the time savings will increase dramatically. Ramp and tunnel time savings estimated by field data collection of travel times of Silver Line during the off-peak – the difference between how long the bus will take to travel on the new route subtracted by the current travel time. No D Street Intersection time savings based on median delays experienced at the intersection, as report in the 2013 MEng Thesis.

Table 5-9: Silver Line 1 running time savings

Silver Line substitutes during construction

Although it is now apparent how "T under D" might appear, there is still the issue of what happens during construction, since Silver Line service will be severely disrupted. To address this, a substitute bus plan should be implemented, with possible routes shown in Figure 5-3.

Figure 5-3: Alternatives A1 (red), L1 (blue) and L2 (green)

There are two routes: a local one (in blue) running along Congress Street with clockwise loops around the Design Center and South Station (using Dorchester-Summer-Greenway-Congress; clockwise is preferred since it minimizes the number of left turns), replicating the SLW/SL2 as much as possible, and an express route (in red) direct from Boston's bus terminal to the airport, to save time for passengers. Looking first at the local route, Congress Street was chosen since it passes through the main part of the District, offering convenient access to most workplaces within the District, as well as serving the World Trade Center, Silver Line Way and SL2 stops. However, the downside is that it does not offer as easy access to the Courthouse area as regular Silver Line service, but on the upside, the Fort Point area is better served (Figure 5-4). An alternative local route (in green) shows the possibility of serving Courthouse by using Boston Wharf Road and Seaport Boulevard before turning onto the Greenway, doing a U-turn, stopping on the east side of the Greenway near South Station then continuing back. Although B Street provides a better connection, it cannot be used since no left turns are allowed onto Congress when the bus travels to the Design Center. The downside to this alternative is that the routing is more convoluted, leading to longer travel times and lowered schedule reliability. Perhaps more significantly, it should be carefully examined whether being closer to Fort Point or Courthouse is more convenient for passengers, particularly since the area around Fort Point currently has numerous offices, and is projected to grow in the future. Further examination is needed to see which alternative provides a better catchment area. Based solely on the ease of operations, however, the first alternative (blue) is likely to be preferable. Although travel times will be longer than regular Silver Line service, the use of bus lanes on Congress Street and its bridge could potentially reduce it to comparable levels with regular service; this will be discussed shortly.

Figure 5-4: Quarter-mile radius from existing (top) and proposed (bottom) stop

Finally, an alternative that requires some (minimal) capital investment is to build a turnaround at the WTC station; this could be achieved by cutting out the platform and replacing it with a turning circle for the buses. A truncated Silver Line service could then be operated (from South Station to WTC), which is useful since a large number of passengers' journeys will not be disrupted in anyway because WTC is the busiest stop in the District. However, this is likely the most expensive option since, in addition to the capital costs, there is still a need to operate substitute bus service to the airport and Design Center/Silver Line Way. Furthermore, it remains to be seen whether there is enough space to build a turning circle for the articulated buses in the first place.

Turning to the airport express route, the alternative shown on Figure 5-3 offers very fast travel times from South Station to Terminal A, between 8-10 minutes during the off-peak according to Google Maps (as opposed to the current 15 minutes), utilizing the HOV ramp at Lincoln St/South Station Connector to I-90 in the outbound direction and a ramp direct from I-90 onto South Station Connector in the inbound direction. The big disadvantage of this route though, is that transfers to/from other public transport modes are difficult since the bus terminal is a 5-10 minutes' walk to the main part of South Station, which involves using stairs or elevators as well as an exposed walk along the commuter rail platform, which would be problematic for airport passengers with luggage. An alternate route is shown in Figure 5-5, which allows the bus to come right past South Station, providing easier transfers to the Red Line and Commuter Rail. This route has the SL1 inbound travel via Congress Street before making a turn on Dorchester to get to Summer, with a stop near the Station. SL1 outbound then travels on Surface Road before using the HOV ramp, the same ramp as in the previous alternative. Of course travel times will be longer since the SL1 now has to spend some time on local streets (SL1 outbound from South Station to Terminal A is expected to take around 10-12 minutes off-peak, according to Google) but at the same time, passengers will be able to save walking time, so total point-to-point time might even be lowered. On the inbound direction, the installation of bus lanes on Congress should also decrease travel time.

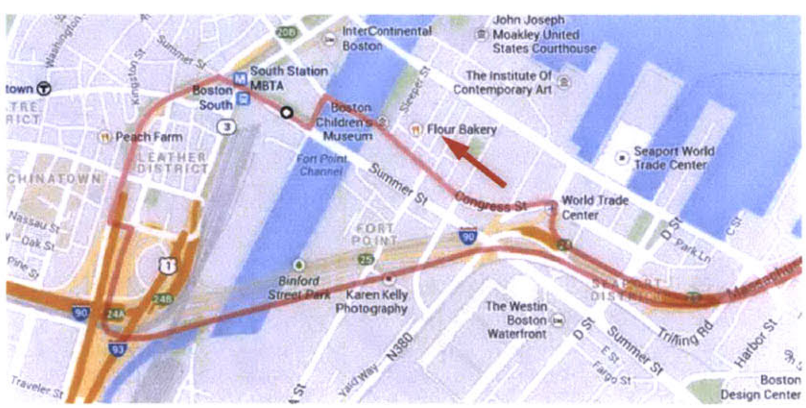


Figure 5-5: Alternative A2

Another alternative (see Figure 5-6) is to route the bus along Congress Street and offer a stop at World Trade Center station, thereby allowing connections to the local substitute bus route and direct access to the Seaport District. The bus travels inbound by turning left onto Congress Street and stopping as soon as possible to allow a short walk transfer to WTC station, then continues on and makes a clockwise loop around the South Station area, stopping on Summer Street. Outbound, the bus goes onto the Greenway then back on Congress, stopping at WTC, then onto the Haul Road before taking the ramp to go onto I-90. Outbound (South Station to Terminal A) off-peak travel time is expected to be between 10-15 minutes, with a 1 minute WTC dwell time included. So, this route has considerably slower speeds than the other two, but does allow direct public transport access from the airport into the District. Installation of bus lanes on Congress Street can really help to improve performance along the route, especially during the peak, since the route travels along much of the road. Although from both our current assessment of the data and field observations, there is limited demand for travel between the airport and the District, it is likely that as the area grows, there will be more airport passengers desiring direct access to the area. Thus, in 2025, the added WTC stop should be a benefit rather than a hindrance.

With respect to the first two alternatives, as mentioned earlier, the first alternative's fast travel time is negated by the difficultly of the transfer to onward public transport routes for passengers; the second seems good at first glance, offering a reasonable travel time with an easy transfer, but the route needs to use surface streets in the outbound direction, which are prone to peak congestion, so unreliability is relatively high. Thus A3 is seems to be the preferred option, and although it uses surface streets and has the highest travel time, the difference is not significant for the latter while for the former, the use of bus lanes should help to limit congestion effects.

Figure 5-6: Alternative A3

A summary of all the cycle times of the various alternatives is shown in Figure 5-10. The cycle times for L1 and L2 presents a significant increase from SL2's time of 30 minutes as expected since the route is now operating on surface streets. Interestingly, A1 has a shorter cycle time than SL1's 45 minutes, due to its ability to quickly access the expressway and no stops in the District. A2 has the same cycle time as SL1, even though it has no stops within the District, because of its route on regular streets. Finally, A3, spends a significant portion of the trip on local streets, as well as stopping at WTC, however because of the bus lanes, the travel time is only 5 minutes slower than SL1. More importantly, it shows the maximum capacity possible using the current Silver Line fleet, which makes clear that for SL1 at least, there will be enough capacity available. Unfortunately, this is not the case for SL2/SLW substitute, where capacity at 1,733 passengers/hour (assumes platoons are used so headways are reasonable) falls far short of projected demand in the medium term, leaving 216 passengers per hour unaccounted for. As noted below, in theory, there is enough capacity if L1 is utilized, but this is infeasible in practice. It is assumed that SLG will use its own, separate bus fleet.

Alternatives	Description	Cycle Time	Headway	Fleet Size	Capacity	Projected Demand
SL1 Substitute						
A1	From Bus Terminal	40	5:45	7	553	347
A2	Big Loop	45	6:30	7	489	347
A3	Congress	50^	7:10	7	444	347
SL2/SLW Substitute						
L1	Via Fort Point	40	2:15*	18	1733	1949
L2	Via Courthouse	50	2:50*	18	1376	1949

* = this is too low for a surface bus route – lowest possible for good operations is around 3-4 minutes. Even if the buses were platooned (so headway is increased to acceptable levels), the fleet is still not large enough to provide the capacity; 20 articulated buses would be needed for L1 to provide a capacity of 1,950 at 2 minute headways. Buses can depart in platoons of 2, increasing headways to a more realistic 4 minutes. 25 buses would be needed for L2 to provide the same level of service.

^ = assumes use of Congress Street bus lanes; without bus lanes, add 5-10 minutes.

For detailed calculations of cycle times, see the Appendix A4.

Table 5-10: Maximum possible service, given current Silver Line fleet

So, this data poses an interesting challenge: either more buses are brought in to service the remaining demand, or the D Street grade separation project should start earlier, before demand builds up to these levels. While the former is possible and is not too difficult, it is a costly option for the financially-constrained MBTA, whereas starting the project earlier can help reduce both construction costs and save money to operate additional buses. In fact, another benefit of an earlier project start is there will be less traffic disruptions too, due to lower demand in the short-term. Thus, it is certainly preferable to start the project even before the mid-term, to avoid the difficulties of accommodating passenger trips during construction.

As can be gathered throughout the discussion of these substitute routes, they are all imperfect replacements to the Silver Line and will inconvenience passengers in one way or another. However, one of the most effective ways to minimize this impact (aside from choosing appropriate routes) is to start construction on "T under D" as soon as possible. This is a particularly crucial point: for every year in which the project is delayed, there will be higher costs for replacement services and greater pain inflicted on travelers. This is because, as discussed repeatedly, throughout this thesis and in many other planning studies, the Seaport District is projected to grow substantially – this growth will inevitably lead to more demand on both the public transport and road networks, so for each year that passes, there will be more passengers on the Silver Line and more cars on the streets. Hence, the later "T under D" takes place, the more replacement buses will have to be run and the more drivers will be impacted, and in fact, more replacement buses will worsen the traffic impact too, so the effect is compounded. Thus, it is imperative that this project be undertaken as soon as possible to ensure the smooth, crisis-free growth of the District.

Congress Street Bus Lanes

In conjunction with the "T under D" project, it is strongly recommended that Congress Street have bus lanes installed along its route and, in particular, the conversion of Congress Street Bridge to bus-only would be ideal. The benefits would be considerable since it allows buses to travel with less traffic interference and avoid the choke points at the bridges during the peak – this is very useful to ensure headway reliability since substitute buses' frequencies will have to be fairly high in order to accommodate the displaced Silver Line riders. Without these lanes, it is very likely that bus travel times will be badly impacted and thus reduce public transport mode share. Even after "T under D" is complete, the bus lanes will still be useful since it means that other local buses, consolidated shuttles and express buses can easily travel into and out of the District. Indeed, the benefits are more than just improving travel times (hence public transport mode shares), the lanes allow increased public transport accessibility to the District, which is crucial as the area grows and becomes denser. Furthermore, the bus lanes provide a redundancy for Silver Line and can help reduce the overreliance on it. In addition to bus lanes, public transport signal priority should be installed, enabling even higher speeds for buses and also increase public transport capacity into the District. There is ample evidence to suggest that all these measures can really help improve bus travel, and may encourage higher usage: many European cities, London being a notable example, have successfully used bus lanes to cut travel times considerably. Within the US, New York City's implementation of Select Bus Service is widely regarded as a success, in addition to the pre-existing bus lanes on Madison Avenue as well as the peak-hour Lincoln Tunnel Exclusive Bus Lane. An important point to note though, is that in all these cities, the lanes must be strictly enforced to prevent both illegal driving and parking by cars, which can quickly render the bus lane ineffective. New York City at one time had a severe issue with abuse of bus lanes, but through more stringent police enforcement and installation of bus lane cameras (with high fines between $100-$150), the problem was largely corrected.

Ferry Connections to East Boston, Chelsea and Charlestown

In the medium term, ferries could be put to effective use since the District offers easy access to the water. Currently, there are only on-demand water taxis and tourist boats for service, which are expensive for commuting, so there could be some latent demand, especially as the area grows further.

The routes must be chosen to avoid redundancies with land transport routes; this leaves East Boston, Charlestown and Chelsea as places possible for new services, as is illustrated in Figure 5-7 with the operating characteristics shown in Table 5-11. For comparison, the ferry from the Long Wharf (near the Aquarium) to Charlestown's Navy Yard takes 10 minutes, so judging by the distance, East Boston should take about the same, Charlestown no more than 15 minutes and Chelsea no more than 20 minutes, which are all quick travel times during the rush hour. Indeed, if higher speed ferries were used on the Charlestown and Chelsea route, travel times could be reduced to about 10 minutes.

Since ferries can only take passengers to the water's edge, inter-model transfers are needed to provide better service. Therefore, the ferry terminals should be connected with rapid transit stations, bus stops and park-and-ride lots to make transfers easier for customers. For example, it would be a good idea to place the East Boston ferry stop close to the Maverick Blue Line station, enabling commuters all the way from Wonderland to access the District fairly quickly without traffic interference. The current ferries from Hingham/Quincy could also stop at the Seaport District in the future, further increasing the range of public transport reach and potentially reducing car travel into the area. As for the ferry stop within the District itself, the location should be selected so as to minimize transfer time, i.e. the stop should be placed as close to Seaport Boulevard as possible to allow easy access to the consolidated shuttle alternative A2 as well as a short walk (5 minutes) to Silver Line's WTC station. The waterfront directly opposite to B Street or Seaport Lane would be good candidates for this.

For ferry services, the captital and operational cost will directly affect the fare and thereby influence the passenger demand. Since higher speed makes little difference in overall travel time for short routes, and the power required to increase speed by 5 knots will probably double the fuel consumption, it is a good idea to initiate services with a more resonable speed of around 20 knots[34]. Besides, it may be feasible to set a relatively high frequency and make the total travel time competitive with driving. This will ultimately result in higher ridership and hence revenue, despite the initial high operational cost which may not be covered by fare revenue at the outset. Thus, a 15-minute headway is recommended during peak hour.

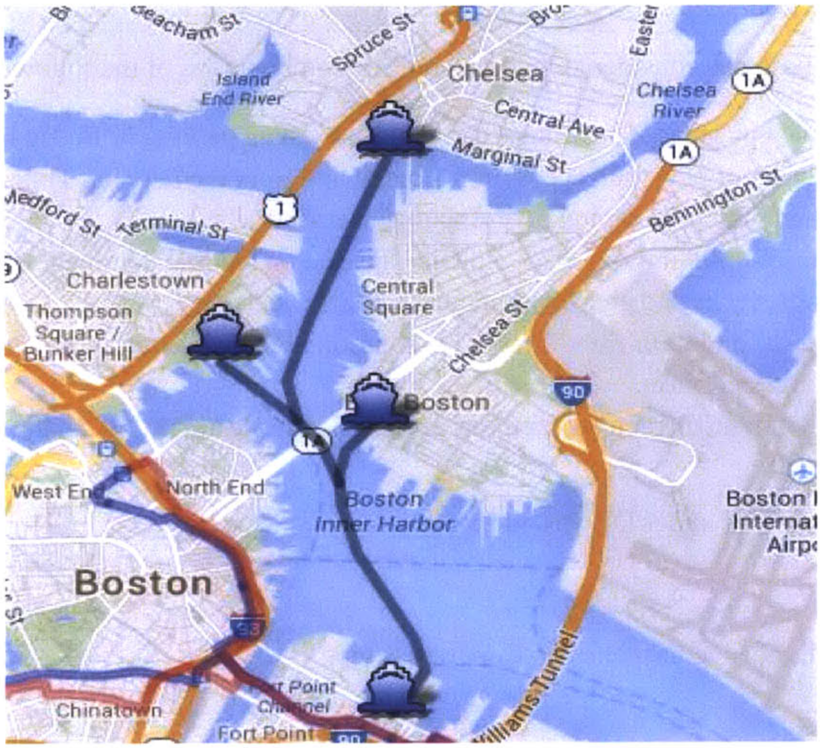


Figure 5-7: Possible ferry routes

Ferries	Connection	Travel time	Headway	Capacity	Speed
To East Boston	Maverick Blue Line station	10 min	15 min	100	20 knots
To Chelsea	N/A	20 min	15 min	100	20 knots
To Charlestown	N/A	15 min	15 min	100	20 knots

Table 5-11: Ferry operating characteristics

[34] Transportation Research Board (2003), Transit Capacity and Quality of Service Manual, 2nd edition, Washington D.C.

5.3.2 Traffic

The traffic analysis focused on:

- Adequately addressing the problems identified in the no-build scenario.
- Attaining the objectives of this thesis by supporting transit-oriented development for the Seaport District.

The strategies considered involved one, or combinations of the following:

- Exclusive bus lanes. These lanes can replace existing parking or traffic lanes.
- Introduction of new road access corridors to and from the District. This was considered only when moderate capital investment is necessary.
- Street access prohibitions. This strategy focused on guiding dominant traffic volumes away from bottlenecks and areas with increased traffic activity.
- Restrictions on left or right turns. This solution aimed to detour turning traffic volumes from congested links.
- Alteration in traffic control methods at specific intersections (e.g. change from yield to signalized).

For this analysis, "T under D" was assumed to be completed by 2025.

Strategy 1 – Exclusive bus lanes on Congress Street

Description:

Congress Street is a significant corridor which serves as the entry point for many trips accessing the Seaport District from the regional highway network. The introduction of one bus lane in each direction starting at the Congress Bridge Street and ending at the intersection of Congress Street and Northern Avenue can (a) prioritize public transport access on Congress Street and (b) serve as a traffic mitigation strategy that will decrease traffic volumes and delays in the corridor.

To introduce the bus lane, the basic approach was to replace the right lane in either direction on Congress Street. Specifically, the introduction of the bus lane requires the following changes on Congress Street:

- Replacing the existing parking lanes on both sides of the road between the Congress Street Bridge and the intersection with East Service Road. In the outbound direction (from the Financial Center to the Seaport District), the right turning bay at the intersection of Congress Street and A Street must also be replaced, leaving only one lane for all three available moves (straight, right and left turns).

- Replacing the right traffic lane between East Service Road and B Street outbound as well as the parking lane inbound. Inbound, the right turning bay from Congress Street to the I-90 on-ramp must serve as a continuation of the bus lane and was hence replaced.
- Replacing the parking lanes in both directions between B Street and D Street with the bus lane. This requires the utilization of the right turning bay, which serves the vehicles that turn from Congress Street to D Street outbound. This turning bay was already unutilized since right turns were prohibited in the short-term strategy.
- From the Congress and D intersection to Northern Avenue, the outbound direction serves as an exclusive bus lane and vehicle access is prohibited. Inbound, the parking lane (until the intersection with Harborview Lane) was replaced by the bus lane.

Figure 5-8 shows the parking (orange lines) and traffic (red lines) lanes that must be replaced. These changes correspond to the elimination of on-street parking on Congress Street, which reduces the District's on-street parking supply to approximately 700 spaces. The changes also correspond to a significant reduction in the road capacity of the corridor, especially in the outbound direction.

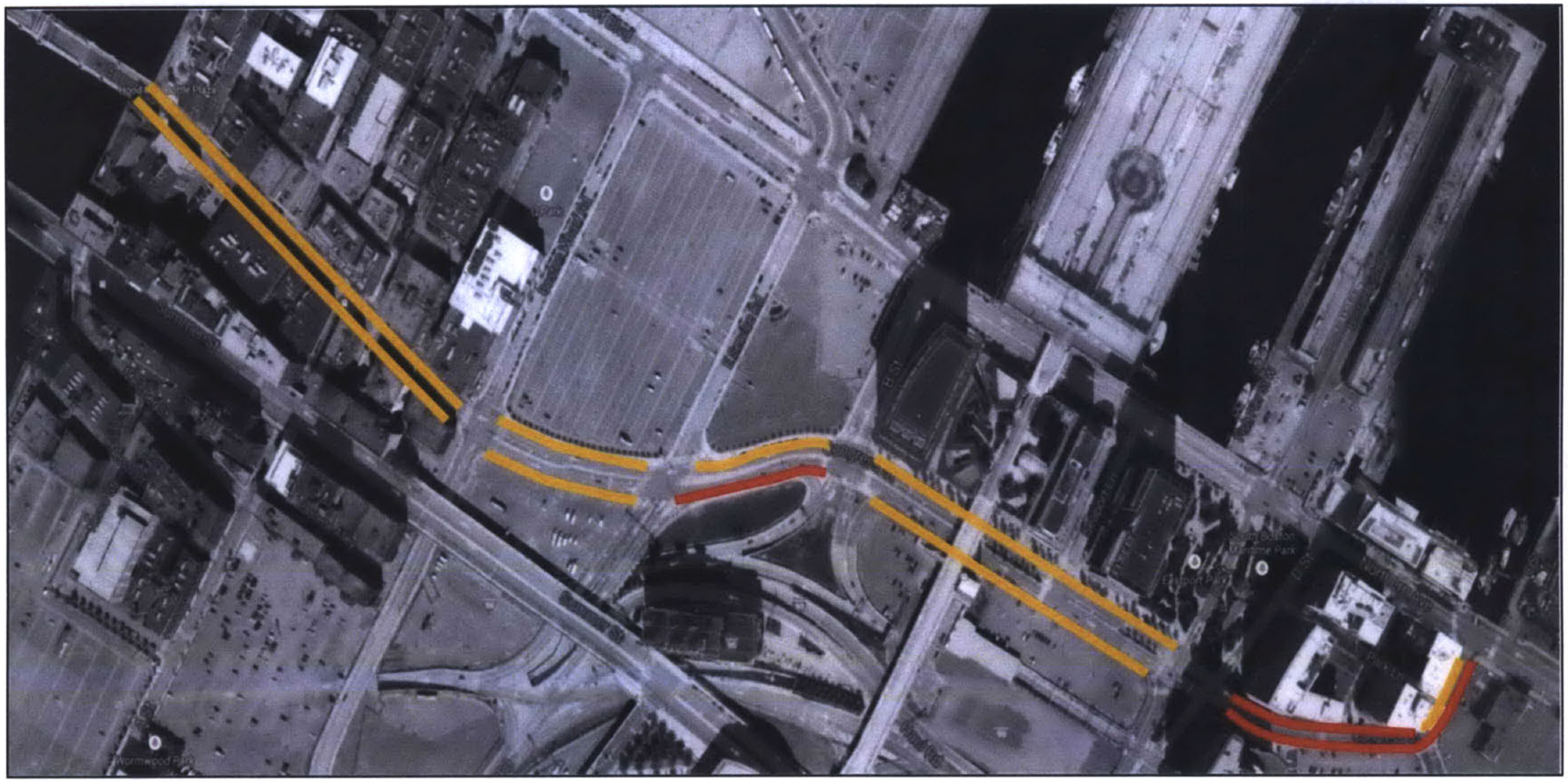


Figure 5-8: Bus lanes on Congress Street

Complications:

A series of complications are associated with this recommended strategy:

- Elimination of about 100 on-street parking spots currently available on Congress Street. However, in the Seaport District, 700 on-street parking spots will remain, while today there is a supply of 12,000 off-street parking spaces. Furthermore, the South Boston Parking Freeze sets the potential off-street parking capacity of the area at 19,500 spots. Therefore, it is likely that the elimination of these 100 parking spots will have minimal impact.
- Road capacity on Congress Street between the intersection of East Service Road and B Street is decreased significantly. This reduction is combined with the increase in traffic congestion in this part of the network, as evident from the results for the no-build scenario. To address this problem, the following modifications to the road network are proposed:

    - The closing of the I-90 EB off-ramp exit to Congress Street. Vehicles entering the District from this part of the highway system must use the exit ramp to the Haul road. This modification will alleviate traffic congestion in the intersection of Congress Street and East Service Road, and will not significantly impact the vehicle flows entering the District from I-90 EB since they still have the option of taking the Haul road into the District. Figure 5-9 shows the proposed change. It should be noted that the Haul Road is a four lane collector with limited access points. Between the I-90 EB off-ramp and the intersection with Northern Avenue there is only one intersection in the Haul Road (with the Pump House Road). Therefore, increasing the traffic volume on this part of the Haul Road by 800 vehicles per hour during the AM peak should cause only minimal deterioration in the current traffic conditions.

