Final Report

Central Square Access and Circulation Study

Prepared for City of Cambridge
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1 Introduction

1.1 Study Purpose and Scope

Central Square is an important mixed-use downtown district in the City of Cambridge, and is located at the center of the Cambridgeport, Riverside, Mid-Cambridge, and Area 4 neighborhoods, and is in close proximity to the Massachusetts Institute of Technology (MIT) and Harvard University. It is a major transportation hub that serves all the surrounding residential communities and the commercial, entertainment, and retail spaces. In order to encourage further development of this area and ensure that Central Square (along with Kendall Square) continues to be an important multi-use area and transportation hub, the Cambridge City Manager commissioned a comprehensive development study. The final report from this study, titled the Kendall Square Central Square (K2C2) Planning Study was released in 2013. One of the recommendations of the K2C2 Planning Study with respect to transit was “to look at routing, layover, and stop changes for the Central Square buses” along with the associated goal to “look at ways to reduce the crowding from people waiting for the bus on narrow sidewalks”.

Following on from this recommendation, IBI Group has been engaged by the City of Cambridge (hereinafter referred to as the ‘City’) to study the transit routing, circulation, and access for MBTA routes around Central Square and to develop recommendations for reducing crowding for people waiting for the bus on narrow sidewalks and to improve access to and circulation around Central Square. The intent is that these recommendations will be implemented and/or become the basis for further refinement by the City. The study was comprehensive but many of the ideas and recommendations would still require further coordination with other agencies such as the MBTA as well as consideration of the effects on and interactions with other modes using the square, as well as important services for businesses such as loading zones.

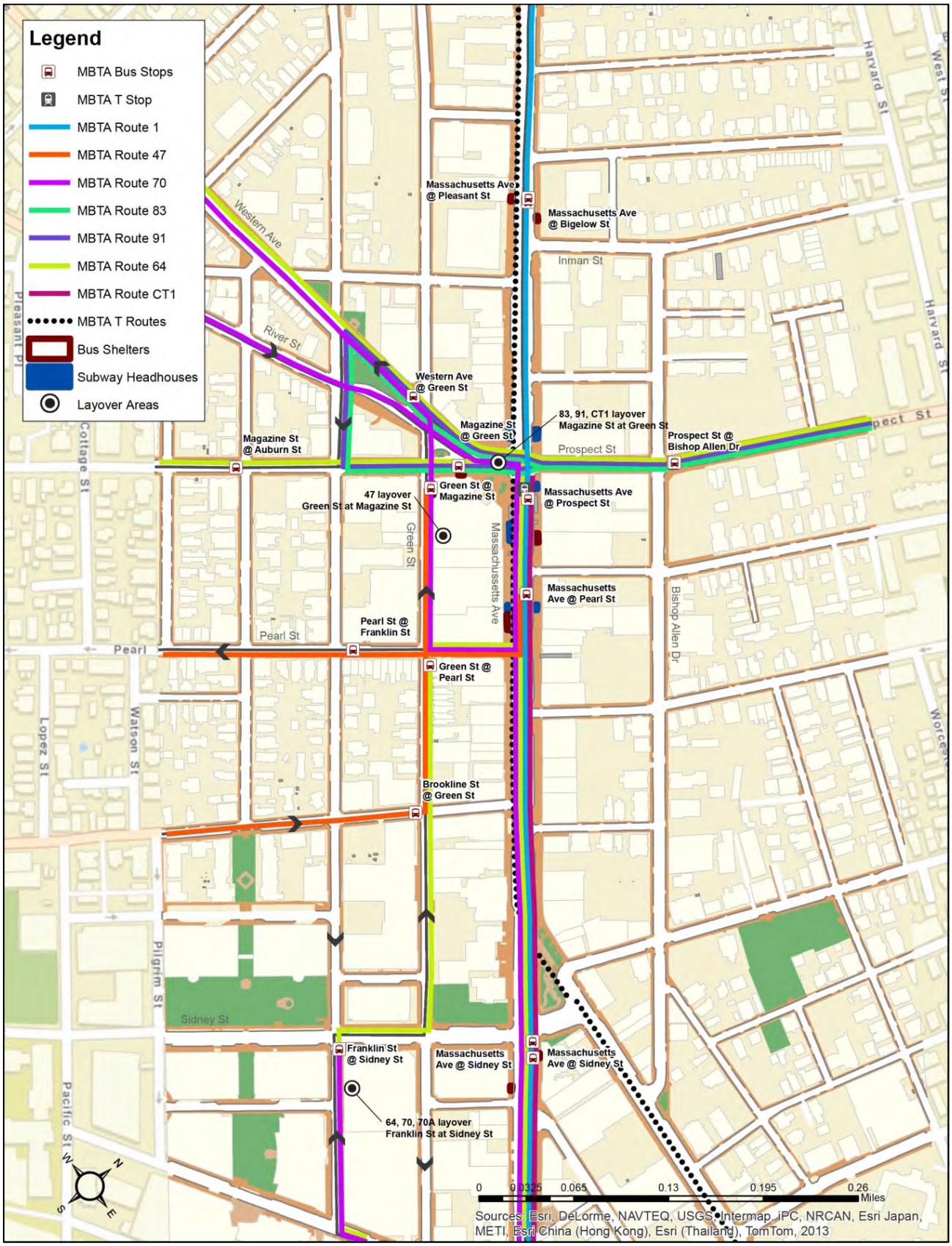
This study was carried out in cooperation with multiple departments within the City of Cambridge as well as with the participation of the Transit Advisory Committee, composed of representatives of various neighborhoods, community groups, advocates, institutions, and businesses.

The Study Area is a rectangular area around Central Square, approximately bounded by Bishop Allen Drive, Landsdowne St, Auburn St., and Bigelow St, with Massachusetts Avenue (or ‘Mass Ave’) running through the Study Area parallel to the longer edge of the rectangle. Figure 1 illustrates the Study Area bounded by the rectangle.

Figure 1: Central Square Study Area (bounded by polygon)

The primary bus and subway related transit features within the Study Area are shown in Figure 2, including the Central Square subway station headhouses, bus stops, and bus shelters. The routing and layover locations of all MBTA bus routes operating within the Study Area are also shown in the figure and include the following routes: 1, CT1, 47, 64, 70, 70A, 83, and 91.

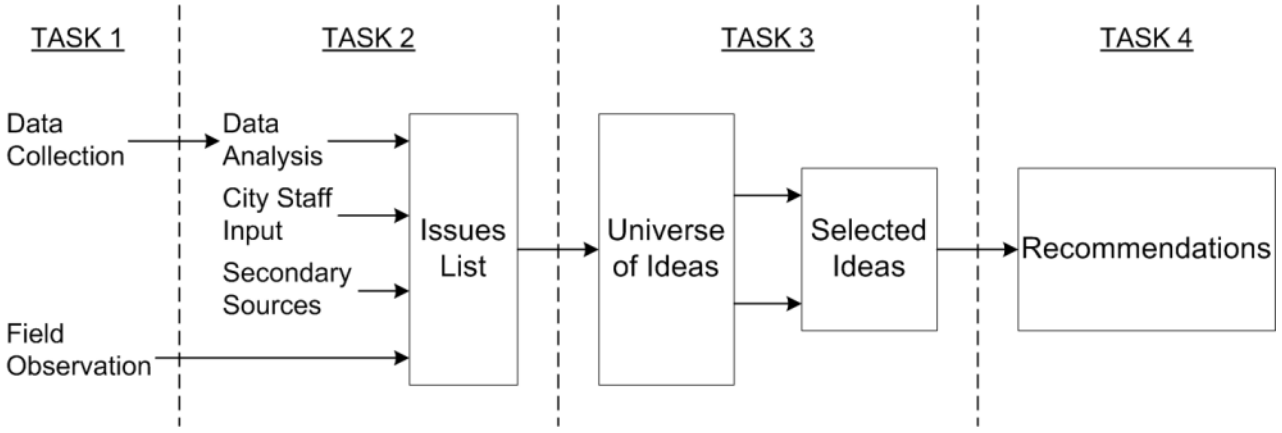
Figure 2: Central Square Study Area and MBTA Existing Conditions



1.2 Study Process

3 illustrates the sequenced tasks involved in this study.

Figure 3: Central Square Project Study Process



Task 1 included data collection and analysis activities to provide information on the existing conditions for transit around Central Square.

Task 2 involved creating a list of issues, starting with those identified by Cambridge staff in the Request for Proposals (RFP), and added to or refined based on background information developed in Task 1 and a review of the 2013 K2C2 Central Square Final Report. The aim of this task was to provide a list of issues to consider while developing ideas for improving bus circulation and access in Central Square.

Task 3 involved developing a universe of potential ideas to improve the bus circulation, routing, stops, and layover locations, and then continued with a refinement of the list based on the effectiveness, cost-effectiveness, and barriers to implementation of each idea.

Task 4 develops a report which accumulates each of the ideas in the refined list into a set of cohesive conceptual design ideas for changes to the bus routing, layover, stops, and wayfinding and passenger information improvements.

1.3 Report Structure and Contents

This document is the final report for the Central Square Access and Circulation Study and is structured as follows:

- Section 1 introduces the purpose and scope of the study, provides an overview of the study process and the structure of this document, summarizes the recommendations resulting from the study, and lists the referenced documents.
- Section 2 describes the process of identifying the issues and presents a categorized list of identified issues.
- Section 3 describes the process of identifying and selecting ideas to resolve the identified issues, and presents a categorized list of the universe of ideas and the ratings associated with assessing the ideas for selection.
- Section 4 synthesizes the selected ideas into recommendations, and describes each selected idea in a bit more detail, along with high-level opinions of probable cost estimates.

1.4 Summary of Recommendations

Section 4 of this report contains recommendations for implementation or further evaluation and development by the City of Cambridge. These include:

- Ideas which could be implemented in the near term with relatively modest investment. They are focused on wayfinding or pedestrian navigation and on passenger information. They can be implemented independently of each other. They may be found in Section 4.1.
- Ideas which would require some further development before implementation, and would generally involve a higher level of investment. They are focused on transit operations, including routing, stop locations, and layover locations. They can be implemented independently, but some are likely to be more effective in combination with other. They may be found in Section 4.2.
- A comprehensive 'Modest Improvements' bus circulation plan, which packages many of the intermediate-term ideas which work well together, assuming that the present use of Green Street as a westbound routing would continue. This plan is described in Section 4.3.1.
- A comprehensive 'Massachusetts Avenue Stop Relocation' bus circulation plan which packages many of the intermediate-term ideas which work well together, assuming a shift of bus stops onto Massachusetts Avenue so as to reduce walking distances between buses and the Red Line. This plan is described in Section 4.3.2.