    - At the intersection of Congress Street and East Service Road, a left turn prohibition for vehicles entering the Seaport District from the I-93 off-ramp is proposed. This will guide the left turning vehicles to Northern Avenue and therefore decrease the inbound volume on Congress Street. This is effective since the inbound direction has little capacity because only one traffic lane is available after the intersection with Boston Wharf Road. Similarly, the left turn would be prohibited for vehicles entering Seaport District from the I-90 WB off-ramp.

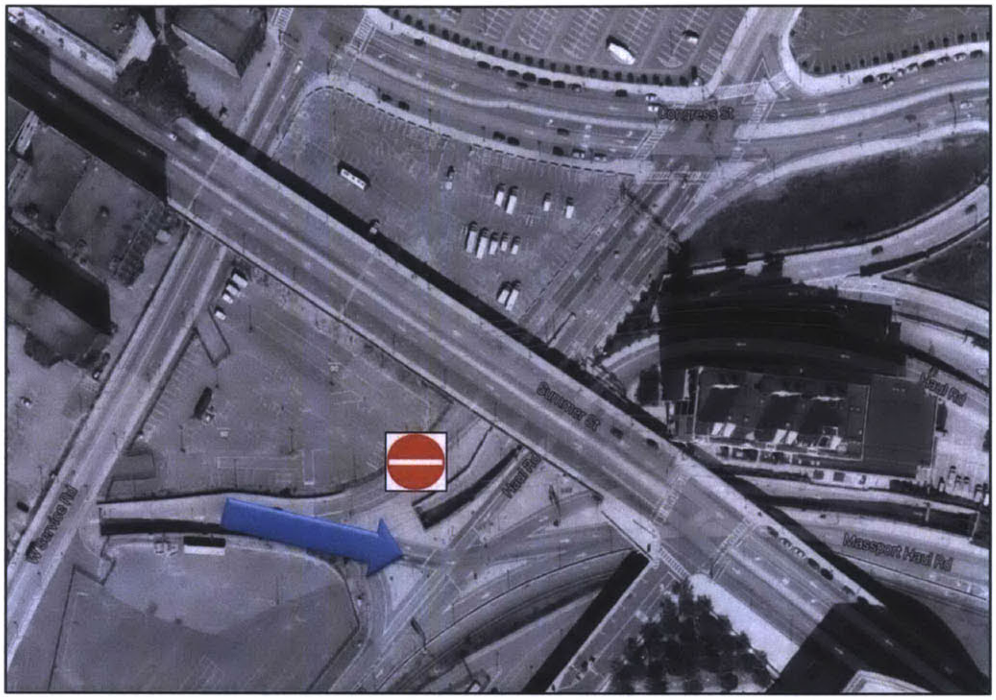


Figure 5-9: Prohibition of the I-90 EB off-ramp

- Prohibition of the right turn from Congress Street to the I-93 on-ramp. This is required since the turning vehicle flows are significant, especially during the PM peak hour, and conflict directly with the bus priority lane. Vehicles can still enter the ramp from Congress Street outbound (by taking a left at the intersection) or from B Street (by traveling straight at the intersection).

- At the intersection of Congress Street and D Street, prohibition of every movement that leads to the outbound direction of Congress Street (towards Northern Avenue). The vehicles affected by this change are mainly those traveling towards the I-90 on-ramp on D Street. However, from the short-term analysis, we recommended prohibiting right turns onto D Street. Hence, if all vehicles are forced to detour to Northern Avenue via D Street, significant delays on both D Street and Northern Avenue will be created. As a result, it is preferred to reinstate the right turns onto D Street during the medium term scenario. However, this generates significant queues and delays at D Street, which spillover to Summer Street. To address this issue effectively, the left turn from Summer Street onto D Street should be prohibited. As a result, vehicles moving on Summer Street and wanting to enter the Interstate system have to turn onto Pumphouse Road and enter I-90 via the Haul Road. In Figure 5-10, vehicles coming from Summer Street are shown with green arrows, while vehicles coming from Congress are shown in blue.

Figure 5-10: Alternative routes towards I-90 on-ramp

- In order to improve the connectivity between Congress Street and Seaport Boulevard, it is important that Thompson Place be open for through traffic. Currently, while the infrastructure exists, Thompson Place is a dead-end, prohibiting access to through traffic. Figure 5-11 shows the current conditions at the intersection of Thompson Place and Seaport Boulevard.

- Finally, signal plans were optimized based on the new traffic volumes at all intersections on Seaport Boulevard, Northern Avenue, Congress Street and Summer Street. In addition, new signals were introduced in the model and include the intersections of:
    - A Street and Melcher Street
    - Haul Road and I-90 EB off-ramp
    - Summer Street and Pumphouse Road

Figure 5-11: Dead-end at Thompson Place and Seaport Boulevard intersection

Results:

The effectiveness of this strategy, and the effectiveness of the strategies to deal with the various complications, can be evaluated based on intersection results and queue lengths formed on I-90 and I-93 off-ramps. As illustrated in Table 5-12 the network can adequately serve the forecast demand, while at the same time prioritize public transport access on Congress Street.

Intersection	2025 – No-build			2025 – Bus Lanes on Congress Street		
	Control Delay (sec/veh)	Average Stops (stops/veh)	LOS	Control Delay (sec/veh)	Average Stops (stops/veh)	LOS
AM Peak Hour						
A St & Melcher St	22.3	0.5	**C**	11.9	0.6	**B**
B St, Congress St, I90 Off-Ramp WB & I93 On-Ramp	36.6	0.8	**D**	41.8	0.9	**D**

Boston Wharf Rd & Seaport Blvd	90.7	1.5	**F**	15.3	0.6	**B**
Congress St & D St	54.5	0.8	**D**	44.2	0.8	**D**
Congress St, A St & Thompson Place	41.3	1.1	**D**	19.7	0.6	**B**
D St & Summer St	39.5	0.9	**D**	40.8	0.9	**D**
Northern Ave & B St	47.9	1	**D**	28.9	0.7	**C**
Northern Ave, East Service Road & Seaport Blvd	50.5	1.2	**D**	22.0	0.6	**C**
Pump House Road & Summer St	-	-	**-**	13.1	0.4	**A**
Sleeper St & Seaport Blvd	17.0	0.7	**B**	26.3	0.7	**C**
Summer St & WTC Ave	17.9	0.6	**B**	14.8	0.5	**B**
PM Peak Hour						
A St & Melcher St	21.6	0.4	**C**	37.1	0.8	**D**
B St, Congress St, I90 Off-Ramp WB & I93 On-Ramp	27.1	1.0	**C**	37.1	0.8	**D**
Boston Wharf Rd & Seaport Blvd	44.2	0.9	**D**	18.5	0.5	**B**
Congress St & D St	47.7	0.8	**D**	48.2	0.8	**D**
Congress St, A St & Thompson Place	22.1	0.6	**C**	44.0	0.7	**D**
D St & Summer St	71.5	1.3	**E**	39.8	1.0	**D**
Northern Ave & B St	30.5	0.8	**C**	27.5	0.8	**C**

Northern Ave, East Service Road & Seaport Blvd	31.0	0.8	**C**	39.4	0.9	**D**
Pump House Road & Summer St	-	-	-	32.7	0.9	**C**
Sleeper St & Seaport Blvd	17.1	0.7	**B**	25.9	0.8	**C**
Summer St & WTC Ave	240.3	3.5	**F**	59.7	1.3	**E**

Max Queue Length (feet)			
Ramp	**I-93**	**I-90 EB**	**I-90 WB**
AM Peak Hour			
2025 – No-Build	419	918	6,796
2025 – Bus Lanes on Congress Street	225	178	910
Difference	**-194**	**-740**	**-5,886**
PM Peak Hour			
2025 – No-Build	137	194	398
2025 – Bus Lanes on Congress Street	160	274	398
Difference	**23**	**80**	**0**

Table 5-12: 2025 no-build and 2025 with bus lanes on Congress Street

Strategy 2 – Opening of the Old Northern Bridge

Description:

The Old Northern Bridge is located in the Northwestern part of the Seaport District, connecting the area with the Financial District (Figure 5-12). The bridge is an extension of Old Northern Avenue and is close to the Federal Courthouse. Currently, the bridge provides access to only to non-motorized modes, including walking and bicycling. The utilization of the Old Northern Bridge by automobiles could provide an extra corridor into the area, and potentially improve the connectivity between the Financial and the Seaport District. The width of the bridge is enough to accommodate at least one lane per direction.

Figure 5-12: Old Northern Bridge

Complications:

The major complication of this strategy is the relatively significant capital cost that would be required to make the bridge available for everyday traffic.

Results:

The importance of refurbishing the bridge was estimated based on the impacts it had on the following intersections:

- Seaport Boulevard and Sleeper Street.
- Seaport Boulevard and Boston Wharf Road.
- Seaport Boulevard, Old Northern Avenue and East Service Road.

The intersections were selected on the basis that the Old Northern Bridge provides a parallel corridor to Seaport Boulevard and therefore serves the same demand. This observation is supported by the fact that the Moakley Bridge and the Old Northern Bridge intersections with Atlantic Avenue are very close together. In addition, Old Northern Avenue has very few exit points; vehicles can either park or join the flows on Seaport Boulevard. In Figure 5-13 the vehicle flows that follow Seaport Boulevard are shown with red arrows, the vehicle flows that follow Old Northern Avenue are shown in blue and the intersections analyzed are circled.

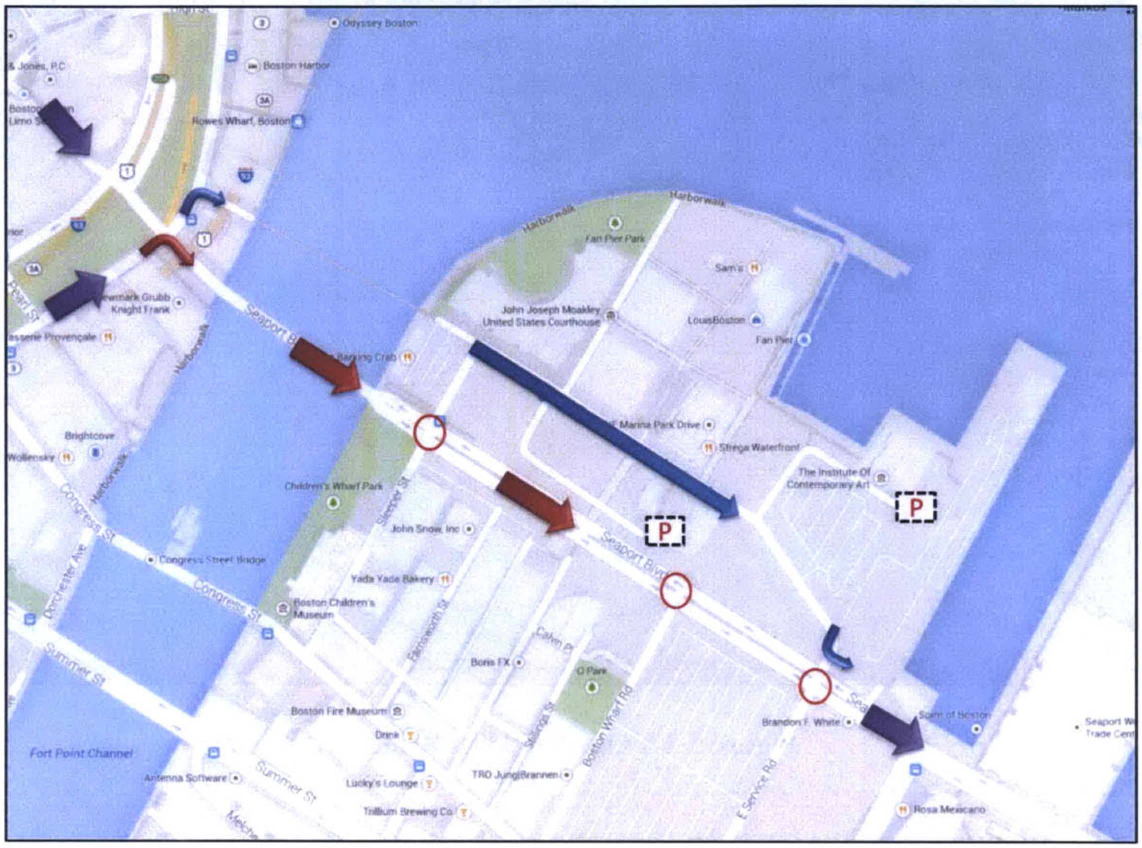


Figure 5-13: Old Northern Bridge and Seaport Boulevard connections

The results, summarized in Table 5-13, demonstrate that introducing the Old Northern Bridge to the road network of the District has no significant impact because the three analyzed intersections displayed no systematic evidence to indicate that this new corridor will benefit the traffic conditions in the Northwest part of Seaport Boulevard.

Intersection	No Old Northern Bridge Average delay (sec/veh)	No Old Northern Bridge Average Stops (stops/veh)	No Old Northern Bridge LOS	With Old Northern Bridge Average delay (sec/veh)	With Old Northern Bridge Average Stops (stops/veh)	With Old Northern Bridge LOS
AM Peak Hour						
Northern Ave, Old Northern Ave, Seaport Blvd	22.0	0.6	**C**	22.7	0.7	**C**
Boston Wharf Rd & Seaport Blvd	15.3	0.6	**B**	14.9	0.6	**B**
Sleeper St & Seaport Blvd	26.3	0.7	**C**	24.6	0.8	**C**
PM Peak Hour						
Northern Ave, Old Northern Ave, Seaport Blvd	39.4	0.9	**D**	45.1	1.0	**D**
Boston Wharf Rd & Seaport Blvd	18.5	0.5	**B**	16.8	0.5	**B**
Sleeper St & Seaport Blvd	25.9	0.8	**C**	24.1	0.8	**C**

Table 5-13: Intersection performance without, and with Old Northern Bridge

Strategy 3 – Extension of Dorchester Avenue

Description:

Today (and during the 2017 scenario), general traffic is prohibited on Dorchester Avenue north of the intersection with West Broadway. The section of Dorchester Avenue between the intersection with West Broadway and the intersection with Summer Street is restricted to US Postal Office vehicles only. Opening Dorchester Avenue for all vehicles would introduce a direct link that connects the southern parts of the Seaport District with the Downtown Boston area, as shown in Figure 5-14. Today's options are limited to A Street and D Street, given that the Haul road has limited access points and B and C Streets are interrupted by the Boston Convention and Exhibition Center.

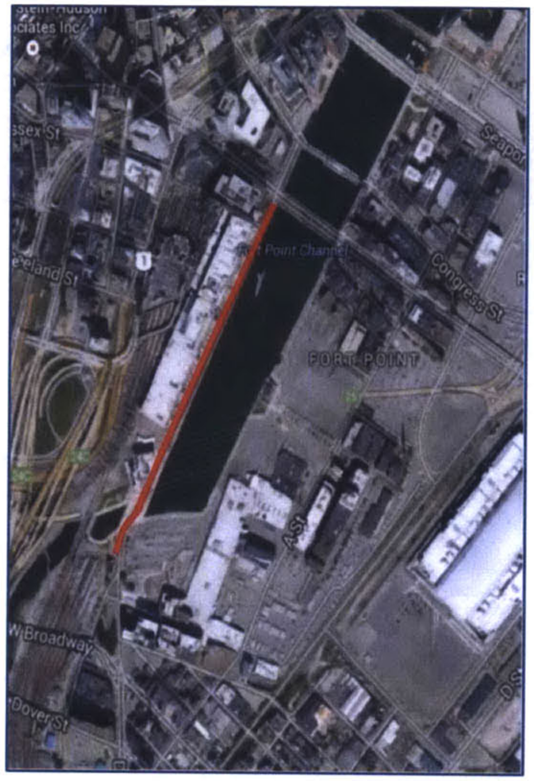


Figure 5-14: Dorchester Avenue extension

Complications:

The extension of Dorchester Avenue does not cause significant complications since the infrastructure already exists. However, today, this part of Dorchester Avenue accommodates loading services for the US Postal Office and, if the Avenue is made available for through traffic, some complications may arise for loading activities.

Results:

The extension of Dorchester Avenue does not improve the conditions in the Seaport District. Traffic conditions in A Street and D Street do not change systematically, indicating that the extension has limited impacts. None of the intersections in the District are affected by the extension.

Strategy 4 – Roundabout at the intersection of Dorchester Avenue and West Broadway

Description:

The intersection of Dorchester Avenue and West Broadway operates at capacity (LOS E) during the AM and the PM peak hours. In the AM peak hour, demand is increased in the northbound direction on Dorchester Avenue, while in the PM peak hour, demand is increased in the outbound direction (towards the Seaport District) on West Broadway, with the majority of vehicles turning right on Dorchester Avenue. A roundabout should increase the capacity of the intersection for all directions and therefore reduce the delays and queues.

Complications:

Two main complications arise related to this strategy:

- The intersection serves significant pedestrians flows due to the "T" Broadway Station. Therefore, safety is an important concern since roundabouts provide limited visibility to pedestrians. However, the combination of a roundabout with other intersection control methods, such as traffic signals, could provide a potential solution.
- The limited capacity of the neighboring road network. Specifically, the intersection of A Street and W Second Street has a limited capacity since it already operates at LOS E. Changes in the traffic signal plans can be examined as a means of improving the capacity of neighboring intersections.

Results:

The results from Table 5-14 show that the conflicting moves can be better served if a two-lane roundabout replaces the existing signalized intersection. However, the network in the area is unable to adequately accommodate the high traffic volumes. Conditions at the intersection of A Street and W Second deteriorate significantly, leading to LOS F. In addition, delays at the intersection of A Street and West Broadway deteriorate, but the intersection still operates adequately.

Intersection	Traffic Signal		Roundabout	
	Control Delay (sec/veh)	LOS	Control Delay (sec/veh)	LOS
AM Peak Hour				
Dorchester Ave, Broadway Brg & W Broadway	76.1	E	12.5	B
A St & W Broadway	24.6	C	74.9	E
A St & W 2nd St	51.3	E	141.1	F
PM Peak Hour				
Dorchester Ave, Broadway Brg & W Broadway	79.0	E	13.0	B
A St & W Broadway	42.7	D	40.5	D
A St & W 2nd St	43.2	D	212.8	F

Table 5-14: Roundabout at Dorchester Avenue and West Broadway

Strategy 5 – Prohibition of left turn on Fargo Street

Description:

Vehicles moving inbound (towards downtown Boston) on Summer Street are allowed to turn left on Fargo Street in order to reach parking areas located between Fargo Street and D Street. These vehicles have to find an acceptable gap between outbound vehicles on Summer Street. These vehicles utilize the left inbound lane of Summer Street as they wait to find an acceptable gap, which forces vehicles upstream to maneuver to the right lane in order to continue their trip. However, because the intersection of Fargo Street and Summer is very close to the intersection of Summer Street and Drydock Avenue, the vehicles waiting for an acceptable gap create significant delays and hence queues inbound on Summer Street, especially during the AM peak hour where traffic volumes are high. A solution that could address the problem is prohibiting the left turn on Fargo Street for Summer Street inbound.

Complications:

Vehicles that are not allowed to turn left on Fargo Street have to proceed through the intersection of D and Summer Street in order to reach their destination. However, this intersection operates adequately during the AM peak hour, even when the turning moves increase due to the prohibition of the left turn onto Fargo Street.

Results:

The results from Table 5-15 indicate that this strategy can address the problem. Average control delay was reduced significantly during the AM peak hour, leading to LOS D. As expected, the strategy did not have a systematic effect on the PM peak hour where inbound traffic volumes on Summer Street are small. Note that the results for the intersection of D Street and Summer Street correspond to the conditions on the network after the introduction of the exclusive bus lanes on Congress Street.

Intersection	Left turn allowed			Left turn prohibited		
	Control Delay (sec/veh)	Average Stops (stops/veh)	LOS	Control Delay (sec/veh)	Average Stops (stops/veh)	LOS
AM Peak hour						
Drydock Ave & Summer St	105.7	1.8	**F**	46.6	1.0	**D**
D St & Summer St	39.5	0.9	**D**	40.8	0.9	**D**
PM Peak Hour						
Drydock Ave & Summer St	28.6	0.8	**C**	29.3	0.7	**C**
D St & Summer St	71.5	1.3	**E**	39.8	1.0	**D**

Table 5-15: Left turn prohibition onto Fargo Street

5.4 RECOMMENDATIONS

Public Transport

In the medium-term, the projection of a 50% increase in demand is conservative. In this scenario, the current public transport system's capacity is barely adequate, with the demand for some routes, such as the North Station bus route, being slightly over capacity. Proactive strategies are recommended since any growth slightly higher than our conservative estimate will easily push the demand in the District over the limit. These strategies are listed thus:

- D Street Grade Separation project should be moved into construction as soon as possible so that the Silver Line can provide a substantial capacity increase for the District, to 3,730 passengers per hour.
- During construction, substitutes for the Logan express route and Design Center route were analyzed. It is found that it may be hard for surface bus routes to accommodate the medium term district demand, and thus the construction needs to be done as soon as possible so that the public transport network can still be sustained during the construction period.

- A bus lane is recommended for Congress Street so that more reliable headways and shorter travel times can be ensured for the District.
- Three ferry routes are proposed to provide regional connections to East Boston, Chelsea and Charlestown. A 15-minute headway is recommended for these ferry routes during the peak hours so that a competitive travel time with auto can be provided to attract passengers.