The two circulation plans could be viewed as medium-term (Modest Improvements) and longer-term (Massachusetts Ave Stop Relocation) improvements. However, it should be noted that the ideas in the two plans may be dependent on or independent of each other. If ideas are phased in over time, the potential impacts of phasing them should be further studied. In addition, several ideas which are common to both circulation plans could be implemented without committing to either one.

2 Identification of Issues

2.1 Methodology

Task 2 compiles a list of issues based on an analysis of the following information:

- Data collected and analyzed in Task 1,
- Two field visits conducted in Task 1 and supplemented with two subsequent follow up visits.,
- Review of Secondary Sources, and
- Input from City staff.

The information and data collected and analyzed as part of Task 1 included the following:

- Transit Access and Transfer Information from MBTA survey results and fare data
- Bus Dwell Time Analysis for stops within Study Area, based on MBTA Automatic Passenger Counter (APC) data
- Time between Scheduled Arrivals and Departures for routes which layover within Study Area, based on APC data
- Passenger Loads Analysis for bus alighting and boarding at stops within Study Area, based on APC data
- Bus Median Alightings and Boardings Analysis for all routes at stops within Study Area, based on APC data

The information from these sources was further analyzed to identify specific operational issues:

- Adequacy of layovers per the Vehicle Curb Utilization Analysis in Appendix B;
- Dwell times at stops per the Vehicle Curb Utilization Analysis in Appendix B;
- Capacity at stops as per Bus Stop Space Consumption Analysis in Appendix C.

The operational issues identified were supplemented based on further information from input by City staff and associated entities such as the City's Transit Advisory Committee, along with a review of secondary information sources (such as the K2C2 report), interviews with other stakeholders such as MBTA staff, and site surveys (please refer to Section 5 in Appendix F). Based on these sources, issues with bus routing, stop capacity, stop signage, wayfinding, and passenger information were identified. The comprehensive list of all these issues may be found in Section 2.2.

2.2 Issues List

The list of issues related to access and circulation in Central Square is presented in Table 1. The issues have been arranged both by an overall category and by location. This list is the result of review of a draft list of issues prepared by IBI Group with City of Cambridge staff.

Table 1: List of Issues related to Bus Access and Circulation in Central Square

Category	Location	Particulars
Bus Routing	MBTA Route 64 Outbound	The use of different stops by time of day (Western and Green in peak periods, and Green Street at Magazine in the off-peak) causes confusion among passengers.
	MBTA Route 47	Per the MBTA-designated routing, Route 47 buses departing the layover on Green St at Magazine St are required to make a right turn

Category	Location	Particulars
		from Green St to River St before proceeding to turn right onto Mass Ave. Many instead turn directly from Green St towards Central Square via Magazine St at Green St (Berth 2). This movement saves buses time but is problematic because the intersection is not designed for it.
	MBTA Route CT1	Per the MBTA-designated routing, Route CT1 buses towards Central Square are required to go around the First Baptist Church by taking a left from Green St towards Western Ave, then a left on Franklin St, and finally a left on Magazine St to pull into Magazine St at Green St (Berth 2), Many instead turn directly from Green St towards Central Square via Magazine St at Green St (Berth 2). This movement saves buses time but is problematic because the intersection is not designed for it.
	MBTA Routes 83 and 91	Buses arriving at Central Square have a circuitous route, as they must continue down Western Ave, turn left on Franklin St, and turn left on Magazine St before pulling into Berth 1.
Operations (Layovers)	MBTA Route 47	The MBTA-designated layover location at Green St at Magazine St is over capacity and bus operators find it sometimes unavailable and awkward to use. Sometimes the eastbound curb lane of Mass Ave west of Pearl Street is informally used as an alternative layover location.
	MBTA Routes 83 and 91	There is insufficient capacity at Berth1 on Magazine St at Green St to accommodate a layover for these routes, which can result in buses blocking traffic on Green Street.
	MBTA route 47	Passengers on curbs desire to board buses that are laying over, especially under inclement conditions.
Bus Stop Capacity	Green Street Westbound at Magazine Street (nearside stop)	This stop has inadequate space for waiting passengers through most of the day. The bus shelter location and the placement of trash bin hinder pedestrian movement by creating a pinch point (refer to Appendix F – Figure 24).
	Magazine Street at Green Street (Berth 1)	This stop has inadequate space for waiting passengers in the PM peak and evenings.
	Massachusetts Avenue at Pearl Street (eastbound)	This stop has inadequate space for waiting passengers in the AM peak and later morning.
	Bus stops at Mass Ave and Pearl St and Mass Ave and Prospect St	Shelters are perceived to be too small or overcrowded.
Bus Stop Signage	Magazine St at Green St (both berths), Green St at Magazine St	Existing signage for buses cannot be easily viewed by passengers at the stop.
	Magazine St at Green St (both berths), Green Street Westbound at Magazine Street (nearside stop)	Signs only face away from Central Square, so are not positioned for passengers approaching these stops from the Red Line looking for their stop.
	Magazine St at Green St Berth 1	Signs are attached to different poles at different heights.
	Magazine St at Green St Berth 1 Green Street Westbound at Magazine Street (nearside stop)	Signs are often located right next to the bus shelters with the remaining space occupied by people waiting to board. Other travelers are required to negotiate around (sometimes into the road area where buses are expected to pull in) to view route signage.
	Green Street Westbound at Magazine Street	Bus schedule information is not always location-specific.
	Green Street Westbound at Magazine Street	The schedules for routes 64, 83, 91, and CT1 are posted, although this stop is for routes 70 and 70A.

Category	Location	Particulars
Bus Stop Visibility	Green Street Westbound at Magazine Street (nearside stop)	Relative to other high-volume bus stops, this one is visible to a lower volume of passing traffic, and is not adjacent to active building frontage. It may be difficult to find and may feel like it is located in an alleyway.
Bus Stop Amenities	Bus stops at Mass Ave and Pearl St and Mass Ave and Prospect St	The bus shelters are not weather protected on the sides.
Use of urban space	Triangle bounded by Magazine St, Green St, and River St	The City is interested in making alternative use of this space.
	Massachusetts Avenue through Central Square	General character perceived to be car-dominated and potentially not ideal to walk or bike.
Operations (Running Delays)	MBTA Route 1 on Mass Ave from Sidney to Prospect Streets (westbound)	Delays are attributable to: interrupted flow from traffic signal spacing, closely spaced and heavily used pedestrian crossings; and a single lane for general traffic movement between Norfolk Street and Essex Street.
	Mass Ave and Pleasant St to Mass Ave and Pearl St	During the PM peak, there is excess running time[1] for Route 1.
	MBTA Route CT1 at Mass Ave and Pearl Street	Left turn conflicts with eastbound through traffic along Mass Ave.
Operations (Dwell Times)	MBTA Routes 1, CT1, 70, 70A at Mass Ave and Pearl St	During AM and PM peak, there are long dwell times (median greater than 40 seconds) at the bus stop.
	MBTA Routes 70 and 70A at Green Street Westbound at Magazine Street (nearside stop)	During AM and PM peak, there are long dwell times at the bus stop.
	MBTA Route 1 at Mass Ave and Prospect St	During PM peak, there are long dwell times at the bus stop.
Rapid Transit Capacity	MBTA Red Line	Passengers experience long waiting times due to irregular service, crowding, and difficulties boarding some trains because of heavy train loads.
Rapid Transit Access/ Egress and bus transfers	MBTA Red Line Outbound Elevator Access near Mass Ave and Prospect St	The approach to the elevator towards the Red Line outbound platform is constricted by the location of bike parking racks and trash bins.
	Connecting bus stops and the Red Line	The walk access distances between the drop-off/pick-up points of various connecting bus routes and the Rapid Transit station are perceived to be long.
Lane Use	Loading zone on eastbound side of Mass Ave between Mass Ave and Magazine/River St and Mass Ave and Pearl St	There does not appear to be compliance with the established use for this space (loading/unloading).
	Taxi stand on Mass Ave Westbound between Norfolk St and Essex St	The location of the taxi lane is a source of conflict with other modes because taxis pull in and out of the stand and may block traffic (particularly bike traffic).
	Bike lanes on Mass Ave	Bicyclists experience conflicts with other vehicles wanting to cross the bicycle lane.
	Bike lanes on Mass Ave	Buses don't always pull all the way in to bus bays and may block bike lanes.

[1] As identified in the Cambridge Transit Service Analysis

Category	Location	Particulars
Sidewalk Capacity	Green St at Magazine St	Hindrance to pedestrian movement due to inadequate sidewalk space.
Wayfinding	Red Line platforms at Central station	The “You are Here” indicator arrow on the station maps at the main exit from the Inbound and Outbound platforms within the subway indicate the wrong exit locations. i.e. on the Outbound platform the map suggests that passengers are exiting from the Inbound side, and on the Inbound platform, the map suggests that passengers are exiting from the Outbound side.
	Central Square main intersection and pedestrian crossings, Exits from Central Square Red Line station	There is minimal signage and very limited wayfinding tools in the Central Square area directing passengers to bus stop locations.
	Red Line Central station	There is no signage within the station directing passengers towards the location of bus stops for different bus routes (for Routes 1, CT1, 47, 64, 70/70A, 83, and 91).
	Massachusetts Avenue to Green Street along Magazine Street	Passengers are required to navigate via a series of signs to find the stop for their route.
Passenger Information	Red Line	Alighting passengers cannot see expected arrival/departure times of connecting buses.
	MBTA Connecting Bus Routes	Transferring bus passengers cannot see expected arrival times of Red Line trains
	General	Passengers are not provided adequate information that fare products can be purchased at the Star Variety store.
	General	Passengers are not provided adequate information that paper schedules are available at the booth located at Magazine St at Green St Berth 2.

3 Identification of Ideas

3.1 Methodology

In Task 3, IBI Group identified a 'Universe' of ideas for addressing the issues identified in Task 2. This list includes multiple ideas related to issues that were identified and listed in the previous section, with some of the ideas being complementary to each other, and some being alternatives to each other.