Traffic

Given the objectives set for this thesis and the results of the analysis for the year 2025, we recommend:

- Introducing exclusive bus lanes on Congress Street. This strategy is associated with many complications that must be addressed in order to be successful. However, the implementation of this strategy can be the key for transit oriented development in the Seaport District. It is also recommended to conduct a further analysis that will investigate the possibility of extending the exclusive bus lane system on Congress through the Financial District all the way to North Station.
- Prohibiting the left turn from Summer Street onto Fargo Street. This strategy has significant impacts on the performance of the intersection of Summer Street and Drydock Avenue, the only entry point to the District from the southeastern section of South Boston.
- Maintaining the existing morning peak period off-street parking restriction policy at 80% utilization.

Based on our analysis and results, the following strategies are not recommended:

- The addition of the Old Northern Bridge to the Seaport District road network. From the analysis it was evident that this would not contribute in the improvement of the traffic conditions in the area, as was shown earlier in Table 5-13. Therefore, it is suggested to consider other uses for the bridge, such as the construction of an exclusive bus access corridor or the improvement of the bridge in order to better accommodate non-motorized forms of transport.
- The introduction of a roundabout at the intersection of Dorchester Avenue and West Broadway. The transformation may benefit the intersection itself, but the high flows cannot be accommodated by the rest of the network, as shown earlier in Table 5-14.

Implementing the recommended strategies can significantly improve the performance of the road network during the AM peak hour compared to the 2025 no-build scenario. The results also reveal moderate improvement during the PM peak hour. Significant improvements are noted at the off-ramps of the Interstate system since queue spillovers can be avoided if the recommended strategies are followed. The improvements of the average trip statistics and the queue spillover are shown in Table 5-16 and Table 5-17. Overall, it is evident from the analysis that with appropriate road management, the road network is able to provide more capacity to public transport vehicles and accommodate the estimated vehicle demand for 2025.

	Average Delay		Average Speed		
		AM Peak Hour			
Scenario	**Mins/veh**	**Change**	**Miles/hour**	**Change**	**# Trips**
2025 no-build	3.7				18,194
2025 build	2.4	-35%	21.5	+32%	18,217
		PM Peak Hour			
2025 no-build	4.8		16.0		20,830
2025 build	4.4	-8%	16.5	+3%	20,823

Table 5-16: Comparison of 2025 no-build and build

	Max Queue Length (feet)		
Ramp	**I-93**	**I-90 EB**	**I-90 WB**
	AM Peak Hour		
2025 – No-Build	419	918	6,796
2025 – Build	225	178	910
Difference	**-194**	**-740**	**-5,886**
	PM Peak Hour		
2025 – No-Build	137	194	398
2025 – Build	160	274	398
Difference	**23**	**80**	**0**

Table 5-17: Highway off-ramp queue lengths in 2025 no-build and build

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6 LONG-TERM ANALYSIS

This chapter focuses on the long-term analysis, corresponding to the year 2035. All the projected development and growth will have occurred by then, meaning that the transportation network in the District will have to accommodate very high demand. In this chapter, we will show our estimates of the 2035 demand, investigate the expected impacts if no improvements are introduced to the transportation network, and propose some alternatives to tackle the expected future problems. Note that in this chapter, "no-build" means that the recommended "build" scenario proposed here for 2025 is implemented as recommended but that the long-term strategies proposed in this chapter are not yet implemented.

6.1 ESTIMATED DEMAND

Future demand was estimated based on the ITE Trip Generation Manual and ABC's estimates (adjusted based on the growth experienced today in the Seaport District) following the methodology described in Chapter 2. The forecast demand for 2035 is shown in Table 6-1.

Person Trips							
		AM Peak Hour			PM Peak Hour		
Year	**Zone Type**	**Total**	**Attracted**	**Generated**	**Total**	**Attracted**	**Generated**
2035	**Office**	11,209	9,864	1345	14,181	2,411	11,770
	Industrial	2,090	1,818	272	2,053	595	1,458
	Hotel	2,200	1,254	946	1,544	448	1,096
	Retail	8,477	5,853	2,625	13,579	7,674	5,904
	Residential	2,258	655	1,603	2,570	1,568	1,002
	Total	**26,233**	**19,443**	**6,790**	**33,926**	**12,696**	**21,231**

Table 6-1: Demand forecast for the long-term analysis

The long-term represents a doubling in the person trips demand as calculated from the ITE manual for 2035. Similar to the short-term and medium-term demand estimations, an important assumption here is that the proportional increase in person trips will be reflected in vehicle trips, meaning that the mode split will remain constant during the peak hours. For trips originating and terminating in the area, a decisive factor that affects mode split is parking supply. As discussed in Chapter 3, the parking capacity in the District today is estimated to be 10,400 parking spots during the AM peak period. Assuming that this number will remain constant until 2035, we estimated whether the parking supply will constrain the vehicle trips in the area, as described below:

From the O-D matrix for the full build conditions in 2035, we estimated 10,400 vehicle trips attracted to the District during the AM peak hour. Assuming an additional 70% of vehicle trips for the rest of the AM peak period (based on current peak hour to peak period demand ratios), the total number of vehicle trips attracted to the District is estimated to be 17,700. Given that there are 10,400 existing parking spaces available during the AM peak period, we can conclude that the parking supply cannot meet the 2035 demand. However, as development occurs, it is highly likely that the parking supply will increase because the South Boston Parking Freeze permits a total of approximately 19,500 spaces in the area. Therefore, there is some likelihood that the mode split will remain constant.

A second decisive factor that affects mode split is the traffic conditions and the public transport capacity which are analyzed later in this chapter.

For the public transport network, the demand also doubles from the 2008 baseline scenario. Therefore, for the no-build medium-term scenario, the following assumptions were made, with the results shown in Table 6-2:

- Initially, the mode split is assumed to remain the same as the current (2008) mode split.
- Current public transport origin-destination pattern will also be maintained.

	Long-term Peak hour Demand - 100% increase	
	AM peak direction	PM peak direction
SL1	360	462
SL2 + SLW	2,598	2,586
North Station Route (northern loop)	613	613
North Station Route (A Street loop)	275	275
Boylston-Chinatown Route (northern loop)	500	500
Boylston-Chinatown Route (A Street loop)	167	167

Table 6-2: Long-Term peak hour public transport demand

Note that the demand is artificially low here since the trips that cannot be handled by the road network have not been distributed yet (see Table 6-7 below for this). In addition, even though the demand is doubled from the baseline, it is still a conservative estimate since the base is small. There is a very high potential that public transport demand will be greater than what is shown here, if the District were to fully develop according to plan and particularly if road network mode share were to be reduced.

6.2 NO-BUILD SCENARIO

This section will describe the impacts that the 2035 demand will have on the transportation network in the District and the performance of the network if no improvements were made to the network. Before discussing the results, it is important to clarify that for the public transport network, the results described in this section assume that the recommended medium-term strategies have already been implemented. Similarly, for the traffic network, the recommended medium-term traffic strategies proved to be successful in improving the conditions of the traffic network and were, therefore, assumed to have been adopted in the 2035 "no-build" scenario. Subsequently, the 2035 demand was assigned to the network. Hence, the results in this section assume that the medium-term strategies have already been implemented.

6.2.1 Traffic

The aggregate statistics for 2035 are shown in Table 6-3. Even after introducing to the traffic network all the improvements recommended as part of the medium-term analysis, we note that the sharp increase in demand between 2025 and 2035 has devastating effects on the aggregate performance of the District's network. During both peak hours, the average delays and the average speeds worsen radically, indicating that the network has clearly exceeded its overall capacity.

	Average Delay		Average Speed		
AM Peak Hour					
Scenario	Mins/veh	Change	Miles/hour	Change	# Trips
2025 build	2.4		21.5		18,217
2035	5.8	142%	11.2	-48%	21,545
PM Peak Hour					
2025 build	4.4		16.5		20,823
2035	7.7	75%	10.9	-34%	24,397

Table 6-3: Aggregate statistics (long-term no-build)

At a more detailed level, Table 6-4 shows the intersections that operate at or above capacity. During the AM peak hour, five intersections operate at LOS E and three intersections operate at LOS F. It is important to note that the three intersections that operate at LOS F experience delays that are greater than 140 seconds, which are very high delays (compared to

Table 2-6), meaning that lengthy queues form and significant demands are not met. In addition, note that two of these three intersections (Dorchester and W Broadway, Drydock and Summer) are particularly important because they are entry points to the District. During the PM peak hour, similar conditions are observed. Four intersections operate at LOS E and three intersections operate at LOS F. The intersections operating at LOS F experience very high delays and are important exit locations. This indicates that the network cannot handle such high vehicle flows at these locations.

Intersection	Control Delay (sec/veh)	Average Stops (stops/veh)	LOS
AM Peak Hour			
A St & W 2nd St	57.9	1.3	E
B St, Congress St, I90 Off-Ramp WB & I93 On-Ramp	77.5	1.6	E
Congress St, W Service Rd & Boston Wharf Rd	79.3	1.3	E
D St & Summer St	73.2	1.5	E
Northern Ave, Old Northern Ave, Seaport Blvd &	60.4	1.2	E
Congress St & D St	152.7	2.2	F
Dorchester Ave, Broadway Brg & W Broadway	141.0	2.5	F
Drydock Ave, Summer St	189.9	3.0	F
PM Peak Hour			
Congress St & D St	56.1	0.9	E
Congress St, A St & Thompson Place	63.9	0.8	E
D St & Summer St	71.9	1.6	E
Drydock Ave, Summer St	78.2	1.3	E
A St & W 2nd St	89.1	1.0	F
Dorchester Ave, Broadway Brg & W Broadway	265.8	3.5	F
Summer St, WTC Ave	175.8	2.9	F

Table 6-4: Intersection statistics (long-term no-build)

As for the queue spillovers, two major problems occur. First, very lengthy queues form at the westbound I-90 off-ramp during both the AM and the PM peak hours. Second, lengthy queues also form at the I-93 off-ramp during the AM peak hour. As shown in Table 6-5 and illustrated in Figure 6-1, the queues spillover to the Interstate greatly disrupting vehicle flows and causing very significant delays.

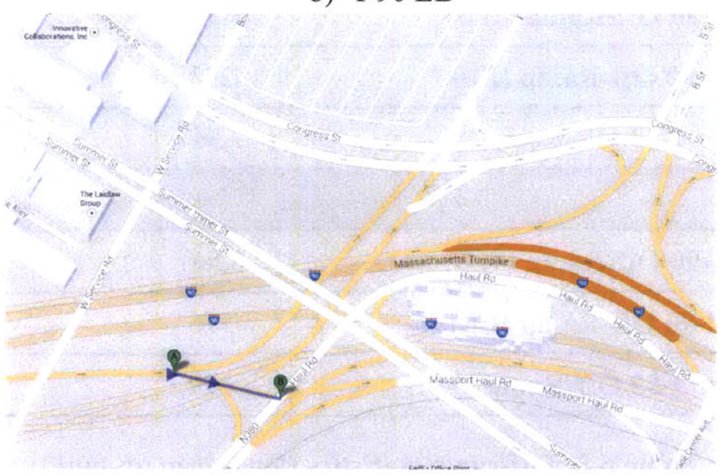
The link delays and usage continue to follow the same trends as in the previous years. Such a pattern is expected, since we have not introduced major changes to the traffic network. As shown in Table 6-6, Summer Street is the most heavily used corridor in both the AM and the PM peak hours, but it is also the corridor that experiences the worst delays.

Ramp	Maximum Queue Length (feet)
AM Peak Hour	
I-90 Off-Ramp (WB)	8,590
I-90 Off-Ramp (EB)	233
I-93 Off-Ramp	3,347
PM Peak Hour	
I-90 Off-Ramp (WB)	8,561
I-90 Off-Ramp (EB)	576
I-93 Off-Ramp	199

Table 6-5: Off-ramp statistics (long-term no-build)

a) I-90 WB

b) I-90 EB



c) I-93

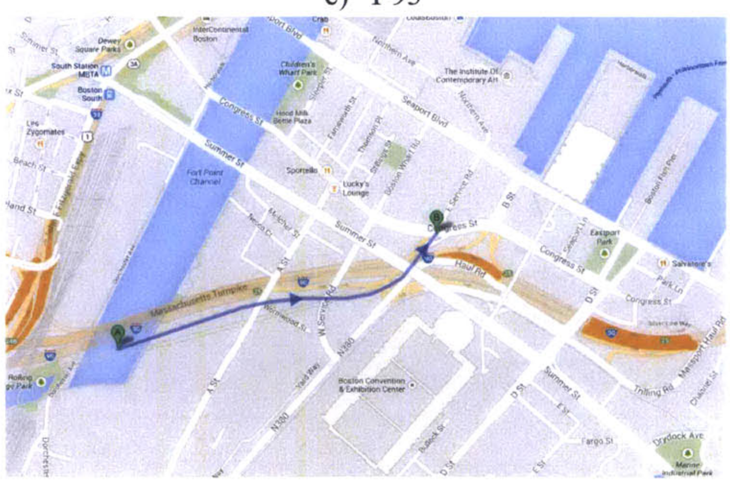


Figure 6-1: Maximum queue lengths at Interstate off-ramps (AM peak hour)

Street	Delay (min/mile)	Street	VMT (veh-mi)
		AM Peak Hour	
Summer St	3.8	**Summer St**	2,488
Seaport Blvd/Northern Ave	4.6	**Seaport Blvd/Northern Ave**	1,483
D St	10.4	**W Broadway**	751
Congress St	8.0	**Haul Road**	627
W Broadway	3.6	**D St**	502
		PM Peak Hour	
Summer St	4.3	**Summer St**	2,704
Seaport Blvd/Northern Ave	3.2	**Seaport Blvd/Northern Ave**	1,416
Congress St	7.0	**Congress St**	628
W Broadway	9.1	**Haul Road**	593
D St	6.6	**D St**	568

Table 6-6: Link statistics (long-term no-build)

Overall, all the indicators show that the network will not be able to accommodate the future demand for vehicle trips because (1) the average travel speed is low for urban streets (2) many intersections operate either at, or over capacity and (3) queues at the westbound I-90 off-ramp and I-93 off-ramp spill onto the Interstate system. Therefore, the additional trips that cannot be accommodated on the road network must be accommodated on public transport and (perhaps) other modes. As a result, we expect a shift in the mode share towards non-auto modes in the long-term.

6.2.2 Public Transport

In the public transport network, two additional assumptions were required to analyze the long-term no-build conditions. The two assumptions are:

1. The residual person trips (i.e. the demand that the traffic network fails to accommodate) will be accommodated by the public transport system.
2. The additional demand on the public transport network will be distributed proportionally across the routes (based on the ratios from the medium-term demand). The assumption is reasonable because the future development is concentrated in the northern section and along A Street.

According to the above assumptions, the long-term demand and no-build capacity of the public transport system are shown in Table 6-7 below.

	Long-term Demand & Capacity		No-build
	AM peak direction	PM peak direction	Peak hour Capacity
Silver Line (to Airport)	360	462	530
Silver Line (to District)	4381	4522	3730
North Station Route (northern loop)	1034	1073	636
North Station Route (A Street loop)	463	480	318
Boylston-Chinatown Route (northern loop)	843	874	530
Boylston-Chinatown Route (A Street loop)	281	291	212

Table 6-7: Long-term peak hour demand by route (considering changes in the mode split)

Even with the "T under D" construction during the medium-term scenario, the capacity of the Silver Line looks likely to be exceeded before 2035 is reached. However, this capacity of 3,730 passengers per hour assumes SLG operates in the tunnel. Without this Chelsea route, Seaport District capacity can be increased to 5,850 (see Table 5-8), with SLW and SL1 only operating in the tunnel, providing ample capacity. However, we need to recognize that the demand is a low estimate, so it is useful to examine potential ways to further enhance the maximum passenger flow possible, in case the demand approaches or exceeds capacity.

From Table 6-7, we can see that the captive demand increases to the extent that the surface bus routes' capacities are exceeded. A five-minute headway and a ten-minute headway during peak hour will be enough for the North Station (A Street loop) route and the Boylston-Chinatown (A Street loop) route, respectively since the base demand is lower, relatively. Yet the headway for the North Station Route in the medium-term has already been set to five minutes, which is quite low for surface bus routes. We need to set the headways to 3 minutes to accommodate the estimated demand, but it is likely that reliability of these two northern loop routes may suffer.

In short, the medium-term public transport network lags behind the long-term economic development of the district mainly because the traffic side can barely accommodate the medium-term demand. As a result, the dramatic demand increase overloads the no-build public transport system.

6.3 IMPROVEMENT STRATEGIES

6.3.1 Public Transport

The medium-term public transport network fails to respond to the dramatic additional demand as a result of the road network's limited margin. As the mode share increases in the long-term scenario, the existing structure of the public transport network needs to be enhanced to meet the rising demand. The following potential strategies that may greatly improve the capacity of the public transport network will be discussed briefly here:

- Convert the Silver Line to Light Rail
- DMU extension to BCEC
- Extend Silver Line 2 to E Street
- Implement transit-oriented development

Due to the uncertainty of future demand, and hence what solutions might be most appropriate in 2035, the strategies discussed here are more akin to ideas and potential plans, rather than in-depth research. Thus, in this section, more innovative (and perhaps radical) ideas are presented, which can be useful to build upon in further long-range planning studies.

Silver Line Light Rail Conversion

As discussed in the no-build scenario, there will be a huge increase in the public transport demand and in order to accommodate this, further changes should be considered to increase capacity, the foremost of which is Silver Line conversion to light rail. Although the grade separation does provide enough capacity, it is not clear that this will be sustainable in the long run, primarily due to the capacity of the vehicles which, at 65 passengers per articulated bus, might not be enough, even with low headways. For comparison, a 2-car light rail train can carry around 200 passengers (6,000 passengers per hour at 2 minute headways), or more than 3 times that of a Silver Line bus – and this assumes loading within the MBTA's service guidelines, so crush loading will be even higher. More cars can be added to provide higher capacity too, in addition, light rail helps to minimize driver costs, since one operator can transport many more passengers than a bus, keeping overall costs low because payroll is often a large share of operating expense.

Another crucial point to consider when examining light rail is how the route should be aligned. It is fortunate that the Silver Line tunnel was designed to accommodate future rail operations, so the route should certainly use the tunnel to access South Station. However, once the tunnel ends at Silver Line Way, there are a number of options available:

- Option 1. Add tracks in the road up to the Design Center. This would significantly increase the capacity to the Seaport District. Trips to Logan Airport will still be accommodated through SL1, which will share the tunnel with the light rail.

- Option 2. Is similar to Option 1, but instead of SL1 using the tunnel, it will now simply travel on the surface direct from the airport to South Station, with the possibility of a stop at WTC (see alternatives A2 and A3 in the medium-term strategies).

- Option 3. In addition to light rail service to the Design Center, another branch is created through a new underground path, parallel to the Ted Williams Tunnel, to Logan Airport. This alternative provides a perfect solution for access to both the Seaport District and the Airport, however, it is extremely costly.

As for SLG, it should continue using the Silver Line buses, and could either travel on the surface or in the tunnel, whichever is most appropriate for operational needs.

Looking at Option 1, although it is convenient for SL1 to use the tunnels, this means that the light rail frequency (hence the District's capacity) will have to be reduced to accommodate the buses. In addition, the MBTA would need to invest in a good signaling system and maintain strict scheduling standards in order to combine running buses and trams effectively, so it is certainly a challenging task.

Whereas for Option 2, the airport service uses surface streets which is not necessarily slower, especially if A2 (from medium term) was utilized, the cycle time is the same as SL1 service, so there is no difference for passengers going to South Station, but the downside is that the District is no longer served. A3 could instead be used, stopping at WTC, but this has a higher cycle time at 60 minutes. Nevertheless, the increased accessibility is useful and allows a direct trip to the District from the airport and, from the passenger's perspective, the travel time increase is not large (around 4 minutes each way) once the layover time is excluded.

Option 3 is an ideal scenario, since it would be very useful to have direct rail access to the airport connecting to both Boston's traditional downtown core and future extension of the downtown area, i.e. the District. Yet the cost is likely to be in the billions, so is difficult to be implemented.

Thus, from the options provided above, Option 2 seems most appropriate since it has relatively low costs while at the same time allowing a higher frequency of service to be operated within the District, which is the main purpose of installing the light rail in the first place. However, additional analysis should be conducted to fully determine the costs and benefits of each option.

Silver Line Phase III

A close complement to Silver Line conversion to light rail is the oft-discussed Silver Line Phase III, which continues the tunnel from South Station and links to Chinatown and Boylston T stations, offering connections to the Orange and Green Line, respectively (see Figure 6-2). Although in the plans, the tunnel is for buses, this should be changed because the T stations that it connects to offer high-volume services through the rail network, so it makes more sense that light rail be installed to these locations, to handle the large numbers of potential transfers to Silver Line (as opposed to bus operations, which does not provide as high a capacity). Phase III itself further enhances Silver Line access to the regional network, particularly important as discussed in the future regional demand analysis in Chapter 4 due to the high likelihood of commuters from the Green Line to the District. In fact, it is almost certain that the Back Bay shuttles proposed in the short-term solution will either encounter severe capacity issues due to the low maximum capacity available or travel time problems as demand to the District increases, so this light rail extension will be a useful way to continue making the District an easy place to travel to. Cost, again, will be the biggest challenge when creating this project – in a preliminary study published on 2004[35], the total cost was estimated at a little less than $1 billion for a BRT version, the current cost with light rail is likely to be in the billions. One possible way to reduce this is to combine the two stations shown in the figure to one, between Washington and Tremont Streets, which can offer connections to both the Orange and Green Lines through either end of the platform. Nevertheless, this project is a difficult undertaking, but the potential benefits that it yields are considerable: the combination of light rail with this extension would transform the way the District is accessed and thus provide a stable foundation for strong and sustained growth in the area.

[35] Boston Regional MPO (Rev. Jan 2004), "Program of Mass Transportation", Boston, MA.