The list of ideas was assessed qualitatively based on the following three attributes:

- **Effectiveness:** The ability of the idea to address the issue(s) for which it was advanced.
- **Cost-effectiveness:** The level of effectiveness relative to the likely range of life cycle costs for the idea.
- **Barriers to Implementation:** An assessment of the likely institutional, policy, and physical obstacles to implementation of the idea.

Each attribute was rated on a scale with five ratings with the interpreted value of the rating being as per Table 2:

Table 2: Ratings Key

Rating	Effectiveness	Cost Effectiveness	Barriers to Implementation
○	Not effective	Not cost-effective	Possibly prohibitive
◔	Not very effective	Likely not cost-effective	Very significant
◑	Somewhat effective	May be cost-effective	Significant
◕	Effective	Cost-effective	Moderate
●	Most effective	Most cost-effective	Few to none

Each idea was further assessed based on the combination of the three rated attributes, with input from City staff and the City's Transit Advisory Committee to select those ideas which would be considered further in advancing the recommendations.

3.2 List of Ideas and Associated Ratings

The list of ideas, the associated ratings by attribute, and the conclusion regarding further consideration for recommendations is presented in Table 3. The ideas have been differentiated firstly by category and then by location, to ensure traceability from the issues list. There are however some additional categories (*e.g*. route interlining) where the ideas may apply to more than one of the categories listed in the issues list. Also, some categories listed in the issues list are not listed in the list of ideas (*e.g.* bus signage), because the ideas associated with resolving these issues can also be found under other categories (e.g. wayfinding and passenger information) in Table 1.

Additionally, while the ideas are listed under a specific category and are traceable to a specific issue, these may have implications for other issues and other ideas. The implications are not explicitly dealt with as part of the list of ideas, but Section 4 compiles the selected ideas into a set of consistent and cohesive recommendations and accounts for these implications.

Table 3: List of Rated Ideas

Category	Location	Idea		Ratings (Refer to Rating Key)			Consider for recommendati-ons?
		#	Description	Effective-ness	Cost-Effective-ness	Barriers to Impleme-ntation	
Bus Routing	MBTA Route 70	1	Change Route 70 bus routing to go through Central Square in the outbound direction (see Figure 16)	◕	◕	◕	Yes
	MBTA Route 64	2	Run Route 64 on common route to Kendall all day (i.e. remove variant to University Park via Broadway and route via Mass Ave) (see Figure 9 and Figure 15)	◕	◕	◕	Yes (Appendix E - Route 64 Alt 2)
		3	*If off-peak routing is not changed*, reroute 64 during the peak to parallel off-peak movement	◑	◑	◕	No
	Route 47	4	Require buses to layover on Magazine St between Franklin St and Green St or on Franklin St between River St and Magazine St (to force use of the MBTA-designated routing (left from Green St onto Western, left from Western onto Franklin, left from Franklin onto Magazine St)	●	◕	◕	Yes
	Route CT1 Outbound	5	Change CT1 bus routing to cross Mass. Ave at Prospect, then in "non-revenue service" turn left at Pleasant St., left at Franklin St., left at Magazine St. to pull into starting location for Inbound (see Appendix E - Route CT1 Alt 2) *Note: This may require curb line and on-street parking modifications for buses to turn left onto Franklin Street. Layover would occur somewhere other than Magazine St at Green St Berth 2.*	●	●	◕	Yes
		6	*As an alternative to routing via Mass Ave,* change CT1 bus routing to move left turn from Mass Ave at Pearl St to Mass Ave at Lansdowne St, and relocating the Mass Ave at Sidney St westbound stop by a block (see Appendix E - Route CT1 Alt 1)	●	◕	◕	Yes
	Routes 83 and 91 Inbound	7	Change 83 and 91 bus routing to turn right at Mass Ave, stop for passenger drop off, turn left at Pleasant St., turn left at Franklin St., then turn left at Magazine St. to pull into Berth 1 (see Appendix E - Route 83, 91 Alt 2) *Note: This may require curb line and on-street parking modifications for buses to turn left onto Franklin Street. Layover would occur somewhere along the route other than Magazine St at Green St.*	●	●	◕	Yes
		8	*Alternative to routing via Mass Ave*, terminate routes without crossing Mass. Ave (see Appendix E - Route 83, 91 Alt 1 and Route 83, 91 Alt 3)	◕	◕	◑	No
Route Interlining	Routes 83 and 64	9	Combine routes to eliminate layover requirements in the vicinity of Central Square	◑	◔	◕	No
	Routes 83 and 47	10	Combine routes to eliminate layover requirements in the vicinity of Central Square	◕	◑	◕	No

Category	Location	Idea		Ratings (Refer to Rating Key)			Consider for recommendati-ons?
		#	Description	Effective-ness	Cost-Effective-ness	Barriers to Impleme-ntation	
	Routes 91 and 64	11	Combine routes to eliminate layover requirements in the vicinity of Central Square	◔	○	◕	No
	Routes 91 and 47	12	Combine routes to eliminate layover requirements in the vicinity of Central Square	◑	◔	◕	No
Operations (Layovers) *(Note: Ideas may be dependent on potential routing changes)*	Eastbound curb lane of Mass Ave between Magazine/River St and Pearl St	13	Formalize as layover location for MBTA Route 47	◕	◕	◕	No
		14	Separate layovers from boarding location to reduce passenger confusion and eliminate source of potential conflict with operators.	●	●	◕	Yes
	Berth 1 on Magazine St. at Green St.	15	Relocate layovers for MBTA Routes 83 and 91 to resolve issues with stop usage (currently over capacity).	●	●	◕	Yes
		16	Separate layover location from boarding location (along potential new routing)	●	●	◕	Yes
	Berth 2 on Magazine St. at Green St.	17	Relocate layover for MBTA Route CT1	●	●	◕	Yes
Bus Stop Relocation *(Note: Ideas may be dependent on potential routing changes)*	MBTA Route 64 Outbound	18	*If off-peak routing is not changed,* Route 64 would not stop at Green St and Magazine St during off-peak (to reduce potential confusion from different peak and off-peak stop locations)	◕	◕	◕	Yes
	Routes 83 and 91 Inbound	19	Relocate bus stop at Prospect St and Bishop Allen Dr closer to Mass. Ave	●	●	●	Yes
	Route 1 - Mass. Ave and Pearl St. eastbound (towards Boston) bus stop	20	Designate separate stops for drop-off and pick-up	●	●	◕	Yes
	Mass. Ave and Pearl St. eastbound (towards Boston) bus stop	21	Reassign bus stops for Eastbound routes (47, 64, 70, 70A, and possibly 1 and CT1) by expanding bus stop locations along the curb lane on Massachusetts Ave between Essex St. and Pearl St.	●	◕	◕	Yes
	Route 1 - Mass. Ave and Prospect St. westbound (towards Harvard) bus stop	22	Designate separate drop-off and pick-up locations (*e.g.* converting existing stop to drop-off only and adding a pick-up stop at Mass. Ave and Pleasant)	◕	◕	◕	Yes
	Mass. Ave and Sidney St. westbound (towards Harvard) bus stop	23	Move bus stop to farside of intersection	◕	◕	●	Yes
	Mass. Ave and Prospect St. westbound (towards Harvard) bus stop	24	Move bus stop to farside of intersection	◕	◕	●	Yes
Bus Stop Capacity	Berth 1 on Magazine St. at Green St.	25	Add additional bus stop shelter(s) or extend existing shelter.	◕	◕	◕	No
		26	Redesign bus shelter and triangle to allow for more space	●	●	◕	Yes
	Bus stop/shelter (Mass Ave and Pearl St/Prospect St)	27	Extend bus stop/shelter	◕	◕	●	Yes

Category	Location	Idea		Ratings (Refer to Rating Key)			Consider for recommendati-ons?
		#	Description	Effective-ness	Cost-Effective-ness	Barriers to Impleme-ntation	
Bus Stop Visibility/ Security	Green St. and Magazine St. westbound (towards Harvard) bus stop	28	Improve lighting	◕	◕	●	Yes
Bus Stop Amenities	Bus stop/shelter (Mass Ave and Pearl St/Prospect St)	29	Provide end protection for inclement weather	◕	◕	●	Yes
Use of urban space	Berths 1 and 2 on Magazine St. at Green St.	30	Redesign island to eliminate bus use of this space (remove both berths)	◕	◑	◕	No
		31	*If bus use of this space is not eliminated,* redesign island to eliminate bus layovers at this space (only pick-up point with one berth) and allow buses to turn right into the single berth	●	◕	◕	Yes
		32	*If bus layovers at this space are not eliminated,* redesign island to allow buses to turn right into the second berth	◕	◕	◕	Yes
Operations (Running Times)	Westbound curb lane of Mass Ave. between Essex St. and Norfolk St.	33	Replace taxi stand with bus queue jump lane (for approaching Essex St.)	●	●	◕	Yes
Operations (Dwell Times)	Mass. Ave and Pearl St. eastbound (towards Boston) bus stop	34	Replace cash fares with off-board payment, e.g. through provision of CharlieTicket machines.	◕	◑	◑	No
		35	Do not accept cash fares at this stop.	●	◕	◑	No
	Green St. and Magazine St. westbound (towards Harvard) bus stop	36	Improve Green St at Pearl St stop by providing more wayfinding information in order to partially spread passenger boardings away from Green at Magazine to Green at Pearl.	◕	◕	◕	Yes
	Mass. Ave and Prospect St. westbound (towards Harvard) bus stop	37	Replace cash fares with off-board payment, e.g. through provision of CharlieTicket machines.	◕	◑	◑	No
		38	Do not accept cash fares at this stop.	●	◕	◑	No
Rapid Transit Capacity	MBTA Red Line	39	Reconfigure/upgrade signal system and/or platform configurations to increase the number of trains per hour that can be operated between Charles/MGH station and South Station Under.	●	◑	○	No
	MBTA Red Line, Kendall-Central	40	Extend bus route 64 to Kendall during off-peak as an alternative	◕	◕	●	Yes
		41	Extend bus routes 70 and 70A to Kendall as an alternative	◑	◑	●	No
Rapid Transit Access/ Egress	access/egress points to/from Red Line (for passengers entering/emerging to/from subway)	42	Relocate bike parking and trash bins away from current location near Central Station elevator access/egress points	◕	◕	●	Yes
Lane Use	Eastbound curb lane of Mass Ave between Magazine/River St and Pearl St	43	Stricter enforcement of no parking and loading zone rules	◕	◕	●	Yes