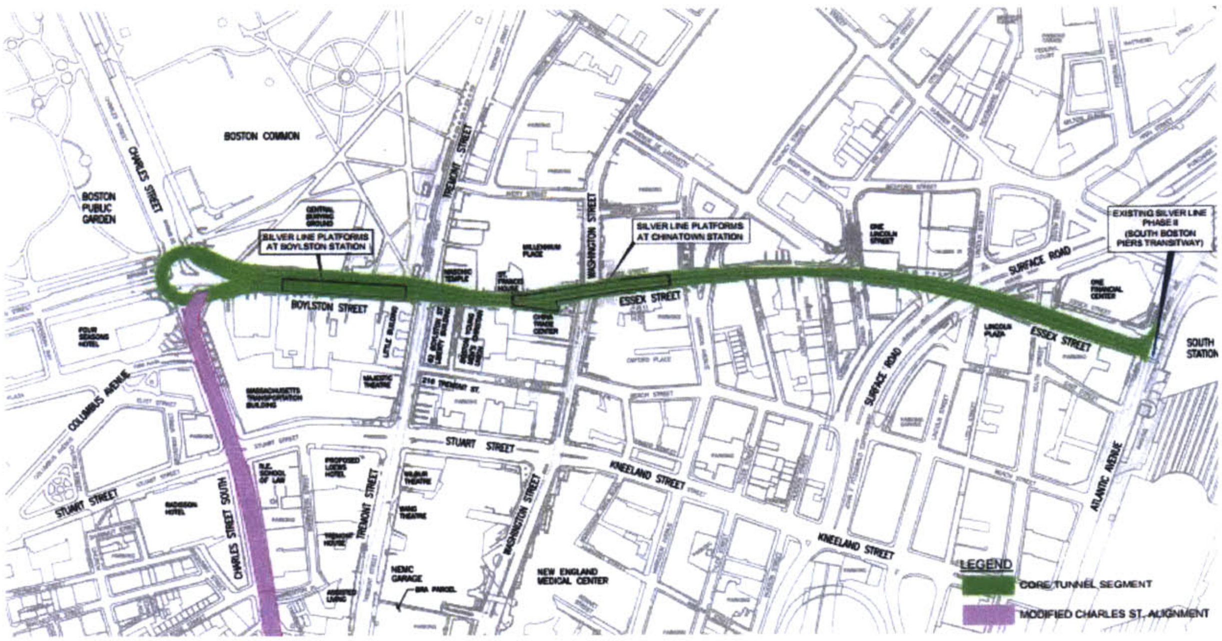


Figure 6-2: MBTA SL3 engineering drawing 2006[36]

Silver Line Expansion to New Developments

Turning to future development areas within the District itself, it is clear that there is still a significant amount of land available for development, as shown in Figure 6-3. Note that some of the areas are designated as 'port facilities', e.g. the northeastern part in green (although it is currently vacant with few buildings), so is currently unavailable for development, while other areas contain light industrial factories/warehouses, like the area bounded by the large green rectangle in the southern part of the District. However, if economic growth is strong in Boston and there is a strong pressure for development in the area, then it is feasible that most of these places will be built upon, thereby generating new demand. In fact, this potential chain of events has already occurred in MIT's own backyard, through Kendall Square's redevelopment from a decaying area with derelict industrial buildings into a technology and biotech hub with numerous high-end residential units. This future seems very likely for the Seaport District, given the current real estate prices in the Boston area, so there is a strong incentive for developers to resume construction once the economy improves and there is higher demand for housing.

[36] MBTA (through ABC: http://www.abettercity.org/transportation/silverline.html)

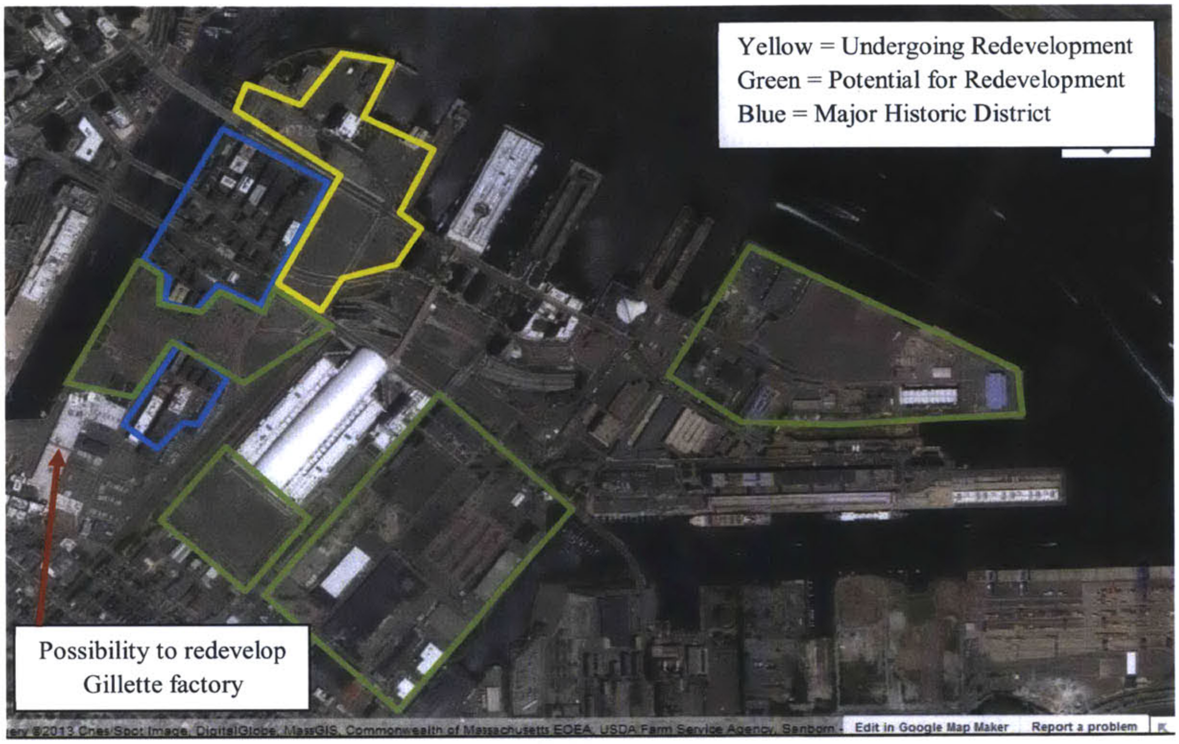


Figure 6-3: Potential development sites

Hence, there is a real potential here for public transport to guide and shape the future development and demand. Indeed, if there is a strong chance that development will occur at new areas such as along E Street, which is a large area currently occupied by assorted light industrial zones (large green rectangle in Figure 6-3), an extension to the Silver Line should be considered to serve that new demand. Currently, there are already some ongoing residential construction projects in the area, so that future might not be as far away as some imagine. This extension can be a surface route (either with a branch of the light rail or bus), with a public transport-only section between Summer and W 1st Streets since there are already 2 parallel, easily accessible roads, as shown in Figure 6-4. Although it is likely to be controversial, this route will be highly beneficial to transit-oriented development and might even allow, once all the buildings have been constructed in the area, for a dense, pedestrian-friendly environment with businesses/shops on either side, similar to Figure 6-5 of Portland's (Oregon) "Transit Mall". Thus, the route should attract new riders and maintain or even increase the public transport mode share for the area. A crucial point here is that the MBTA should pay particular attention to where new developments will be occurring and engage with the developers through partnerships in order to try to attract the new residents or employees who will rely on public transport. For example, the MBTA could discuss with developers beforehand about the locations of entrances/exits of major office or residential buildings and move the bus stops closer to make it more accessible for passengers.

Or the public transport agency could discuss reducing the parking ratios in new buildings (to both developers and the city's planning office) by promising, as well as delivering, new public transport improvements/routes, and provide discounted public transport passes for employers who buy them in bulk for their workers. An aggressive advertising campaign should also be launched to raise awareness of public transport, including highlighting its benefits, to newcomers to the District so that everyone knows that it is easily available. It is important to bear in mind though that in order to retain the new riders, improvements to the system must also be made.

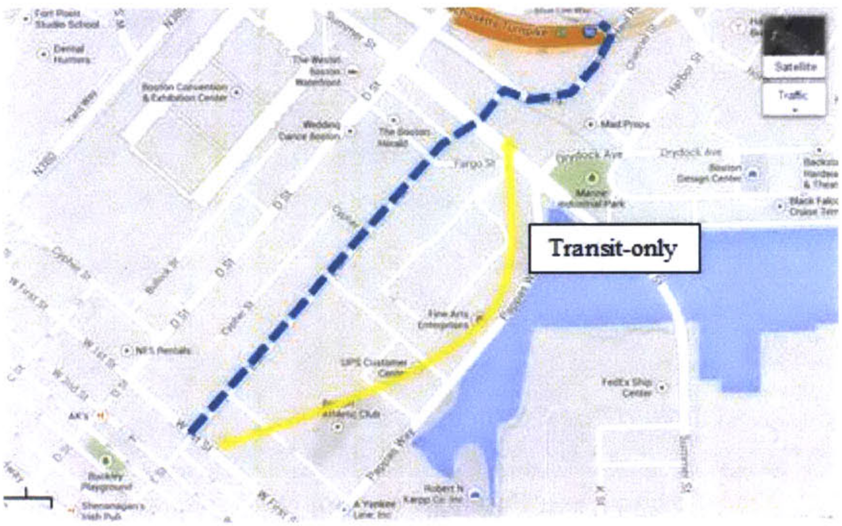


Figure 6-4: Potential Silver Line Extension

Figure 6-5: Portland (Oregon) Transit Mall

DMU Extension

DMU (diesel multiple unit) extension is another possible strategy to enhance the public transport system in the long-term scenario. It would use the (currently) unused Track 61 from the South Bay Rail Yard to the Convention Center off the Southeast Expressway, as shown in Figure 6-6, with trips taking 10-15 minutes each way. DMU trains can be less expensive than traditional rail (as the trains are much shorter) and are self-propelled which is ideal for short distance and frequent stops because they do not need locomotive engines. This extension can be helpful to the future public transport system and local economy since it connects the Convention Center, with its annual attendance of around a quarter of a million conventioneers, to the hotels in Back Bay which is beneficial because the main constraint for BCEC is available hotel supply. However, the project faces significant implementation barriers. First, it requires the use of eminent domain, which is always an unpopular political action, and second the project is extremely complex since it requires passage through the rail yard of South Station, having to go through multiple switches and cross train paths. The latter point is particularly challenging because it demands complex signaling operations which may not be practical. Grade separation could instead be used at this point, but that would be extremely costly because it is difficult for trains to overcome grades of more than 4% and therefore, long ramps are required. An additional point to note is that the route itself is convoluted and requires a long detour, adding to running costs and travel time, so the Back Bay shuttles proposed in Chapter 4 may still be faster. Thus overall, the DMU extension is a very expensive and technically complex project that does not appear to be viable. If financing of the project is possible, then it will better if these funds are allocated to Silver Line light rail conversion or Silver Line Phase III, or even the Silver Line expansion along E Street, where the return on investment is more clear-cut.

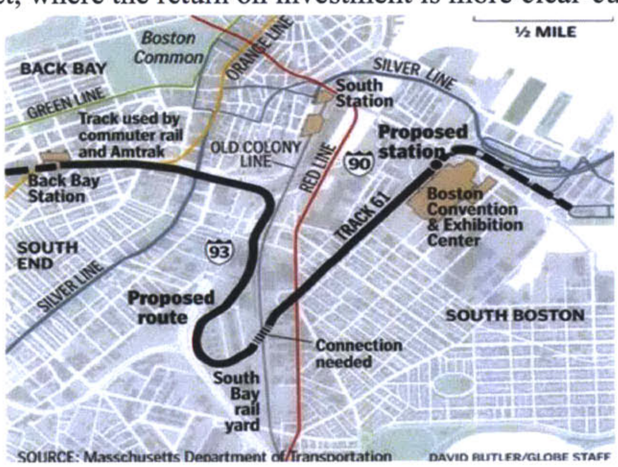


Figure 6-6: Map of DMU Extension[37]

[37] Boston Globe: http://www.bostonglobe.com/business/2013/09/05/state-begin-innovative-rail-service-between-seaport-district-and-back-bay/oHUinYj30lzOV6KNCQUMEJ/igraphic.html

Bus Lane Expansion

The shuttle route to North Station so far has been unaddressed in the long-term strategies. However, it is still a crucial part of the various links to the Seaport District, and in fact, there will likely be too much demand to handle in the long-term, due to the low capacity of the shuttles. But an effective way to deal with this, would be to install bus lanes along the Greenway, extending the Congress Street bus lanes adopted in the medium-term strategy. An effectively managed bus lane direct from North Station to the District could help lower headways from around 5 to 3 minutes, almost doubling the capacity. Furthermore, cycle times will be lowered, improving passengers' travel time and increasing the efficiency of the bus fleet. The barrier to implement this is also relatively low, since it simply involves painting the road and effectively enforcing the bus lane, with the latter being the key to the strategy. A more substantial cost might be incurred if articulated buses are used to provide greater capacity, but this is still considerably cheaper than a major capital construction project.

6.3.2 Traffic

In the long-term scenario, we did not introduce any changes to the traffic network for three reasons:

1. The network has been significantly improved by the medium-term and any additional changes do not have substantial effects
2. Possible capital intensive solutions (such as constructing new tunnels) are inconsistent with the objectives of this thesis, as our focus is to provide robust public transport
3. The proposed improvements in the public transport section should be able to adequately serve the future demand

6.4 RECOMMENDATIONS

Based on our analyses for both the public transport and the traffic networks, we summarize our recommendations that aim to accommodate the expected demand and maintain the transportation network at a good operational level in 2035.

Note that these recommendations are best thought of as innovative ideas for further exploration, because the unpredictability of future development and limited resources mean that the analysis here is more preliminary in nature.

Public Transport

1. It is reasonable to convert the Silver Line to light rail so that the capacity will be less of an issue in the long-term scenario. New surface tracks from Silver Line Way to Design Center need to be constructed while SL1 service should use the surface route, as suggested in the medium-term substitute bus alternative A3.
2. Silver Line Phase III can well replace the surface Boylston/Chinatown-Seaport District shuttle route. It is recommended to install rail tracks for this phase so that transfer capacity provided by light rail services will be enough to meet Orange/Green Line demand.
3. While the DMU extension provides a quick link between the Seaport District and Back Bay area, the high construction cost and technical difficulties render this alternative less attractive.
4. Transit-oriented development strategies, such as public transport-only road and fewer parking spaces, should be implemented in the Seaport District in the long term, especially for areas that are currently less-developed. The MBTA needs to proactively increase the mode share to attract choice riders instead of passively accommodating the long-term additional captive ridership.

Traffic

Given that no changes were introduced to the traffic network for the long-term scenario, the main recommendation focuses on parking policy, as below:

1. Even if all the permitted parking spaces are built by 2035 (i.e. parking supply reaches the allowed maximum), there would still be an excess demand for parking.
2. This chapter has shown that the network will not be able to operate at the 2035 demand.

Based on these two observations, we recommend the re-evaluation of the existing morning peak period off-street parking restriction policy. Specifically, since we estimate that the traffic network is not able to handle demands much higher than the medium-term (2025) demand, we recommend that if all the permitted spaces are built by 2035, then the morning peak period off-street restriction policy should be increased from 20% to 35%.

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7 FINAL RECOMMENDATIONS AND TOPICS FOR FUTURE STUDY

This chapter focuses on providing the final recommendations for both the public transport system and the road network for each term of analysis. In addition, in the final part of this chapter, a list of potential topics that should be analyzed in the future is presented.

7.1 FINAL RECOMMENDATIONS

The analyses showed that significant changes in the transportation network of the Seaport District are required to accommodate the future demand. In particular, the analyses showed that an effective and comprehensive public transport network is essential to the future development of the Seaport District, especially in the long term when the booming Seaport District will attract and generate a huge number of person trips and the public transport mode share will dramatically increase.

In the short-term, the resources and efforts of the involved transportation constituents should focus on:

- Implement Transit Signal Priority to reduce Silver Line delay at the D Street intersection; allow Silver Line buses to use the State police ramp to enter I-90 in order to reduce the travel times by 2 minutes; implementing the scheduled platooning of Silver Line 1 and the Shuttle in order to separate the demand to Logan Airport from the demand to the Seaport District.
- Consolidate the current private shuttles, perhaps in the manner of Cambridge's EZRide service under the auspices of the Seaport TMA, as a means of providing high frequency and reliable service to commuters. The consolidated route will connect rapid transit lines and commuter rails with all the future developing locations in the district. North Station-Seaport District and Boylston/Chinatown-Seaport District routes are recommended during peak hours.
- Shifting the green wave during the AM peak hour from Congress Street and Seaport Boulevard to the Interstate off-ramps. This strategy will accommodate the demand coming from the highway system better, avoiding spillover effects on the regional system.
- Altering the lane configuration in the outbound direction of West Broadway, at the intersection with Dorchester Avenue. This will significantly improve the performance of the intersection, especially during the PM peak hour.
- Prohibiting the right turn in the outbound directions of Congress Street at the intersection with D Street. This will lead the majority of the commuters to enter the highway on-

ramps through the Haul Road, alleviating the traffic congestion at the intersection of Congress and D during the PM peak hour.
- Changing the AM peak hour traffic signal phasing at the intersection of Drydock Avenue and Summer Street in order to better accommodate the high traffic volumes traveling in the inbound direction (towards the Financial District) of Summer Street.

The medium-term efforts of improving the transportation network should focus on:

- Implement grade separation at D Street to provide larger public transport capacity to the District in order to decrease the total travel time of the Silver Lines and to improve reliability. Moreover, the construction should be conducted as soon as possible since otherwise the substitute surface bus routes will fail to accommodate the fast growing Silver Line demand.
- Initiate ferry routes from Seaport District to East Boston, Chelsea and Charlestown with competitive total travel time and reasonable fare to attract a fair number of passengers.
- Introducing exclusive bus lanes on Congress Street by replacing parking and traffic lanes on the right side of each direction. A number of issues must be addressed in order to effectively implement this recommended strategy, including closing the I-90 EB off-ramp on Congress Street, prohibiting a series of turns, and optimizing traffic signals.
- Prohibiting the left turn from Summer Street to Fargo Street. This improves the operations at the intersection of Summer Street and Drydock Avenue.

The long-term final recommendations should focus on:

- Intensifying the parking restriction policy which currently mandates that a magnitude of 80% of the off-street parking supply can be utilized during the AM peak period. It is recommended that this proportion be decreased to 65% since the District's network will not be able to adequately accommodate more than a 50% increase in the peak hour vehicle demand.

There are several important aspects to note about the final recommendations. First, our short-term recommendations are the most robust of the three sets because (1) our methodology assumes that demand patterns will remain unchanged and (2) our methodology assumes that mode split will remain unchanged until 2017, which are both very likely to happen since changes in demand patterns and/or mode split usually occur within longer time periods. Our medium-term recommendations are also solid, but should be viewed with more caution because (1) our analyses assume that all of the short-term recommendations are implemented by the end of 2017 (i.e. before the start of the medium-term growth), which is a very important assumption because a delay in the completion of any of the recommendations will result in different future conditions, which may require some change in our recommendations. Our long-term recommendations are based on the same assumptions as in the short and medium terms. This means that a slight change in annual growth assumptions for demand could, by 2035, accumulate into a large total difference and therefore heavily impact our results. As such, our long-term recommendations should be regarded as potential future ideas rather than solid recommendations.

Second, our analyses and recommendations show that both "T under D" and the exclusive bus lane on Congress Street should occur by 2025. The public transport analyses showed the necessity of "T under D". In addition, an important notion that adds to the immediacy of constructing "T under D" is the exclusive bus lane on Congress Street because (1) if the exclusive bus lanes on Congress Street are introduced before the construction of "T under D", then that service would likely have to be disrupted once the construction of "T under D" begins and (2) it is not practical to introduce the exclusive bus lanes on Congress Street during the construction of "T under D" since buses would not be able to turn around due to the construction. Therefore, the exclusive bus lane on Congress Street should be introduced after the construction of "T under D". This condition further emphasizes the necessity of constructing "T under D" as soon as possible because this project is essential to accommodate the future transportation demand in the District.

Third, if unexpected delays occur in the implementation of the short-term recommendations, then it would be important to reconsider some of the medium-term strategies and perhaps implement them sooner. For instance, the introduction of exclusive bus lanes on Congress Street or the introduction of the analyzed ferry routes to East Boston, Charlestown, and Chelsea could be employed in the short-term if such a measure becomes essential to carry demand due to the of unexpected delays.

7.2 TOPICS FOR FUTURE STUDY

This thesis covered a large range of topics and analyzed many scenarios on the future transportation conditions in the Seaport District. A number of topics that could further improve the transportation network in the District need to be analyzed in detail. These topics include:

- The extension of the Silver Line to cover E Street since potential future developments in the Seaport District could be focused there; this extension will facilitate transit-oriented development in the area.
- The introduction of light rail along the Silver Line to the Design Center to greatly increase the public transport capacity to meet the long-term demand.
- The improvement of signal operations at intersections on the Financial District side to further improve traffic conditions in the Seaport District

- The possible refurbishment of the Old Northern Bridge to accommodate non-motorized modes.
- The possibility of introducing an exclusive bus lane on Seaport Boulevard.
- The introduction of an extensive bicycle network to the transportation network in the Seaport District.
- The in-depth analysis of multiple water transport routes to further improve the multimodal connectivity of the District.

APPENDICES

A1 SIMULATION MODEL

A microscopic simulation model was developed for the South Boston Seaport District as part of this thesis. The simulation model was developed in TransModeler 3.0, which "applies a variety of mathematical models of driver behavior and traffic flow theory to simulate traffic phenomena"[38].

Road Network

The first step in the process was the development of the road network of the Seaport District. A road network from a four-step regional model[39] was used as the basis of the microscopic network. Significant improvements were made regarding the network's geometry. Traffic control information was also included in the model and these include:

- 13 signalized intersections, as described in section 2.2.1
- 9 stop/yield intersections
- One roundabout (located in the intersection of Northern Avenue and the Haul Road)

The simulated road network and its geographical fit with the actual Seaport District road network can be seen in Figure A-1.

The simulated network includes 38 centroids, 12 of which represent areas in the Seaport District while the remaining 26 represent entry and exit points of the regional network that attract or produce vehicle trips to the area. The 38 centroids are consistent with the centroids of the regional four-step model. Centroid connectors are used to connect these centroids with the simulated road network. The Origin-Destination Matrix was estimated based on these centroids, which were also used during the calibration process described in section 2.2.2.

On-street and off-street parking was also included in the model. The location of on-street parking spots were identified from satellite images of the area (Google Earth). Major off-street parking lots and garages were modeled as entry points to, and exit points from, the road network (i.e. no parking capacity constraints were considered during the simulation). The locations of these off-street garages were identified based on the parking inventory provided by the City of Boston (for a detailed description refer to Figure 3-44 and Appendix A2).

Finally, each street in the simulated network was classified based on the road classes included in the simulation software. Each road class has different traffic and capacity characteristics. The classification was based on traffic flows, traffic signal priority patterns, field visits and accessibility characteristics (i.e. Summer Street has few intersection points thus serving mobility in the area and therefore was classified as arterial). Table A-1 shows the classes assigned to some of the most important streets of the Seaport District network.

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[38] Caliper Corporation (2013), "TransModeler Traffic Simulation Software – Version 3.0 User's Guide", Newton, MA.

[39] Courtesy of MIT lecturer and research associate Mikel Murga

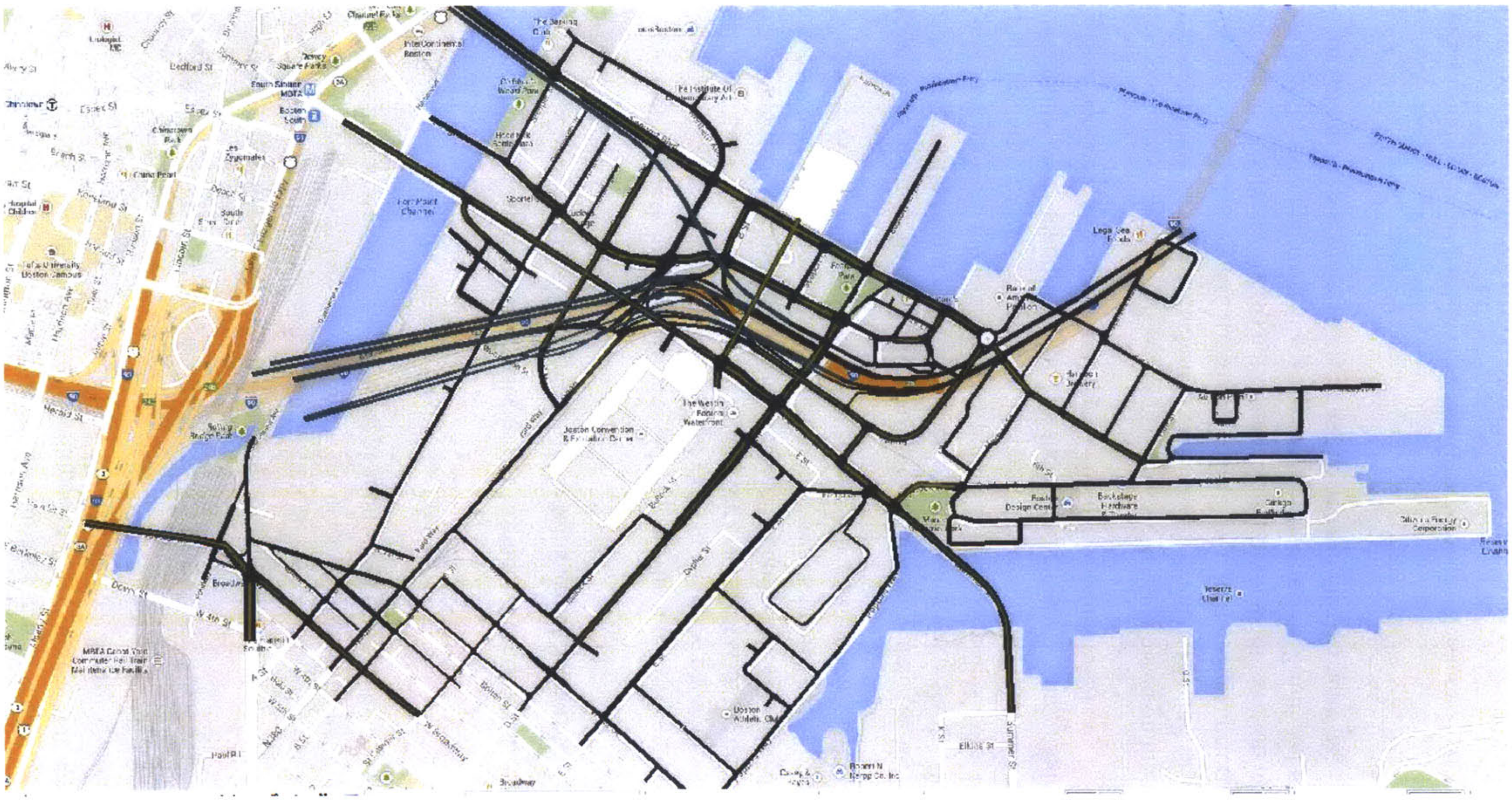


Figure A-1: Simulated road network

Street	Class
Summer St	Major Arterial
Fargo St	Local Street
Northern Ave	Minor Arterial
Congress St	Minor Arterial
D St	Collector
Mass Pike	Expressway
Broadway Brg	Major Arterial
A St	Collector
W 1st St	Local Street
Cypher St	Local Street
E St	Local Street
B St	Local Street
W Broadway	Major Arterial
W 2nd St	Local Street
W 3rd St	Local Street
Dorchester Ave	Local Street
C St	Local Street
Garage Access Rd	Local Street
Melcher St	Local Street
Necco St	Local Street
F St	Local Street
E 1st St	Local Street
E 3rd St	Local Street
W Service Rd	Local Street
Farnsworth St	Access Road
Boston Wharf Rd	Local Street
Seaport Blvd	Minor Arterial
Sleeper St	Local Street
Drydock Ave	Local Street
Design Center Pl	Local Street
Harbor St	Local Street
Channel St	Local Street
Tide St	Local Street

Table A-1: Street classification

Public Transport Network

The developed simulation model also includes the public transport routes that are serving the Seaport District. The software is capable of simulating the public transport performance with moderate accuracy and simulating the impacts that traffic congestion has on these routes. With the appropriate information (alightings and boardings), which was provided as inputs in the developed Seaport District model, the software can also simulate dwell times per stop. The public transport network can be observed in Figure A-2 and the required inputs for each route are summarized in Table A-2. Headway and HeadwayPM correspond to the headways (in seconds) for each route during the AM and PM peak hour respectively. Similarly, SD_Headway and SD_HeadwayPM correspond to the estimated standard deviation (in seconds) for the AM and PM peak hours respectively. Vehicle types are separated to buses (B) and articulated buses (AB), depending on the type of vehicle used to serve each route. Finally, since most routes do not start their trip within the limits of the simulated network, the initial load corresponds to each route's passenger load when entering the Seaport District road network. This last input serves as a congestion indicator, which is important in the dwell time simulation.

Route_ID	Route_Name	Headway	SD_Headway	Vehicle	Init_Load	Preemption_Priority	HeadwayPM	SD_HeadwayPM	Init_LoadPM
1	SL1_OUT	600.00	150.00	AB	46	None	600.00	150.00	31
2	SL1_IN	600.00	150.00	AB	23	None	600.00	150.00	38
3	SL2	300.00	100.00	AB	50	None	300.00	100.00	14
15	SL_SHUTLE	300.00	60.00	AB	50	None	300.00	60.00	14
21	11_OUT	1200.00	260.00	B	–	None	660.00	140.00	–
22	7_OUT	300.00	156.00	B	15	None	360.00	156.00	40
23	7_IN	300.00	175.00	B	48	None	360.00	175.00	8
24	4AM	930.00	235.00	B	11	None	–	–	–
25	4PM	–	–	B	0	None	1200.00	235.00	2
26	448_IN	1800.00	900.00	B	14	None	–	–	–
27	449_IN	1800.00	900.00	B	13	None	–	–	–
28	459_IN	1800.00	900.00	B	14	None	1800.00	900.00	10
29	448_OUT	1800.00	900.00	B	1	None	1800.00	900.00	8
30	449_OUT	1800.00	900.00	B	1	None	1800.00	900.00	12
31	459_OUT	1800.00	900.00	B	8	None	1800.00	900.00	14

Table A-2: Inputs for public transport simulation

Outputs

Output extraction requires an iterative process, based on dynamic traffic assignment. Due to the stochastic nature of the process, every result reported in this thesis as simulation-based was the statistical outcome of 10 iterations.

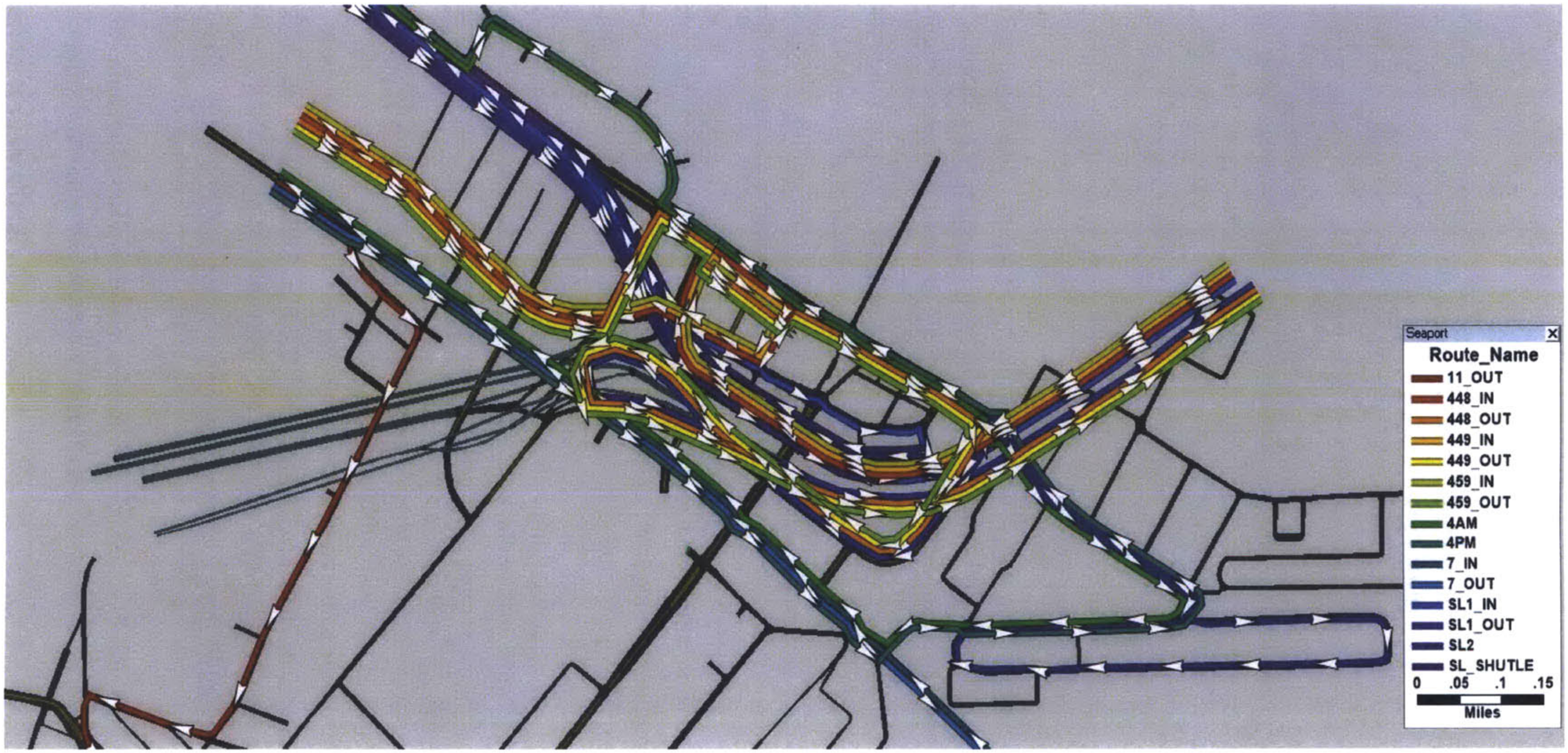


Figure A-2: Simulated public transport network

Implementation of Strategies

A simulation-based assessment was conducted for each considered strategy. The strategies required changes in the traffic control characteristics, public transport and road network.

The traffic control characteristics were altered based on simulation-based signal optimization techniques. The optimization can focus on improving (a) the overall network performance, (b) the performance of a specific corridor, or (c) the performance of a specific isolated intersection. The optimization level was selected based on the implemented strategy. So, for instance, in the shift of the green waves (strategy implemented during the short-term analysis) from Seaport Boulevard to the Interstate off-ramps, a series of corridor optimizations were implemented.

Important changes were introduced in the road network as well. Depending on the strategy one, or a combination, of the following was implemented:

- Changes in the lane connectors. Lane connectors are used to describe the allowed moves in each intersection. Prohibition of left or right turns was modeled with the removal of the corresponding lane connectors. Changes in lane configuration were modeled in the same way.
- Changes in the lane usage. Lanes in the original network were dedicated to parking or buses depending on the implemented strategy.
- Changes in design characteristics of intersections. Turning a signalized intersection to a roundabout involves changes in the road network.

The public transport network was following the changes in the road network. In addition, a new high-frequency bus lane was introduced on Congress Street in order to evaluate the performance of the strategy of the exclusive bus lanes, which was introduced in the medium-term scenario.

A2 OFF-STREET PARKING INVENTORY[40]

[40] Provided by the City of Boston Environment Department

Street Number	Street Name	Type	Zone	Permitted Spaces
253	Summer Street	Surface	Piers	43
11	Melcher Street	Surface	Piers	0
19	Melcher Street	Surface	Piers	0
29	Melcher Street	Surface	Piers	0
	Necco Court	Surface	Piers	0
244	A Street	Surface	Piers	1236
232	A Street	Surface	Piers	20
288	A Street	Surface	Piers	11
10	Necco Street	Garage	Piers	657
	South Boston Manufacturing Center	Surface	Indus/Comm	0
	South Boston Manufacturing Center	Surface	Indus/Comm	0
	South Boston Manufacturing Center	Surface	Indus/Comm	1798
	South Boston Manufacturing Center	Surface	Indus/Comm	0
	South Boston Manufacturing Center	Surface	Indus/Comm	0
	South Boston Manufacturing Center	Surface	Indus/Comm	0
	South Boston Manufacturing Center	Surface	Indus/Comm	0
105	W. First Street	Surface	Indus/Comm	43
100	West Second Street	Surface	Indus/Comm	10
	South Boston Manufacturing Center	Surface	Indus/Comm	0
	South Boston Manufacturing Center	Surface	Residential	0
28-36	Sleeper Street	Surface	Piers	24
66	Sleeper Street	Surface	Piers	55
25	Northern Avenue	Surface	Piers	922
390	Congress Street	Surface	Piers	1417
55	Thomson Place	Surface	Piers	149
145	Seaport Boulevard	Surface	Piers	579
374	Congress Street	Surface	Piers	19
22	Boston Wharf Road	Surface	Piers	591
29	Stillings Street	Surface	Piers	150
44	Stilling Street	Surface	Piers	10
368	Congress Street	Surface	Piers	27
47	Thomson Place	Surface	Piers	0

	Thomson Place	Surface	Piers	7
344	Congress Street	Surface	Piers	8
17	Farnsworth Street	Garage	Piers	361
	Farnsworth Street	Surface	Piers	16
24	Farnsworth Street	Surface	Piers	40
12	Farnsworth Street	Surface	Piers	10
338	Congress Street	Surface	Piers	18
11	Sleeper Street	Surface	Piers	21
12	Northern Ave	Surface	Piers	70
11	Fan Pier Blvd	Garage	Piers	450
28-70	Northern Avenue	Surface	Piers	538
1	Marina Park Drive	Garage	Piers	375
130	Northern Avenue	Surface	Piers	0
140	Northern Avenue	Surface	Piers	1280
660	Summer St	Surface	Piers	0
	Summer St	Surface	Piers	76
430	Summer Street	Surface	Piers	15
335	B Street	Surface	Piers	0
	Trilling Way	Surface	Piers	120
295	Northern Avenue	Surface	Piers	0
315	Northern Avenue	Surface	Piers	0
	Congress Street	Surface	Piers	6
369	Congress Street	Surface	Piers	9
381	Congress Street	Surface	Piers	10
332	Summer Street	Surface	Indus/Comm	40
305	Congress Street	Surface	Piers	0
313	Congress Street	Surface	Piers	23
321	Congress Street	Surface	Piers	83
343	Congress Street	Garage	Piers	60
347	Congress Street	Surface	Piers	10
290	Summer Street	Garage	Piers	0
274	Summer Street	Surface	Piers	2
262	Summer Street	Surface/Garag e	Piers	12
10	Melcher Street	Surface	Piers	1
273	Summer Street	Surface	Piers	2
281	Summer Street	Surface	Piers	1
285	Summer Street	Surface/Garag e	Piers	14
	South Boston Manufacturing Center	Surface	Indus/Comm	0
	South Boston Manufacturing	Surface	Indus/Comm	0

	Center			
	South Boston Manufacturing Center	Surface	Indus/Comm	0
	South Boston Manufacturing Center	Surface	Indus/Comm	0
	South Boston Manufacturing Center	Surface	Indus/Comm	0
	South Boston Manufacturing Center	Surface	Indus/Comm	0
	South Boston Manufacturing Center	Surface	Indus/Comm	0
	South Boston Manufacturing Center	Surface	Indus/Comm	0
	South Boston Manufacturing Center	Surface	Indus/Comm	0
261	A Street	Surface	Piers	130
	A Street	Surface	Piers	0
135	A Street	Garage	Indus/Comm	190
27	Wormwood Street	Surface	Indus/Comm	110
	Wormwood Street	Surface	Piers	200
1	Channel Center Street	Garage	Indus/Comm	924
309	A Street	Surface	Piers	1597
319	A Street	Surface	Piers	4
323	A Street	Surface	Piers	4
321	Summer Street	Surface	Piers	27
	Summer Street	Surface	Piers	375
	B Street	Surface	Piers	0
330	C Street	Surface	Indus/Comm	5
184	W. First Street	Surface	Indus/Comm	90
	W. First Street & B Street	Surface	Indus/Comm	24
346	D Street	Surface	Indus/Comm	0
	W First Street	Surface	Indus/Comm	0
	W First Street	Surface	Indus/Comm	115
325	C Street	Surface	Indus/Comm	0
	Summer Street	Surface	Indus/Comm	1704
415	Summer Street	Garage	Piers	500
525	E Street	Surface	Indus/Comm	535
	E. First Street	Surface	Indus/Comm	100
370	W. First Street	Surface	Indus/Comm	0
451	D Street	Garage	Piers	58
	Summer St	Surface	Piers	23
	Summer St	Surface	Piers	94
69	Fargo Street	Surface	Indus/Comm	86

	Fargo Street	Surface	Indus/Comm	0
560	E Street	Surface	Indus/Comm	470
460	E Street	Surface	Indus/Comm	90
420	E Street	Surface	Indus/Comm	0
410	E Street	Surface	Indus/Comm	0
	D Street	Surface	Indus/Comm	361
411	D Street	Surface	Indus/Comm	80
280	West First Street	Surface	Indus/Comm	174
	Total			19509

Table A-3: Off-street parking inventory in the Seaport District

A3 SENSITIVITY ANALYSIS RESULTS

AM Peak Hour

Scenario 1: Increase attracted trips by 10%, generated trips by 9%, passing through trips by 5.7%

	Average Delay		Average Speed		
Scenario	Mins/veh	Change	Miles/hour	Change	# Trips
Baseline	2.8		16.7		14,158
1	3.5	25%	16.0	-4%	15,182

Table A-4: Aggregate statistics (Scenario 1--AM peak hour)

Intersection	Control Delay (sec/veh)	Average Stops (stops/veh)	LOS
A St & W 2nd St	18.0	0.6	B
A St & W Broadway	27.0	0.7	C
A St, Melcher St	17.0	0.4	C
B St, Congress St, I90 Off-Ramp WB & I93 On-Ramp	56.4	1.1	E
Boston Wharf Rd & Seaport Blvd	108.6	1.6	F
Congress St & D St	70.8	1.3	E
Congress St, A St & Thompson Place	43.3	1.1	D
Congress St, W Service Rd & Boston Wharf Rd	54.7	1.1	D
D St & Summer St	49.9	1.1	D
D St, Transit Way	13.4	0.4	B
Dorchester Ave, Broadway Brg & W Broadway	43.9	1.2	D
Drydock Ave, Summer St	167.2	2.8	F
Haul Road & W Service Rd	21.6	0.3	C

I90 Off-Ramp EB, I93 Off-Ramp, Congress St	113.4	1.9	**F**
Northern Ave & B St	32.4	0.8	**C**
Northern Ave & Congress St	18.0	0.3	**C**
Northern Ave & D St	25.3	0.6	**C**
Northern Ave & D St	52.6	1.2	**D**
Northern Ave, Old Northern Ave, Seaport Blvd	101.4	1.6	**F**
Pump House Road & Summer St	0.0	0.1	**A**
Sleeper St & Seaport Blvd	17.4	0.6	**B**
Summer St & Melcher St	23.9	0.8	**C**
Summer St, WTC Ave	23.1	0.6	**C**

Table A-5: Intersection statistics (Scenario 1--AM peak hour)

Ramp	Max Queue Length (feet)
I-90 Off-Ramp (WB)	766
I-90 Off-Ramp (EB)	942
I-93 Off-Ramp	521

Table A-6: Off-ramp statistics (Scenario 1--AM peak hour)

a) I-90 WB

b) I-90 EB

c) I-93

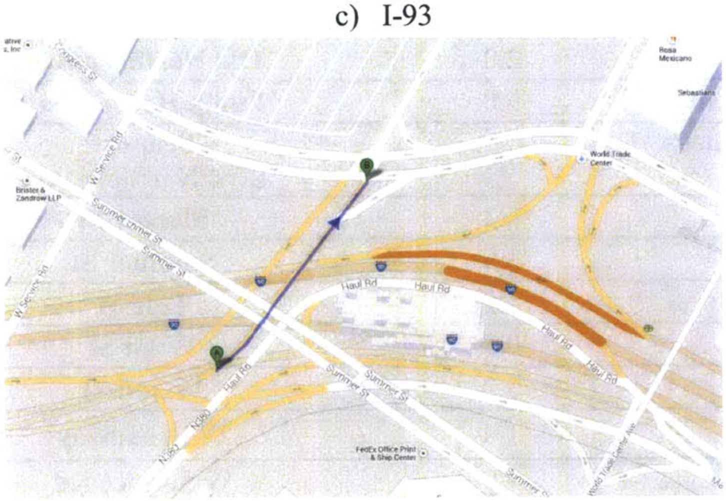


Figure A-3: Maximum queue lengths at Interstate off-ramps (Scenario 1--AM peak hour)

Street	Delay (min/mile)	Street	VMT (veh-mi)
A St	1.9	A St	283
B St	4.4	B St	65
Boston Wharf Rd	11.3	Boston Wharf Rd	46
Broadway Brg	6.7	Broadway Brg	17
C St	1.8	C St	10
Congress St	9.4	Congress St	569
Cypher St	1.6	Cypher St	11
D St	4.1	D St	420
Design Center Pl	1.2	Design Center Pl	10
Dorchester Ave	3.5	Dorchester Ave	260
Drydock Ave	0.9	Drydock Ave	109
E St	1.5	E St	161
F St	2.0	F St	3
Fargo St	0.3	Fargo St	18
Garage Access Rd	0	Garage Access Rd	0
Harbor St	0.4	Harbor St	31
Haul Road	0.3	Haul Road	208
HOV line	0.0	HOV line	73
I90 Off-Ramp EB	31.3	I90 Off-Ramp EB	57
I90 Off-Ramp WB	19.7	I90 Off-Ramp WB	28
I93 Off-Ramp	11.1	I93 Off-Ramp	122
I93 On-Ramp	0.9	I93 On-Ramp	7
Mass Pike/Massachuse	0.7	Mass Pike/Massachuse	7,171
Melcher St	4.9	Melcher St	33
Old Northern Ave	2.0	Old Northern Ave	3
Pump House Road	6.0	Pump House Road	4
Seaport Blvd/Northern Ave	7.0	Seaport Blvd/Northern Ave	1,115
Sleeper St	3.3	Sleeper St	57
Summer St	3.5	Summer St	1,850
Tide St	1.5	Tide St	4
W 1st St	0.5	W 1st St	192
W 2nd St	3.0	W 2nd St	54
W Broadway	1.4	W Broadway	664
W Service Rd	1.0	W Service Rd	36