Category	Location	Idea		Ratings (Refer to Rating Key)			Consider for recommendati-ons?
		#	Description	Effective-ness	Cost-Effective-ness	Barriers to Impleme-ntation	
	Curb lane of Mass Ave in study area	44	Provide adequate width for buses to stop at bus stops along Mass Ave. without encroaching on bike lane	●	◕	◔	No
Sidewalk Capacity	Green St. and Magazine St. westbound (towards Harvard) bus stop	45	Create separate berths and shelters for routes stopping at this bus stop.	●	●	◕	Yes
	Green St. and Pearl St. westbound (towards Harvard) bus stop	46	Widen sidewalk, remove parking on opposite side, and improve bus stop (add shelter) to attract passenger boardings from Green St at Magazine St.	◕	◑	◕	No
Wayfinding	Red Line Platforms at Central station (for alighting passengers)	47	Suggest MBTA provide signage directing travelers to appropriate exit for each bus route (similar to Harvard station). This could possibly be combined with real-time displays of bus departure times.	◕	●	●	Yes
		48	Suggest MBTA provide properly located "You are Here" indicator arrows on station maps	◕	●	●	Yes
	Egress points from Red Line Central station (for passengers emerging from subway)	49	Compass orientation for bus routes painted on sidewalk	◕	●	●	Yes
		50	Bus route directional signage on poles carrying large 'T' symbol	●	●	●	Yes
	Sidewalks/commercial properties between station and stop/stop areas	51	Directional signage to bus routes and Red Line entrances (by direction) on buildings in proximity	●	●	◕	Yes
		52	Incorporate wayfinding information in sidewalks	◕	◕	◕	Yes
	Multi-berth bus stops or bus stop 'clusters' (e.g. Magazine and Green Streets)	53	Summary signs at approach(es) to complex stop areas, informing passengers where they are (map with "You are Here" indicator), bus stop locations within the area, and which routes serve each bus stop.	●	●	●	Yes
	Bus stop/shelter	54	Apply MBTA standards for bus stop signs consistently, and augment as necessary to clearly indicate from both sidewalk directions, at a consistent height, which routes serve the stop.	●	●	●	Yes
Passenger Information	At each egress point from Red Line Platforms at Central station (for alighting passengers)	55	Real-time next bus arrival/departure prediction displays by route. It may be possible to combine this with a directional arrow to reduce signage.	●	◕	◕	Yes
	Access points to Red Line Central station (for passengers entering subway)	56	Real-time next train arrival prediction signs at each of the entrances location, repeating information for the corresponding platforms (i.e. Inbound entrances only have Inbound train real-time prediction information)	◕	◑	◕	No

Category	Location	Idea		Ratings (Refer to Rating Key)			Consider for recommendati-ons?
		#	Description	Effective-ness	Cost-Effective-ness	Barriers to Impleme-ntation	
	Public or commercial properties generally visible from Massachusetts Avenue sidewalks	57	Larger outside 'broadcast' signs for real-time next train arrival prediction signs for both platforms	◕	◔	◑	No
	Lobbies or other generally accessible locations at public or larger private entities	58	Encourage display of available real-time arrival/prediction information (e.g. by Transit Screen) within the vicinity of Central Square	◕	◑	●	Yes
	Bus stops/shelters	59	Enhance and update MBTA bus stop information with location of nearest fare product vendor	◕	◕	◕	Yes
		60	Enhance MBTA bus stop information with electronic passive high-quality information signs *e.g.* E-paper signs at or near the shelters for schedules, maps, etc.	●	◕	◕	Yes
	MBTA public timetables/website	61	Include the Star Variety store as a Charlie Card source and check whether the other sources shown are still valid. Keep the source information up to date.	◑	●	●	Yes

4 Recommendations

The recommendations of this study for the City of Cambridge are based on the list of ideas advanced for further consideration in Section 3. These have been further categorized on the basis of the timeframe that each of the ideas would take for planning and implementation. The following timeframes have been chosen:

- Near-term – Ideas for which implementation planning could start immediately upon authorization. (Section 4.1)
- Intermediate term – Ideas for which further development or design is likely required before implementation. (Section 4.2). These intermediate term recommendations are generally independent of longer term recommendations and could be done regardless of what is done in the longer term). Some (indicated by an asterisk (*) next to the timeframe entry in Table 4) form part of one or both of the longer-term bus circulation plans.
- Longer term – The ideas both require further study and would likely take more time and effort to implement than the above two timeframes. These longer term recommendations, plus some compatible intermediate term recommendations, are grouped into two multi-element bus circulation plans - 1.) Modest Improvements Plan and 2.) Mass. Avenue Stop Relocation Plan. The two plans are likely to have significant impact on the existing infrastructure and operations and would require further development and design. (Section 4.3)

The recommendations can be further categorized as able to be planned and implemented by the City with limited or no input from other agencies, or as not able to be planned and implemented by the City without help from other agencies. The latter category of ideas would either require significant assistance by other agencies (such as the MBTA) or could only be implemented by other agencies.

Table 4 lists the recommended ideas, the expected timeframe, and the lead agency (*i.e*. whether the project is under the direct control of the 'City' or would require another agency to lead the project). In some cases because a recommendation requires the cooperation of BOTH the City and another agency, the two agencies are both listed instead of a single "lead" agency.