Table A-7: Link statistics (Scenario 1--AM peak hour)

Scenario 2: Increase attracted trips by 20%, generated trips by 16%, passing through trips by 9.2%

	Average Delay		Average Speed		
Scenario	**Mins/veh**	**Change**	**Miles/hour**	**Change**	**# Trips**
Base line	2.8		16.7		14,158
2	4.3	53%	14.7	-12%	15,936

Table A-8: Aggregate statistics (Scenario 2--AM peak hour)

Intersection	Control Delay (sec/veh)	Average Stops (stops/veh)	LOS
A St & W 2nd St	18.6	0.6	**B**
A St & W Broadway	27.5	0.7	**C**
A St, Melcher St	17.6	0.4	**C**
B St, Congress St, I90 Off-Ramp WB & I93 On-Ramp	59.2	1.1	**E**
Boston Wharf Rd & Seaport Blvd	145.7	1.9	**F**
Congress St & D St	72.9	1.3	**E**
Congress St, A St & Thompson Place	52.2	1.2	**D**
Congress St, W Service Rd & Boston Wharf Rd	57.2	1.2	**E**
D St & Summer St	54.2	1.1	**D**
D St, Transit Way	16.4	0.4	**B**
Dorchester Ave, Broadway Brg & W Broadway	54.1	1.4	**D**
Drydock Ave, Summer St	220.1	3.7	**F**

Haul Road & W Service Rd	22.5	0.4	**C**
I90 Off-Ramp EB, I93 Off-Ramp, Congress St	124.7	2.0	**F**
Northern Ave & B St	33.5	0.8	**C**
Northern Ave & Congress St	17.5	0.3	**C**
Northern Ave & D St	25.5	0.6	**C**
Northern Ave & D St	60.4	1.3	**E**
Northern Ave, Old Northern Ave, Seaport Blvd	108.2	1.7	**F**
Pump House Road & Summer St	0.0	0.1	**A**
Sleeper St & Seaport Blvd	46.9	1.1	**D**
Summer St & Melcher St	24.8	0.8	**C**
Summer St, WTC Ave	42.3	0.9	**D**

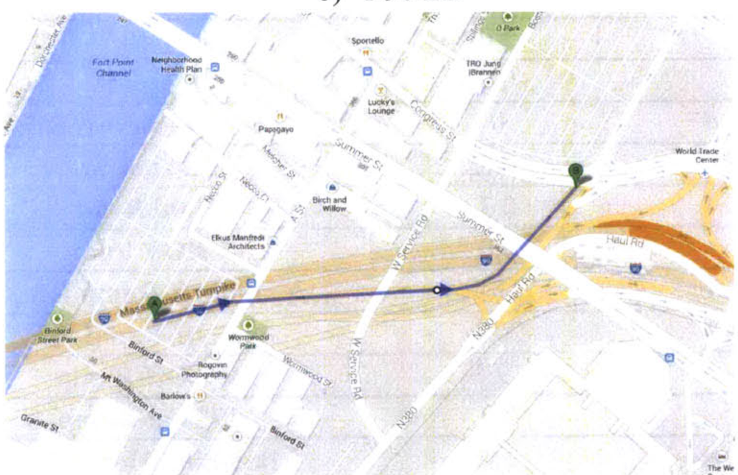
Table A-9: Intersection statistics (Scenario 2--AM peak hour)

Ramp	Max Queue Length (feet)
I-90 Off-Ramp (WB)	3,206
I-90 Off-Ramp (EB)	2,317
I-93 Off-Ramp	1,715

Table A-10: Off-ramp statistics (Scenario 2--AM peak hour)

a) I-90 WB

b) I-90 EB



c) I-93

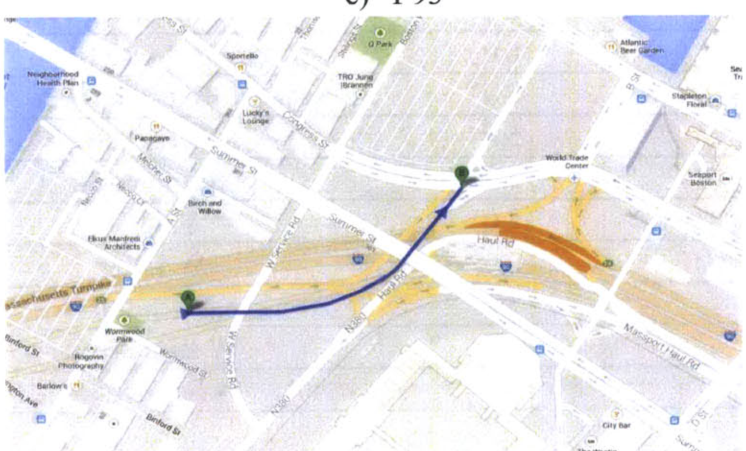


Figure A-4: Maximum queue lengths at Interstate off-ramps (Scenario 2--AM peak hour)

Street	Delay (min/mile)	Street	VMT (veh-mi)
A St	2.2	**A St**	296
B St	5.9	**B St**	67
Boston Wharf Rd	12.6	**Boston Wharf Rd**	47
Broadway Brg	6.3	**Broadway Brg**	18
C St	1.6	**C St**	11
Congress St	9.5	**Congress St**	607
Cypher St	1.6	**Cypher St**	11
D St	4.3	**D St**	439
Design Center Pl	1.2	**Design Center Pl**	10
Dorchester Ave	3.2	**Dorchester Ave**	426
Drydock Ave	1.0	**Drydock Ave**	111
E 1st St	0.0	**E 1st St**	16
E St	1.4	**E St**	162
F St	2.0	**F St**	3
Fargo St	0.3	**Fargo St**	18
Garage Access Rd	0	**Garage Access Rd**	0
Harbor St	0.6	**Harbor St**	32
Haul Road	0.3	**Haul Road**	219
HOV line	0.0	**HOV line**	75
I90 Off-Ramp EB	31.9	**I90 Off-Ramp EB**	58
I90 Off-Ramp WB	20.1	**I90 Off-Ramp WB**	28
I93 Off-Ramp	17.5	**I93 Off-Ramp**	121
I93 On-Ramp	0.9	**I93 On-Ramp**	7
Mass Pike/Massachuse	1.0	**Mass Pike/Massachuse**	8,543
Melcher St	5.0	**Melcher St**	36
Old Northern Ave	2.0	**Old Northern Ave**	3
Pump House Road	6.0	**Pump House Road**	4
Seaport Blvd/Northern Ave	8.0	**Seaport Blvd/Northern Ave**	1,193
Sleeper St	5.9	**Sleeper St**	58
Summer St	4.3	**Summer St**	2,004
Tide St	2.0	**Tide St**	3
W 1st St	0.6	**W 1st St**	199
W 2nd St	3.2	**W 2nd St**	55
W Broadway	1.5	**W Broadway**	657
W Service Rd	1.1	**W Service Rd**	40

Table A-11: Link statistics (Scenario 2--AM peak hour)

Scenario 3: Increase attracted trips by 30%, generated trips by 22%, passing through trips by 12.9%

	Average Delay		Average Speed		
Scenario	**Mins/veh**	**Change**	**Miles/hour**	**Change**	**# Trips**
Base line	2.8		16.7		14,158
3	5.0	79%	13.5	-20%	16,657

Table A-12: Aggregate statistics (Scenario 3--AM peak hour)

Intersection	Control Delay (sec/veh)	Average Stops (stops/veh)	LOS
A St & W 2nd St	19.1	0.6	**B**
A St & W Broadway	30.0	0.8	**C**
A St, Melcher St	20.0	0.5	**C**
B St, Congress St, I90 Off-Ramp WB & I93 On-Ramp	65.7	1.2	**E**
Boston Wharf Rd & Seaport Blvd	155.8	2.0	**F**
Congress St & D St	66.5	1.2	**E**
Congress St, A St & Thompson Place	61.6	1.3	**E**
Congress St, W Service Rd & Boston Wharf Rd	64.2	1.2	**E**
D St & Summer St	52.6	1.1	**D**
D St, Transit Way	17.8	0.4	**B**
Dorchester Ave, Broadway Brg & W Broadway	62.5	1.6	**E**

Drydock Ave, Summer St	234.0	3.9	**F**
Haul Road & W Service Rd	23.3	0.4	**C**
I90 Off-Ramp EB, I93 Off-Ramp, Congress St	129.1	2.1	**F**
Northern Ave & B St	35.2	0.8	**D**
Northern Ave & Congress St	17.4	0.3	**B**
Northern Ave & D St	25.7	0.6	**C**
Northern Ave & D St	58.6	1.3	**E**
Northern Ave, Old Northern Ave, Seaport Blvd	113.7	1.8	**F**
Pump House Road & Summer St	0.0	0.1	**A**
Sleeper St & Seaport Blvd	61.0	1.4	**E**
Summer St & Melcher St	25.1	0.8	**C**
Summer St, WTC Ave	43.7	0.9	**D**

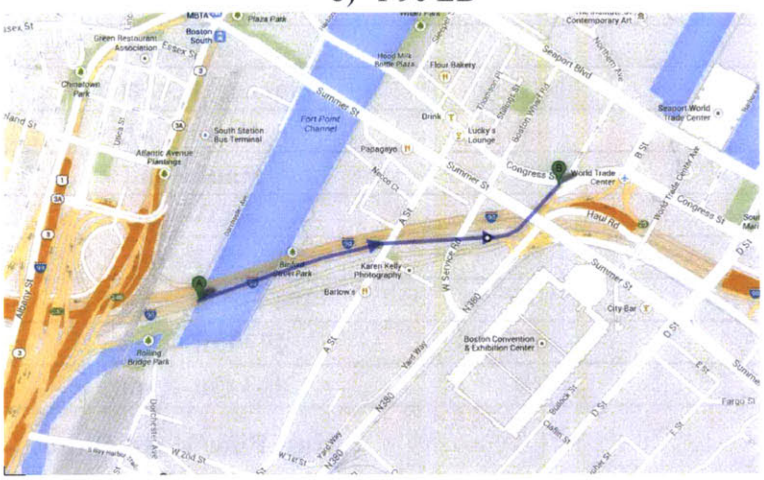
Table A-13: Intersection statistics (Scenario 3--AM peak hour)

Ramp	Max Queue Length (feet)
I-90 Off-Ramp (WB)	5,338
I-90 Off-Ramp (EB)	3,217
I-93 Off-Ramp	5,702

Table A-14: Off-ramp statistics (Scenario 3--AM peak hour)

a) I-90 WB

b) I-90 EB



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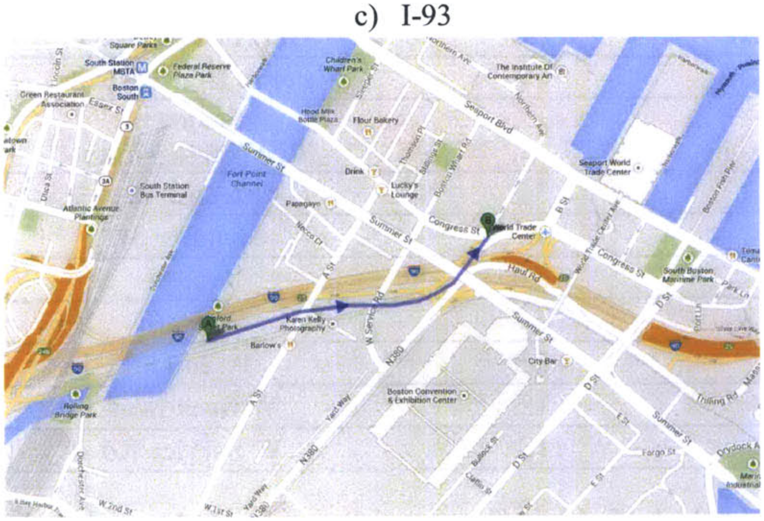


Figure A-5: Maximum queue lengths at Interstate off-ramps (Scenario 3--AM peak hour)

Street	Delay (min/mile)	Street	VMT (veh-mi)
A St	2.7	**A St**	313
B St	7.6	**B St**	69
Boston Wharf Rd	13.2	**Boston Wharf Rd**	49
Broadway Brg	6.7	**Broadway Brg**	18
C St	1.8	**C St**	10
Congress St	9.5	**Congress St**	645
Cypher St	1.6	**Cypher St**	11
D St	4.3	**D St**	463
Design Center Pl	1.2	**Design Center Pl**	10
Dorchester Ave	4.9	**Dorchester Ave**	340
Drydock Ave	1.1	**Drydock Ave**	112
E St	1.4	**E St**	171
F St	2.0	**F St**	3
Fargo St	0.3	**Fargo St**	20
Garage Access Rd	6.0	**Garage Access Rd**	1
Harbor St	0.6	**Harbor St**	32
Haul Road	0.3	**Haul Road**	216
HOV line	0.1	**HOV line**	100
I90 Off-Ramp EB	35.3	**I90 Off-Ramp EB**	54
I90 Off-Ramp WB	19.7	**I90 Off-Ramp WB**	28
I93 Off-Ramp	18.4	**I93 Off-Ramp**	122
I93 On-Ramp	0.9	**I93 On-Ramp**	7
Mass Pike/Massachuse	1.3	**Mass Pike/Massachuse**	9,042
Melcher St	5.2	**Melcher St**	37
Old Northern Ave	2.0	**Old Northern Ave**	3
Pump House Road	6.0	**Pump House Road**	4
Seaport Blvd/Northern Ave	8.3	**Seaport Blvd/Northern Ave**	1,223
Sleeper St	5.9	**Sleeper St**	60
Summer St	3.7	**Summer St**	2,479
Tide St	2.0	**Tide St**	3
W 1st St	0.7	**W 1st St**	209
W 2nd St	3.3	**W 2nd St**	57
W Broadway	1.5	**W Broadway**	706
W Service Rd	1.1	**W Service Rd**	44

Table A-15: Link statistics (Scenario 3--AM peak hour)

Scenario 4: Increase attracted trips by 40%, generated trips by 27%, passing through trips by 18.1%

	Average Delay		Average Speed		
Scenario	**Mins/veh**	**Change**	**Miles/hour**	**Change**	**# Trips**
Base line	2.8		16.7		14,158
4	6.2	120%	12.8	-23%	17,457

Table A-16: Aggregate statistics (Scenario 4--AM peak hour)

Intersection	Control Delay (sec/veh)	Average Stops (stops/veh)	LOS
A St & W 2nd St	24.2	0.7	**C**
A St & W Broadway	33.0	0.8	**C**
A St, Melcher St	18.9	0.5	**B**
B St, Congress St, I90 Off-Ramp WB & I93 On-Ramp	80.1	1.4	**F**
Boston Wharf Rd & Seaport Blvd	171.3	2.2	**F**
Congress St & D St	78.5	1.4	**E**
Congress St, A St & Thompson Place	70.5	1.4	**E**
Congress St, W Service Rd & Boston Wharf Rd	63.6	1.2	**E**
D St & Summer St	55.6	1.1	**E**
D St, Transit Way	20.6	0.5	**C**
Dorchester Ave, Broadway Brg & W Broadway	78.9	1.8	**E**

Drydock Ave, Summer St	285.8	4.8	**F**
Haul Road & W Service Rd	24.3	0.4	**C**
I90 Off-Ramp EB, I93 Off-Ramp, Congress St	134.3	2.1	**F**
Northern Ave & B St	36.3	0.9	**D**
Northern Ave & Congress St	17.7	0.3	**B**
Northern Ave & D St	26.4	0.6	**C**
Northern Ave & D St	57.0	1.3	**E**
Northern Ave, Old Northern Ave, Seaport Blvd	114.2	1.8	**F**
Pump House Road & Summer St	0.0	0.1	**A**
Sleeper St & Seaport Blvd	79.4	1.7	**E**
Summer St & Melcher St	24.3	0.8	**C**
Summer St, WTC Ave	46.4	1.0	**D**

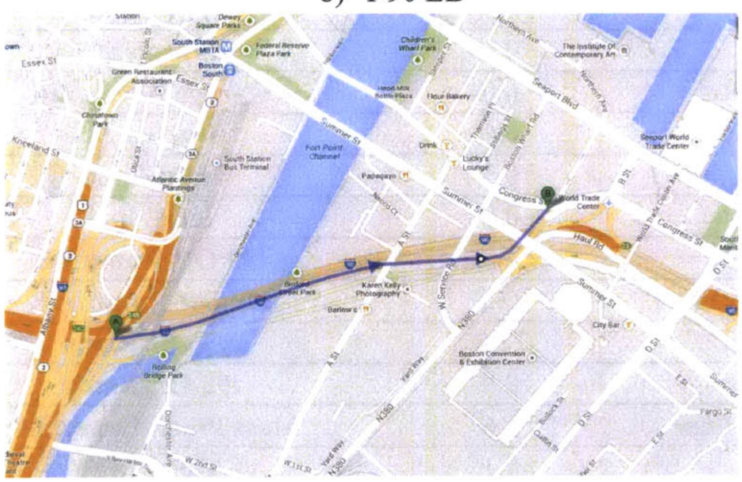
Table A-17: Intersection statistics (Scenario 4--AM peak hour)

Ramp	Max Queue Length (feet)
I-90 Off-Ramp (WB)	6,898
I-90 Off-Ramp (EB)	4,021
I-93 Off-Ramp	5,737

Table A-18: Off-ramp statistics (Scenario 4--AM peak hour)

a) I-90 WB

b) I-90 EB



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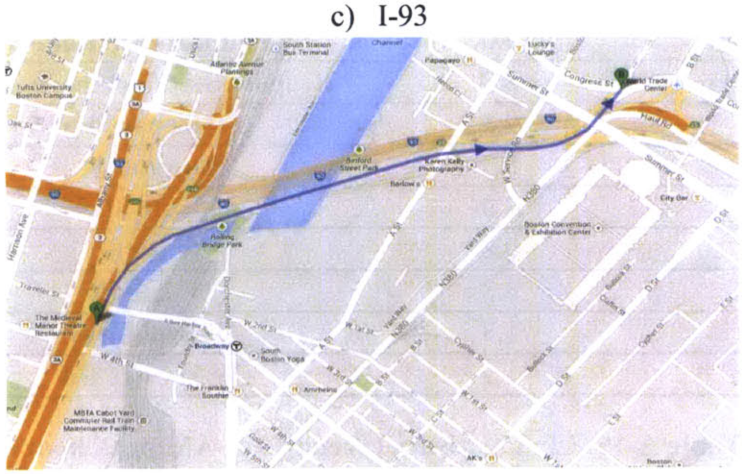


Figure A-6: Maximum queue lengths at Interstate off-ramps (Scenario 4--AM peak hour)

Street	Delay (min/mile)	Street	VMT (veh-mi)
A St	2.9	A St	319
B St	8.2	B St	69
Boston Wharf Rd	14.4	Boston Wharf Rd	52
Broadway Brg	6.3	Broadway Brg	19
C St	1.8	C St	10
Congress St	10.1	Congress St	684
Cypher St	2.2	Cypher St	11
D St	4.5	D St	470
Design Center Pl	1.1	Design Center Pl	11
Dorchester Ave	3.7	Dorchester Ave	621
Drydock Ave	1.1	Drydock Ave	113
E 1st St	0.0	E 1st St	18
E St	1.5	E St	171
F St	2.0	F St	3
Fargo St	0.3	Fargo St	20
Garage Access Rd	6.0	Garage Access Rd	1
Harbor St	0.6	Harbor St	32
Haul Road	0.3	Haul Road	227
HOV line	0.0	HOV line	146
I90 Off-Ramp EB	36.0	I90 Off-Ramp EB	53
I90 Off-Ramp WB	23.8	I90 Off-Ramp WB	25
I93 Off-Ramp	21.3	I93 Off-Ramp	115
I93 On-Ramp	0.9	I93 On-Ramp	7
Mass Pike/Massachuse	1.6	Mass Pike/Massachuse	10,312
Melcher St	5.1	Melcher St	39
Old Northern Ave	2.0	Old Northern Ave	3
Pump House Road	9.0	Pump House Road	4
Seaport Blvd/Northern Ave	8.5	Seaport Blvd/Northern Ave	1,272
Sleeper St	9.5	Sleeper St	59
Summer St	5.3	Summer St	2,047
Tide St	2.0	Tide St	3
W 1st St	0.8	W 1st St	218
W 2nd St	3.8	W 2nd St	61
W Broadway	1.3	W Broadway	861
W Service Rd	1.3	W Service Rd	47

Table A-19: Link statistics (Scenario 4--AM peak hour)

Scenario 5: Increase attracted trips by 50%, generated trips by 30%, passing through trips by 23.5%

	Average Delay		Average Speed		
Scenario	**Mins/veh**	**Change from Baseline**	**Miles/hour**	**Change from Baseline**	**# Trips**
Base line	2.8		16.7		14,158
1	3.5	25%	16.0	-4%	15,182
2	4.3	53%	14.7	-12%	15,936
3	5.0	79%	13.5	-20%	16,657
4	6.2	120%	12.8	-23%	17,457
5	7.2	157%	12.7	-24%	18,220

Table A-20: Aggregate statistics (Scenario 5--AM peak hour)

Intersection	Control Delay (sec/veh)	Average Stops (stops/veh)	LOS
A St & W 2nd St	36	0.9	**C**
A St & W Broadway	34	0.9	**C**
A St, Melcher St	25	0.5	**C**
B St, Congress St, I90 Off-Ramp WB & I93 On-Ramp	79	1.4	**E**
Boston Wharf Rd & Seaport Blvd	169	2.1	**F**
Congress St & D St	79	1.4	**E**
Congress St, A St & Thompson Place	86	1.6	**F**
Congress St, W Service Rd & Boston Wharf Rd	71	1.3	**E**
D St & Summer St	60	1.2	**E**
D St, Transit Way	23	0.5	**C**

Dorchester Ave, Broadway Brg & W Broadway	98	2.1	**F**
Drydock Ave, Summer St	280	4.8	**F**
Haul Road & W Service Rd	26	0.4	**C**
I90 Off-Ramp EB, I93 Off-Ramp, Congress St	133	2.1	**F**
Northern Ave & B St	39	0.9	**D**
Northern Ave & Congress St	19	0.3	**C**
Northern Ave & D St	27	0.6	**C**
Northern Ave & D St	57	1.3	**E**
Northern Ave, Old Northern Ave, Seaport Blvd	114	1.8	**F**
Pump House Road & Summer St	0	0.2	**A**
Sleeper St & Seaport Blvd	95	1.8	**F**
Summer St & Melcher St	25	0.8	**C**
Summer St, WTC Ave	59	1.3	**E**

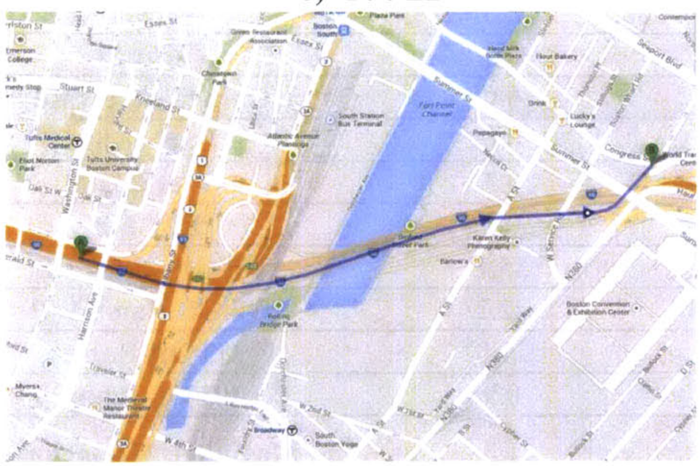
Table A-21: Intersection statistics (Scenario 5--AM peak hour)

Ramp	Max Queue Length (feet)
I-90 Off-Ramp (WB)	8,132
I-90 Off-Ramp (EB)	5,702
I-93 Off-Ramp	7,404

Table A-22: Off-ramp statistics (Scenario 5--AM peak hour)

a) I-90 WB

b) I-90 EB



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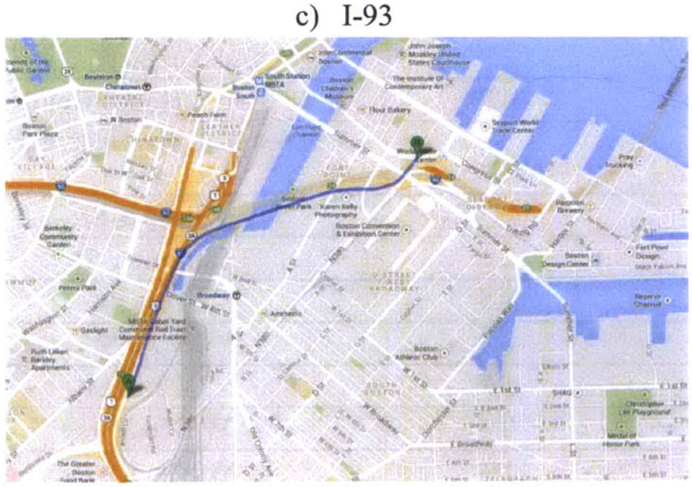


Figure A-7: Maximum queue lengths at Interstate off-ramps (Scenario 5--AM peak hour)

Street	Delay (min/mile)	Street	VMT (veh-mi)
A St	3.8	**A St**	332
B St	8.1	**B St**	73
Boston Wharf Rd	14.2	**Boston Wharf Rd**	55
Broadway Brg	4.1	**Broadway Brg**	16
C St	2.4	**C St**	10
Congress St	13.3	**Congress St**	552
Cypher St	2.2	**Cypher St**	11
D St	4.8	**D St**	489
Design Center Pl	1.1	**Design Center Pl**	11
Dorchester Ave	3.7	**Dorchester Ave**	819
Drydock Ave	1.1	**Drydock Ave**	115
E St	1.6	**E St**	171
F St	2.0	**F St**	3
Fargo St	0.3	**Fargo St**	19
Garage Access Rd	6.0	**Garage Access Rd**	1
Harbor St	0.6	**Harbor St**	32
Haul Road	0.3	**Haul Road**	238
HOV line	0.1	**HOV line**	575
I90 Off-Ramp EB	35.7	**I90 Off-Ramp EB**	52
I90 Off-Ramp WB	22.2	**I90 Off-Ramp WB**	26
I93 Off-Ramp	21.0	**I93 Off-Ramp**	115
I93 On-Ramp	0.9	**I93 On-Ramp**	7
Mass Pike/Massachuse	1.2	**Mass Pike/Massachuse**	15,769
Melcher St	5.7	**Melcher St**	41
Old Northern Ave	2.0	**Old Northern Ave**	3
Pump House Road	12.0	**Pump House Road**	4
Seaport Blvd/Northern Ave	4.2	**Seaport Blvd/Northern Ave**	2,681
Sleeper St	13.7	**Sleeper St**	59
Summer St	2.5	**Summer St**	4,544
Tide St	1.5	**Tide St**	4
W 1st St	0.9	**W 1st St**	227
W 2nd St	5.1	**W 2nd St**	63
W Broadway	0.5	**W Broadway**	2,190
W Service Rd	1.4	**W Service Rd**	53

Table A-23: Link statistics (Scenario 5--AM peak hour)

PM Peak Hour

Scenario 1: Increase attracted trips by 9%, generated trips by 10%, passing through trips by 5.7%

	Average Delay		Average Speed		
Scenario	**Mins/veh**	**Change**	**Miles/hour**	**Change**	**# Trips**
Base line	2.9		17.6		16,203
1	3.6	25.8%	17.6	0%	17,329

Table A-24: Aggregate statistics (Scenario 1--PM peak hour)

Intersection	Control Delay (sec/veh)	Average Stops (stops/veh)	LOS
A St & W 2nd St	18.2	0.4	**D**
A St & W Broadway	28.2	0.8	**C**
A St, Melcher St	17.9	0.4	**B**
B St, Congress St, I90 Off-Ramp WB & I93 On-Ramp	42.2	1.1	**D**
Boston Wharf Rd & Seaport Blvd	42.9	1.0	**D**
Congress St & D St	59.5	1.1	**E**
Congress St, A St & Thompson Place	84.7	1.4	**F**
Congress St, W Service Rd & Boston Wharf Rd	36.9	0.9	**D**
D St & Summer St	37.4	0.9	**D**
D St, Transit Way	26.0	0.7	**C**
Dorchester Ave, Broadway Brg & W Broadway	47.6	1.1	**D**

Drydock Ave, Summer St	45.2	1.0	**D**
Haul Road & W Service Rd	26.6	0.4	**D**
I90 Off-Ramp EB, I93 Off-Ramp, Congress St	23.1	0.8	**C**
Northern Ave & B St	22.1	0.7	**C**
Northern Ave & Congress St	21.8	0.3	**C**
Northern Ave & D St	11.4	0.4	**B**
Northern Ave & D St	14.7	0.6	**B**
Northern Ave, Old Northern Ave, Seaport Blvd	33.3	0.8	**C**
Pump House Road & Summer St	0.1	0.1	**A**
Sleeper St & Seaport Blvd	15.0	0.6	**B**
Summer St & Melcher St	25.4	0.8	**C**
Summer St, WTC Ave	17.5	0.4	**B**

Table A-25: Intersection statistics (Scenario 1--PM peak hour)

Ramp	Max Queue Length (feet)
I-90 Off-Ramp (WB)	175
I-90 Off-Ramp (EB)	110
I-93 Off-Ramp	82

Table A-26: Off-ramp statistics (Scenario 1--PM peak hour)

Street	Delay (min/mile)	Street	VMT (veh-mi)
A St	1.3	A St	331
B St	10.0	B St	91
Boston Wharf Rd	5.8	Boston Wharf Rd	38
Broadway Brg	6.4	Broadway Brg	15
C St	2.0	C St	15
Congress St	8.3	Congress St	552
Cypher St	1.2	Cypher St	15
D St	5.8	D St	416
Design Center Pl	1.3	Design Center Pl	9
Dorchester Ave	2.2	Dorchester Ave	266
Drydock Ave	7.6	Drydock Ave	90
E 1st St	0.3	E 1st St	19
E St	3.0	E St	124
F St	2.0	F St	3
Fargo St	1.3	Fargo St	9
Garage Access Rd	0	Garage Access Rd	0
Harbor St	3.8	Harbor St	25
Haul Road	0.2	Haul Road	305
HOV line	0.0	HOV line	148
I90 Off-Ramp EB	3.1	I90 Off-Ramp EB	31
I90 Off-Ramp WB	10.6	I90 Off-Ramp WB	21
I93 Off-Ramp	2.7	I93 Off-Ramp	38
I93 On-Ramp	1.0	I93 On-Ramp	23
Mass Pike/Massachuse	0.1	Mass Pike/Massachuse	8,309
Melcher St	5.0	Melcher St	35
Old Northern Ave	0.0	Old Northern Ave	1
Pump House Road	4.7	Pump House Road	9
Seaport Blvd/Northern Ave	2.9	Seaport Blvd/Northern Ave	1015
Sleeper St	11.5	Sleeper St	37
Summer St	1.0	Summer St	1,948
Tide St	2.0	Tide St	3
W 1st St	0.8	W 1st St	287
W 2nd St	13.3	W 2nd St	49
W 3rd St	2.0	W 3rd St	3
W Broadway	2.5	W Broadway	635
W Service Rd	1.4	W Service Rd	60

Table A-27: Link statistics (Scenario 1--PM peak hour)

Scenario 2: Increase attracted trips by 16%, generated trips by 20%, passing through trips by 9.2%

	Average Delay		Average Speed		
Scenario	**Mins/veh**	**Change**	**Miles/hour**	**Change**	**# Trips**
Base line	2.9		17.6		16,203
2	4.1	44.4%	17.1	-2.8%	18,143

Table A-28: Aggregate statistics (Scenario 2--PM peak hour)

Intersection	Control Delay (sec/veh)	Average Stops (stops/veh)	LOS
A St & W 2nd St	19.6	0.5	**B**
A St & W Broadway	33.0	0.9	**C**
A St, Melcher St	18.5	0.4	**C**
B St, Congress St, I90 Off-Ramp WB & I93 On-Ramp	43.9	1.1	**D**
Boston Wharf Rd & Seaport Blvd	42.7	1.0	**D**
Congress St & D St	66.4	1.1	**E**
Congress St, A St & Thompson Place	95.7	1.6	**F**
Congress St, W Service Rd & Boston Wharf Rd	37.1	0.9	**D**
D St & Summer St	48.2	1.0	**D**
D St, Transit Way	39.3	0.9	**D**
Dorchester Ave, Broadway Brg & W Broadway	94.2	1.9	**F**
Drydock Ave, Summer St	43.2	0.9	**D**
Haul Road & W Service Rd	28.5	0.4	**C**

I90 Off-Ramp EB, I93 Off-Ramp, Congress St	24.2	0.8	**C**
Northern Ave & B St	24.2	0.8	**C**
Northern Ave & Congress St	22.9	0.3	**C**
Northern Ave & D St	14.5	0.4	**B**
Northern Ave & D St	14.8	0.6	**B**
Northern Ave, Old Northern Ave, Seaport Blvd	34.7	0.8	**C**
Pump House Road & Summer St	0.1	0.1	**A**
Sleeper St & Seaport Blvd	15.0	0.6	**B**
Summer St & Melcher St	27.9	0.8	**C**
Summer St, WTC Ave	54.2	0.9	**E**

Table A-29: Intersection statistics (Scenario 2--PM peak hour)

Ramp	Max Queue Length (feet)
I-90 Off-Ramp (WB)	216
I-90 Off-Ramp (EB)	119
I-93 Off-Ramp	99

Table A-30: Off-ramp statistics (Scenario 2--PM peak hour)

Street	Delay (min/mile)	Street	VMT (veh-mi)
A St	1.8	A St	339
B St	12.1	B St	93
Boston Wharf Rd	5.9	Boston Wharf Rd	40
Broadway Brg	8.0	Broadway Brg	15
C St	2.0	C St	15
Congress St	8.3	Congress St	606
Cypher St	1.5	Cypher St	16
D St	7.2	D St	423
Design Center Pl	1.3	Design Center Pl	9
Dorchester Ave	2.4	Dorchester Ave	442
Drydock Ave	6.8	Drydock Ave	93
E 1st St	0.3	E 1st St	20
E St	3.0	E St	124
F St	2.0	F St	3
Fargo St	1.3	Fargo St	9
Garage Access Rd	0	Garage Access Rd	0
Harbor St	3.4	Harbor St	25
Haul Road	0.2	Haul Road	320
HOV line	0.0	HOV line	153
I90 Off-Ramp EB	3.5	I90 Off-Ramp EB	33
I90 Off-Ramp WB	11.2	I90 Off-Ramp WB	22
I93 Off-Ramp	2.9	I93 Off-Ramp	39
I93 On-Ramp	1.1	I93 On-Ramp	22
Mass Pike/Massachuse	0.1	Mass Pike/Massachuse	9,965
Melcher St	5.2	Melcher St	38
Old Northern Ave	0.0	Old Northern Ave	2
Pump House Road	4.0	Pump House Road	9
Seaport Blvd/Northern Ave	2.8	Seaport Blvd/Northern Ave	1140
Sleeper St	14.3	Sleeper St	37
Summer St	1.4	Summer St	2,121
Tide St	2.0	Tide St	3
W 1st St	1.4	W 1st St	295
W 2nd St	15.6	W 2nd St	49
W 3rd St	2.4	W 3rd St	5
W Broadway	4.3	W Broadway	608
W Service Rd	1.5	W Service Rd	63

Table A-31: Link statistics (Scenario 2—PM peak hour)

Scenario 3: Increase attracted trips by 22%, generated trips by 30%, passing through trips by 12.9%

	Average Delay		Average Speed		
Scenario	Mins/veh	Change	Miles/hour	Change	# Trips
Base line	2.9		17.6		16,203
3	4.5	57.9%	16.7	-5.3%	18,957

Table A-32: Aggregate statistics (Scenario 3--PM peak hour)

Intersection	Control Delay (sec/veh)	Average Stops (stops/veh)	LOS
A St & W 2nd St	20.1	0.5	C
A St & W Broadway	36.1	0.9	D
A St, Melcher St	19.5	0.4	C
B St, Congress St, I90 Off-Ramp WB & I93 On-Ramp	46.2	1.1	D
Boston Wharf Rd & Seaport Blvd	43.3	1.0	D
Congress St & D St	64.0	1.1	E
Congress St, A St & Thompson Place	129.6	2.1	F
Congress St, W Service Rd & Boston Wharf Rd	37.0	0.9	D
D St & Summer St	46.9	1.0	D
D St, Transit Way	43.8	1.0	D
Dorchester Ave, Broadway Brg & W Broadway	116.9	2.2	F
Drydock Ave, Summer St	48.0	1.0	D

Haul Road & W Service Rd	30.9	0.4	**D**
I90 Off-Ramp EB, I93 Off-Ramp, Congress St	26.9	0.9	**C**
Northern Ave & B St	26.0	0.8	**C**
Northern Ave & Congress St	24.8	0.3	**C**
Northern Ave & D St	13.2	0.4	**B**
Northern Ave & D St	15.0	0.6	**B**
Northern Ave, Old Northern Ave, Seaport Blvd	36.7	0.8	**D**
Pump House Road & Summer St	0.1	0.1	**A**
Sleeper St & Seaport Blvd	16.6	0.6	**B**
Summer St & Melcher St	30.0	0.9	**C**
Summer St, WTC Ave	76.1	1.4	**E**

Table A-33: Intersection statistics (Scenario 3--PM peak hour)

Ramp	Max Queue Length (feet)
I-90 Off-Ramp (WB)	220
I-90 Off-Ramp (EB)	142
I-93 Off-Ramp	119

Table A-34: Off-ramp statistics (Scenario 3--PM peak hour)

Street	Delay (min/mile)	Street	VMT (veh-mi)
A St	2.2	A St	345
B St	13.3	B St	93
Boston Wharf Rd	5.7	Boston Wharf Rd	44
Broadway Brg	8.4	Broadway Brg	15
C St	2.4	C St	15
Congress St	9.1	Congress St	660
Cypher St	1.5	Cypher St	16
D St	7.2	D St	436
Design Center Pl	1.2	Design Center Pl	10
Dorchester Ave	3.8	Dorchester Ave	342
Drydock Ave	8.1	Drydock Ave	96
E 1st St	0.3	E 1st St	21
E St	3.0	E St	130
F St	2.0	F St	3
Fargo St	1.2	Fargo St	10
Farnsworth St	0.0	Farnsworth St	1
Garage Access Rd	0	Garage Access Rd	0
Harbor St	9.8	Harbor St	24
Haul Road	2.6	Haul Road	32
HOV line	0.1	HOV line	202
I90 Off-Ramp EB	3.8	I90 Off-Ramp EB	36
I90 Off-Ramp WB	11.5	I90 Off-Ramp WB	24
I93 Off-Ramp	3.4	I93 Off-Ramp	42
I93 On-Ramp	1.1	I93 On-Ramp	22
Mass Pike/Massachuse	0.2	Mass Pike/Massachuse	11,012
Melcher St	5.4	Melcher St	40
Northern Ave	3.3	Northern Ave	484
Old Northern Ave	0.0	Old Northern Ave	2
Pamp House Road	5.3	Pamp House Road	9
Seaport Blvd	2.5	Seaport Blvd	711
Seaport Blvd/Northern Ave	2.8	Seaport Blvd/Northern Ave	1,194
Sleeper St	14.8	Sleeper St	38
Summer St	1.4	Summer St	2,646
Tide St	4.0	Tide St	3
W 1st St	2.2	W 1st St	301
W 2nd St	18.0	W 2nd St	48
W 3rd St	2.4	W 3rd St	5
W Broadway	4.7	W Broadway	646
W Service Rd	1.7	W Service Rd	68

Table A-35: Link statistics (Scenario 3--PM peak hour)

Scenario 4: Increase attracted trips by 27%, generated trips by 40%, passing through trips by 18.1%

	Average Delay		Average Speed		
Scenario	**Mins/veh**	**Change**	**Miles/hour**	**Change**	**# Trips**
Base line	2.9		17.6		16,203
4	5.5	90.7%	16.3	-7.4%	19,881

Table A-36: Aggregate statistics (Scenario 4--PM peak hour)

Intersection	Control Delay (sec/veh)	Average Stops (stops/veh)	LOS
A St & W 2nd St	20.8	1.5	**C**
A St & W Broadway	44.7	1.0	**D**
A St, Melcher St	20.1	0.5	**C**
B St, Congress St, I90 Off-Ramp WB & I93 On-Ramp	48.0	1.2	**D**
Boston Wharf Rd & Seaport Blvd	44.3	1.0	**D**
Congress St & D St	67.6	1.2	**E**
Congress St, A St & Thompson Place	161.9	2.8	**F**
Congress St, W Service Rd & Boston Wharf Rd	36.7	0.9	**D**
D St & Summer St	58.0	1.1	**E**
D St, Transit Way	42.3	0.9	**D**
Dorchester Ave, Broadway Brg & W Broadway	175.9	3.1	**F**
Drydock Ave, Summer St	48.7	1.0	**D**

Haul Road & W Service Rd	30.4	0.5	**D**
I90 Off-Ramp EB, I93 Off-Ramp, Congress St	29.7	1.0	**C**
Northern Ave & B St	28.9	0.9	**C**
Northern Ave & Congress St	25.7	0.2	**C**
Northern Ave & D St	19.2	0.5	**B**
Northern Ave & D St	16.1	0.6	**B**
Northern Ave, Old Northern Ave, Seaport Blvd	41.7	0.9	**D**
Pump House Road & Summer St	0.1	0.1	**A**
Sleeper St & Seaport Blvd	16.6	0.6	**B**
Summer St & Melcher St	32.6	0.9	**C**
Summer St, WTC Ave	134.0	2.3	**F**

Table A-37: Intersection statistics (Scenario 4--PM peak hour)

Ramp	Max Queue Length (feet)
I-90 Off-Ramp (WB)	220
I-90 Off-Ramp (EB)	305
I-93 Off-Ramp	132

Table A-38: Off-ramp statistics (Scenario 4--PM peak hour)

Street	Delay (min/mile)	Street	VMT (veh-mi)
A St	3.6	**A St**	348
B St	14.9	**B St**	92
Boston Wharf Rd	5.8	**Boston Wharf Rd**	48
Broadway Brg	9.9	**Broadway Brg**	14
C St	2.4	**C St**	15
Congress St	9.7	**Congress St**	736
Cypher St	2.1	**Cypher St**	17
D St	8.1	**D St**	449
Design Center Pl	1.8	**Design Center Pl**	10
Dorchester Ave	3.6	**Dorchester Ave**	601
Drydock Ave	8.5	**Drydock Ave**	96.
E 1st St	0.3	**E 1st St**	22
E St	3.1	**E St**	128
F St	2.0	**F St**	3
Fargo St	1.2	**Fargo St**	10
Farnsworth St	0.0	**Farnsworth St**	1
Garage Access Rd	0	**Garage Access Rd**	0
Harbor St	15.1	**Harbor St**	25
Haul Road	0.3	**Haul Road**	348
HOV line	0.1	**HOV line**	296
I90 Off-Ramp EB	4.6	**I90 Off-Ramp EB**	38
I90 Off-Ramp WB	11.8	**I90 Off-Ramp WB**	25
I93 Off-Ramp	3.7	**I93 Off-Ramp**	45
I93 On-Ramp	1.1	**I93 On-Ramp**	21
Mass Pike/Massachuse	0.2	**Mass Pike/Massachuse**	13,319
Melcher St	5.4	**Melcher St**	42
Old Northern Ave	0.0	**Old Northern Ave**	2
Pump House Road	4.8	**Pump House Road**	10
Seaport Blvd/Northern Ave	2.9	**Seaport Blvd/Northern Ave**	1,291
Sleeper St	14.9	**Sleeper St**	41
Summer St	2.4	**Summer St**	2,169
Tide St	0.5	**Tide St**	23
W 1st St	2.8	**W 1st St**	304
W 2nd St	21.1	**W 2nd St**	44
W 3rd St	3.4	**W 3rd St**	7
W Broadway	5.7	**W Broadway**	733
W Service Rd	0.2	**W Service Rd**	701

Table A-39: Link statistics (Scenario 4--PM peak hour)

Scenario 5: Increase attracted trips by 30%, generated trips by 50%, passing through trips by 23.5%

	Average Delay		Average Speed		
Scenario	**Mins/veh**	**Change from Baseline**	**Miles/hour**	**Change from Baseline**	**# Trips**
Base line	2.9		17.6		16,203
1	3.6	25.8%	17.6	-0.2%	17,329
2	4.1	44.4%	17.1	-2.8%	18,143
3	4.5	57.9%	16.7	-5.3%	18,957
4	5.5	90.7%	16.3	-7.4%	19,881
5	6.2	116.1%	13.6	-22.9%	20,813

Table A-40: Aggregate statistics (Scenario 5--PM peak hour)

Intersection	Control Delay (sec/veh)	Average Stops (stops/veh)	LOS
A St & W 2nd St	21.6	0.5	**E**
A St & W Broadway	50	1.1	**D**
A St, Melcher St	21	0.5	**C**
B St, Congress St, I90 Off-Ramp WB & I93 On-Ramp	53	1.2	**D**
Boston Wharf Rd & Seaport Blvd	46	1.0	**D**
Congress St & D St	77	1.3	**E**
Congress St, A St & Thompson Place	197	3.0	**F**
Congress St, W Service Rd & Boston Wharf Rd	36	0.9	**D**
D St & Summer St	71	1.3	**E**
D St, Transit Way	48	0.9	**D**
Dorchester Ave, Broadway Brg & W Broadway	226	3.7	**F**

Drydock Ave, Summer St	52	1.0	**D**
Haul Road & W Service Rd	37	0.5	**D**
I90 Off-Ramp EB, I93 Off-Ramp, Congress St	42	1.1	**D**
Northern Ave & B St	34	1.0	**C**
Northern Ave & Congress St	26	0.2	**C**
Northern Ave & D St	23	0.5	**C**
Northern Ave & D St	16	0.6	**B**
Northern Ave, Old Northern Ave, Seaport Blvd	44	1.0	**D**
Pump House Road & Summer St	0	0.3	**A**
Sleeper St & Seaport Blvd	17	0.7	**B**
Summer St & Melcher St	41	1.1	**D**
Summer St, WTC Ave	190	2.9	**F**

Table A-41: Intersection statistics (Scenario 5--PM peak hour)

Ramp	Max Queue Length (feet)
I-90 Off-Ramp (WB)	221
I-90 Off-Ramp (EB)	350
I-93 Off-Ramp	234

Table A-42: Off-ramp statistics (Scenario 5--PM peak hour)

Street	Delay (min/mile)	Street	VMT (veh-mi)
A St	4.1	A St	356
B St	16.0	B St	94
Boston Wharf Rd	5.8	Boston Wharf Rd	49
Broadway Brg	10.3	Broadway Brg	14
C St	2.4	C St	15
Congress St	5.6	Congress St	1,449
Cypher St	2.8	Cypher St	17
D St	10.1	D St	430
Design Center Pl	1.6	Design Center Pl	11
Dorchester Ave	2.6	Dorchester Ave	1,101
Drydock Ave	8.6	Drydock Ave	98
E 1st St	1.6	E 1st St	23
E St	3.5	E St	131
F St	6.0	F St	3
Fargo St	2.4	Fargo St	10
Farnsworth St	0.0	Farnsworth St	1
Harbor St	16.8	Harbor St	25
Haul Road	0.3	Haul Road	356
HOV line	0.1	HOV line	1,162
I90 Off-Ramp EB	7.7	I90 Off-Ramp EB	39
I90 Off-Ramp WB	13.1	I90 Off-Ramp WB	27
I93 Off-Ramp	8.3	I93 Off-Ramp	46
I93 On-Ramp	1.2	I93 On-Ramp	20
Mass Pike/Massachuse	0.2	Mass Pike/Massachuse	19,672
Melcher St	5.7	Melcher St	41
Old Northern Ave	0.0	Old Northern Ave	2
Pump House Road	10.2	Pump House Road	10
Seaport Blvd/Northern Ave	1.5	Seaport Blvd/Northern Ave	2,848
Sleeper St	15.6	Sleeper St	43
Summer St	1.4	Summer St	4,945
Tide St	4.0	Tide St	3
W 1st St	3.6	W 1st St	298
W 2nd St	26.2	W 2nd St	43
W 3rd St	3.4	W 3rd St	7
W Broadway	4.3	W Broadway	1,211
W Service Rd	2.1	W Service Rd	70

Table A-43: Link statistics (Scenario 5--PM peak hour)

A4 CAPACITY CALCULATIONS

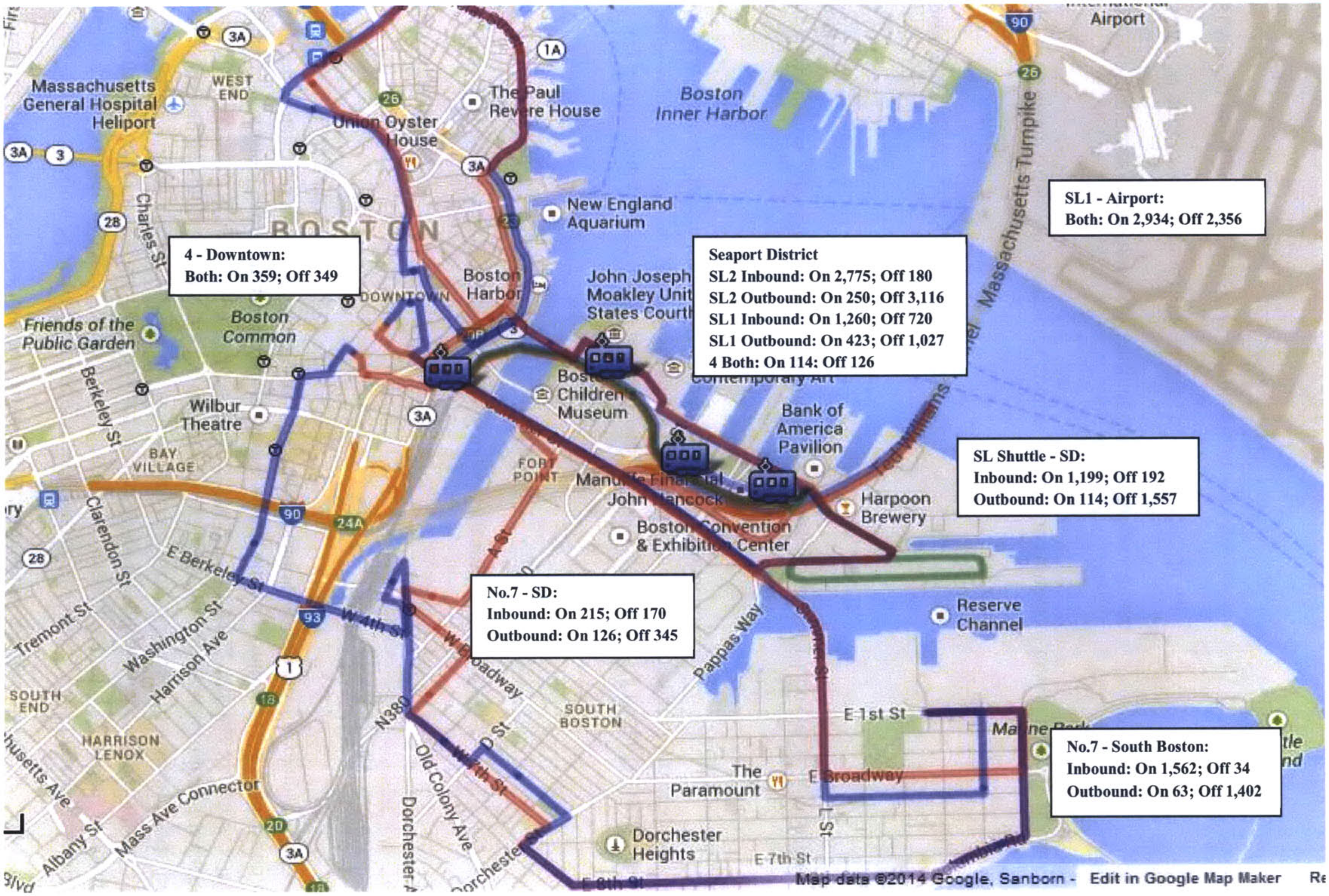


Figure A-8: Detailed ridership by route

Potential Capacity Calculations for Silver Line, short- and medium-term

In this section, SL capacities are developed to see how many transit passengers can be accommodated, using both the current situation and the assumption that "T under D" occurs. For the former scenario, AVL data will be used as a basis for the calculations, whereas for the latter, new recovery times, the location of the layovers and new travel times will be estimated. Layover locations can be complicated since the number of terminals need to be determined for each route: currently, SL2 and SLW operate with the conventional 2 terminals, whereas SL1 does a loop at the airport without ever being completely empty, so has only 1 terminal. This is acceptable right now, but when the D Street separation occurs, these locations might have to change; this will be discussed in the next section.

Bus capacities:

24 buses (SLW & SL2) @ 65 passengers planned capacity

8 buses (SL1 only) @ 53 passengers planned capacity

A key assumption (conservative) for improving the service without "T under D" is that the headway cannot be lower than 90 seconds – this is to avoid congestion at D Street since a lower value will mean that the lights will have to change too frequently.

In all scenarios, 20% bus reserve is assumed, i.e. 7 buses total with 1 bus in SL1, 6 for the other routes.

<u>Scenarios without D Street grade separation:</u>

1. Current Situation (reverse calculation to get the number of buses currently in use)

SL1: (50 minutes cycle time) / (10 minutes/bus) = 5 buses in use

SL2: (30 minutes cycle time) / (5 minutes/bus) = 6 buses in use

SLW: (20 minutes cycle time) / (5 minutes/bus) = 4 buses in use

15 buses in total, which matches with the AVL October 2013 data for the AM Peak since 15 buses are used during that period.

So, the MBTA is only using a small part of its total fleet of 32, which is good news for capacity expansion.

Current capacity: 1,878 passengers per hour in peak direction (318 for SL1; 780 each for SL2 and SLW).

2. Realistic Maximum Capacity (SL1 & SLW only)

This uses AVL data, plus the assumptions of 90 second headways and that SL2 is either served by a surface route from South Station or through a timed connection at SL Way.

Bus platoons will also be assumed, with the SL1 and SLW traveling together whenever possible, to maximize capacity without lowering the headway.

20% spare ratio used, i.e. 7 buses in reserve, with 6 from SLW and 1 from SL1.

Note that there is the 90 second headway constraint, which translates to a maximum of 40 buses/hr (3600/90).

SLW:

65 passengers per bus * 40 buses per hour = 2,600 passengers per hour

Check to see if there are enough buses for service:

13 minutes (95^{th} percentile time) / 1.5 minutes per bus = 9 buses needed

So, enough capacity since 24-6 = 18 available > 9 buses

SL1 – assume buses run in platoons with SLW, so the 90 seconds headway is not reduced further.

45 minutes / 7 buses = 7 minutes headway.

53*(60/7) = 454 passengers per hour

Total Capacity: 2,600 passengers per hour in peak direction for SLW; 454 passengers per hour in peak direction for SL1

3. Conservative Maximum Capacity (SL1 & SLW only)

All assumptions same as in Scenario 2, except the combined headway cannot be lower than 120 second (i.e. what it is currently).

SLW

65 * 30 buses per hour: 1,950 passengers per hour

SL1

454 passengers per hour (same calculation as in Scenario 2)

Total Capacity: 1,950 passengers per hour in peak direction for SLW; 454 passengers per hour in peak direction for SL1

4. Realistic Maximum Capacity (all routes)

Assumptions: AVL data used, 90 second headways (40 buses/hr max), SL1-SLW platoons, SL2 maintains 5-minute headways, 20% spare ratio.

SL2

30 minutes / 5 mins per bus = 6 buses needed

65*12 = 780 passengers per hour

SLW

40-12 = 28 buses per hour possible

13 / (60/28) = 6 buses required

6+6 = 12 < 18, so is acceptable

65*28 = 1,820 passengers per hour

SL1 – assume buses run in platoons with SLW, so the 90 seconds headway is not reduced further.

45 minutes / 7 buses = 7 minutes headway.

53*(60/7) = 454 passengers per hour

Total Capacity: 2,600 passengers per hour in peak direction for SL2/SLW combined; 454 passengers per hour in peak direction for SL1

5. Capacity with Chelsea branch and 3 routes (SL1, SL2, SLW)

Assumptions: AVL data used, 90 second headways (40 buses/hr max), SL1 platoons with SLW or SL2, SL2 maintains 5-minute headways, 20% spare ratio (6 in reserve for SLW, 1 for SL1).

Chelsea branch: 70 minutes cycle time (conservative – 55 minutes travel, 15 layover). 10 minute headway

SL2

30 minutes / 5 mins per bus = 6 buses needed

65*12 = 780 passengers per hour

Chelsea branch –

70 minutes / 10 mins per bus = 7 buses needed

65*6 = 390 passengers per hour

SLW

40-[(60/5)+(60/10)] = 22 buses per hour possible

13 / (60/22) = 5 buses required

6+7+5 = 18 = 18 max number of buses available, so is acceptable

65*22 = 1,430 passengers per hour

SL1 – assume buses run in platoons with SLW, so the 90 seconds headway is not reduced further.

45 minutes / 7 buses = 7 minutes headway.

53*(60/7) = 454 passengers per hour

Total Capacity: 2,600 passengers per hour in peak direction for SL2/SLW combined; 454 passengers per hour in peak direction for SL1

<u>Scenarios with D Street grade separation:</u>

6. Maximum Service with 2 routes (SL1 & SLW)

Assumptions: AVL data used, SL1-SLW platoons, 20% spare ratio, SL1 saves 5 minutes per cycle due to “T under D”, while SLW saves 1 minute per cycle.

New cycle times: SL1 – 40; SLW – 12

SLW

12/18 = 40 seconds headway (note that there has to be a turnaround at SL Way for this to occur)

65*(60/0.6666) = 5,850 passengers per hour

SL1 – uses platoon, so does not reduce headway further.

40/7 = 6 minutes headway

53*(60/6) = 530 passengers per hour

Total: 5,850 passengers per hour in peak direction for SLW; 530 for SL1

7. Maximum Service with 3 routes (SL1, SL2, SLW)

Assumptions: AVL data used, SL1-SLW platoons, 10% spare ratio (3 buses in reserve; 1 SL1 bus, 2 SL2/SLW bus), SL1 saves 5 minutes per cycle due to "T under D", SL2 saves 1 minute per cycle, while SLW saves 1 minute per cycle. Assume 5-minute headways are maintained for SL2.

New cycle times: SL1 – 40; SL2 – 29; SLW – 12

SL2

29 minutes / 5 mins per bus = 6 buses needed

65*12 = 780 passengers per hour

18-6 = 12 buses left available

SLW

12/12 = 1 minute headway

65*(60/1) = 3,900 passengers per hour

SL1 – uses platoon, so does not reduce headway further.

40/7 = 6 minutes headway

53*(60/6) = 530 passengers per hour

Total: 4,680 passengers per hour in peak direction (SL2/SLW combined); 530 for SL1

8. Maximum Service with 2 routes (SL1 & SLW) + SLG

Assumptions: AVL data used, SL1-SLW platoons, 20% spare ratio, SL1 and SLG saves 5 minutes per cycle due to "T under D", while SLW saves 1 minute per cycle.

SLG has 10 minute headways.

New cycle times: SL1 – 40; SLG – 65; SLW – 12

SLG

65 mins cycle time / 10 mins headway = 7 buses needed

65*(60/10) = 390 passengers per hour

SLW

18-7 = 11 buses left for use

12/11 = 1:10 minutes headway (note that there has to be a turnaround at SL Way for this to occur)

65*(60/1.167) = 3,340 passengers per hour

SL1 – uses platoon, so does not reduce headway further.

40/7 = 6 minutes headway

53*(60/6) = 530 passengers per hour

Total: 3,730 passengers per hour in peak direction for SLW/SLG; 530 for SL1

9. Maximum Service with 3 routes (SL1, SL2 & SLW) + SLG

Assumptions: AVL data used, SL1-SLW platoons, 10% spare ratio, SL1 and SLG saves 5 minutes per cycle due to "T under D", while SL2 and SLW saves 1 minute per cycle.

SLG has 10 minute headways, SL2 has 5 mins headway.

New cycle times: SL1 – 40; SL2 – 29; SLG – 65; SLW – 12

SLG

65 mins cycle time / 10 mins headway = 7 buses needed

65*(60/10) = 390 passengers per hour

SL2

29 mins cycle time / 5 mins headway = 6 buses needed

65*(60/5) = 780 passengers per hour

SLW

18-13 = 5 buses left for use

12/5 = 2.5 minutes headway (rounded up)

65*(60/2.5) = 1,560 passengers per hour

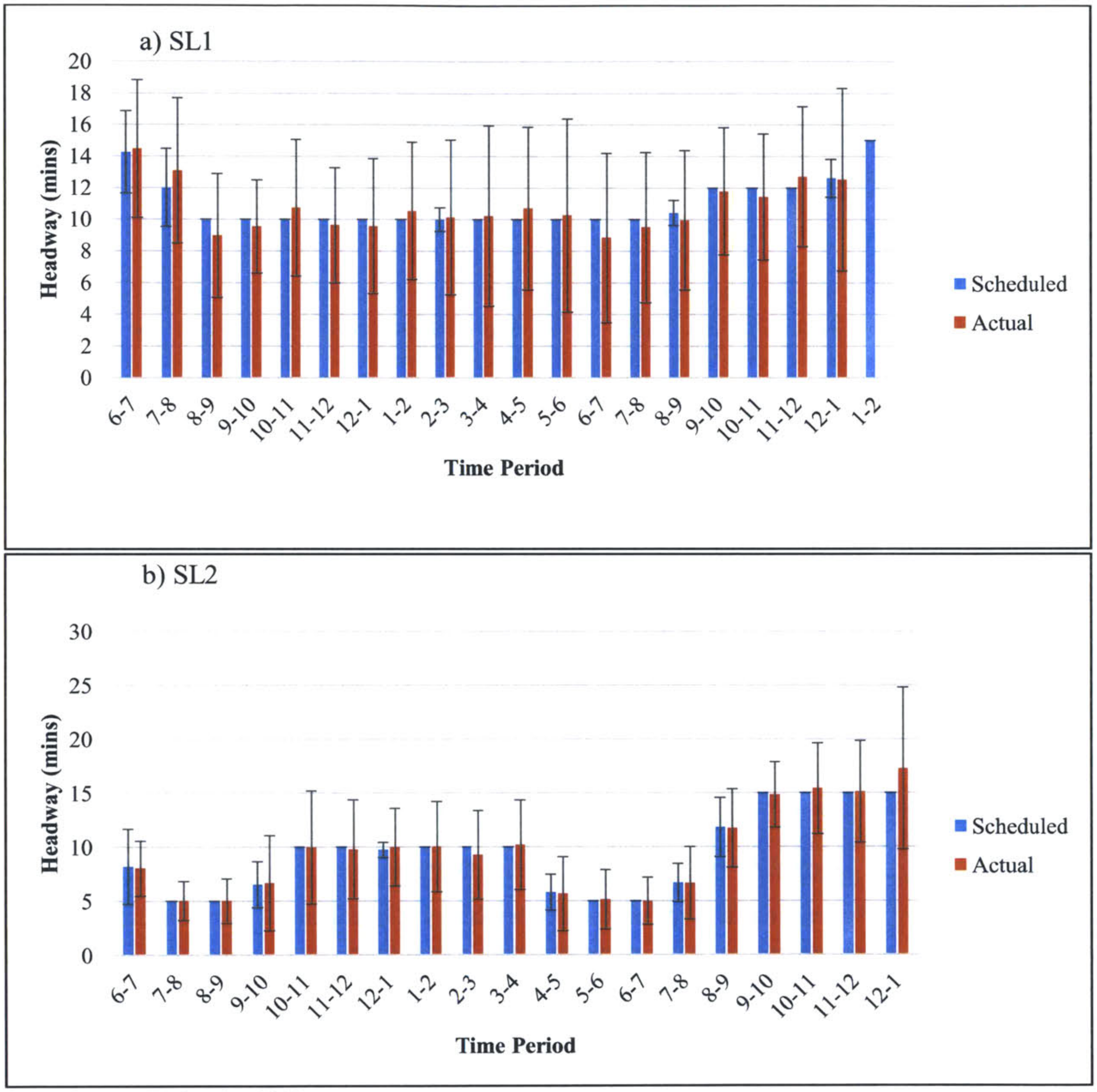
SL1 – uses platoon, so does not reduce headway further.

40/7 = 6 minutes headway

53*(60/6) = 530 passengers per hour

Total: 2,730 passengers per hour in peak direction for SLW/SLG/SL2; 530 for SL1

SL1 and SL2 in-depth headways analysis



*Data from AVL October 2013

Figure A-9: Silver Line scheduled and actual headways

The Silver Line can be characterized as a high-frequency service, with headways every 10-15 minutes, providing frequent service to passengers and encouraging public transport. However, the reliability in performance of the route is poor. This is measured through the standard deviation of the headways (represented by the bars on the charts), rather than on-time performance. The reason for this is SL's designation as a 'walk-up' service: most passengers do not consult schedules when using SL, so even if a bus is late, but the headways are maintained to a high standard, then travelers are not affected significantly. With this in mind, it can be seen that throughout the whole day, SL's reliability leaves something to be desired due to the high standard deviation. Many buses arrived after short or long headways compared with the scheduled headway, which can cause frustration for customers waiting at the stops. More detailed data and commentary can be seen as shown by the bar charts in Figure A-9—the average scheduled and average actual headways of SL1 for each hour, measured in the inbound direction at the WTC/Courthouse stop.

It can be seen that SL1 operates at the minimum average scheduled weekday headway of around 10 minutes between 8 am and 9 pm, which is quite good service for most of the day. Note that there is no extra service during the peak periods. However, a troubling characteristic is that the standard deviation of the headway is high (around 4 minutes) for most of the midday period. The PM peak is especially bad, with a standard deviation of 6 minutes—around 30% of the buses have headways either less than 4 or greater than 16 minutes. This is partly because, when heading inbound, SL1 has to take regular roads in mixed traffic until the WTC stop, so delays are possible. Another likely reason is that since, the Silver Line is free from the airport, passenger loads are high, causing long dwell times from airport passengers carrying cumbersome luggage. Furthermore, it would be difficult to factor longer running times into the schedules since planes arrive at different times, with passengers arriving at the stops in 'groups', causing some buses to be completely full while other buses are relatively empty and hence the bunching.

The equivalent headway data is also shown in Figure A-9. Note the considerable difference in scheduled headways in comparison to SL1: the Weekday headway follows the conventional pattern of lowest headways during the rush hour (down to 5 minutes for both AM and PM peak) while increasing to 10 minutes during midday off-peak and 15 minutes in the evenings. The standard deviation of the weekday headways is high, often around 40-50% of the scheduled headway, even during the off-peak. This suggests operational issues since SL2 has a relatively short route. Additionally, traffic is not high and there is no clear reason why buses might experience delays during the off-peak since the Design Center area is not very busy. The delays could be attributed to blocking from the delayed SL1 buses, but nevertheless, the scheduling, recovery times and operational protocols of the route should be examined to improve reliability. In terms of the actual headways, the graph shows that there is a small difference (1-2 minutes max) with respect to scheduled headways; however, there is still the problem with averaging the values as mentioned earlier. Finally, there is also a special peak hour shuttle, operating only between the Silver Line Way and South Station, at 5 minute intervals, complementing the regular SL service. All three services combined provide an average peak headway of 2 minutes.

Route alternatives calculations during D Street Grade Separation construction

Replacement services – peak times						
Airport express	**A1**		**A2**		**A3**	
Roundtrip driving time (mins)	25		30		30	
Time at stop (5 stops – 1 min each)	5		5		7	(7 stops)
Stopped time at terminal	2.5		2.5		2.5	
Running Time (mins)	32.5		37.5		39.5	
Layover %	39	20%	45	20%	49.375	25%
Cycle Time	40		45		50	
Headway (mins)	5.71	5:45	6.43	6:30	7.14	7:10
Capacity (passengers/hour)	553		489		444	
Local	**L1**		**L2**			
Roundtrip driving time (mins)	20		25			
Time at stop (12 stops – 45s each)	9		9			
Stopped time at terminal	2		2			
Running Time (mins)	31		36			
Layover %	38.75	25%	46.8	30%		
Cycle time (mins)	40		50			
Headway (mins)	2.22	2:15	2.78	2:50		
Capacity (passengers/hour)	1733		1376			

Table A-44: Replacement services alternatives during "T under D"