Table 4: Recommendations List

Category	Location	Idea		Timeframe	Lead Agency (City / Other)
		#	Description		
Bus Routing	MBTA Route 70	1	Change Route 70 bus routing to go through Central Square in the outbound direction (see Appendix E - Route 70 Alt 1 and Route 70 Alt 2)	Longer term	MBTA
	MBTA Route 64	2	Run Route 64 on common route to Kendall all day (i.e. remove variant to University Park via Broadway and route via Mass Ave) (see Appendix E - Route 64 Alt 1 and Route 64 Alt 2)	Longer term	MBTA
	Route 47	4	Require buses to layover on Magazine St. between Franklin St. and Green St (to require use of the MBTA-designated routing (left from Green St onto Western, left from Western onto Franklin, left from Franklin onto Magazine St)	Intermediate term	MBTA
	Route CT1 Outbound	5	Change CT1 bus routing to cross Mass. Ave at Prospect, then in "non-revenue service" turn left at Pleasant St., left at Franklin St., left at Magazine St. to pull into starting location for Inbound (see Appendix E - Route CT1 Alt 2) *Note: This may require curb line and on-street parking modifications for buses to turn left onto Franklin Street. Layover would occur somewhere other than Magazine St at Green St Berth 2.*	Longer term	MBTA

Category	Location	Idea		Timeframe	Lead Agency (City / Other)
		#	Description		
		6	*As an alternative to routing via Mass Ave,* change CT1 bus routing to move left turn from Mass Ave at Pearl St to Mass Ave at Landsdowne St, and relocating the Mass Ave at Sidney St westbound stop by a block (see Appendix E - Route CT1 Alt 1)	Longer term	MBTA
	Routes 83 and 91 Inbound	7	Change 83 and 91 bus routing to turn right at Mass Ave, stop for passenger drop off, turn left at Pleasant St., turn left at Franklin St., then turn left at Magazine St. to pull into Berth 1 (see Appendix E - Route 83, 91 Alt 2) *Note: This may require curb line and on-street parking modifications for buses to turn left onto Franklin Street. Layover would occur somewhere along the route other than Magazine St at Green St.*	Longer term	City and MBTA
Operations (Layovers) *(Note: Ideas may be dependent on potential routing changes)*	Eastbound curb lane of Mass Ave between Magazine/River St and Pearl St	14	Separate layovers from boarding location to reduce passenger confusion and eliminate source of potential conflict with operators.	Longer term	MBTA
	Berth 1 on Magazine St. at Green St.	15	Relocate layovers for MBTA Routes 83 and 91 to resolve issues with stop usage (currently over capacity).	Intermediate to long term*	MBTA
		16	Separate layover location from boarding location (along potential new routing)	Longer term	MBTA
	Berth 2 on Magazine St. at Green St.	17	Relocate layover for MBTA Route CT1	Intermediate to long term*	MBTA
Bus Stop Relocation *(Note: Ideas may be dependent on potential routing changes)*	MBTA Route 64 Outbound	18	*If off-peak routing is not changed,* Route 64 would not stop at Green St and Magazine St during off-peak (to reduce potential confusion from different peak and off-peak stop locations)	Intermediate*	MBTA
	Routes 83 and 91 Inbound	19	Relocate bus stop at Prospect St and Bishop Allen Dr closer to Mass. Ave	Intermediate	City and MBTA
	Route 1 - Mass. Ave and Pearl St. eastbound (towards Boston) bus stop	20	Designate separate stops for drop-off and pick-up	Longer term	MBTA
	Mass. Ave and Pearl St. eastbound (towards Boston) bus stop	21	Reassign bus stops for Eastbound routes (47, 64, 70, 70A, and possibly 1 and CT1) by expanding bus stop locations along the curb lane on Massachusetts Ave between Essex St. and Pearl St.	Intermediate term*	MBTA
	Route 1 - Mass. Ave and Prospect St. westbound (towards Harvard) bus stop	22	Designate separate drop-off and pick-up locations (*e.g.* converting existing stop to drop-off only and adding a pick-up stop at Mass. Ave and Pleasant)	Longer term	City and MBTA
	Mass. Ave and Sidney St. westbound (towards Harvard) bus stop	23	Move bus stop to farside of intersection	Intermediate term	City and MBTA
	Mass. Ave and Prospect St. westbound (towards Harvard) bus stop	24	Move bus stop to farside of intersection	Intermediate term	City and MBTA
Bus Stop Capacity	Berth 1 on Magazine St. at Green St.	26	Redesign bus shelter and triangle to allow for more space	Longer term	City and MBTA
	Bus stop/shelter (Mass Ave and Pearl St/Prospect St)	27	Extend bus stop/shelter	Intermediate term	City
Bus Stop Visibility/ Security	Green St. and Magazine St. westbound (towards Harvard) bus stop	28	Improve lighting	Intermediate term	City
Bus Stop Amenities	Bus stop/shelter (Mass Ave and Pearl St/Prospect St)	29	Provide end protection for inclement weather	Intermediate term	City

Category	Location	Idea		Timeframe	Lead Agency (City / Other)
		#	Description		
Use of urban space	Berths 1 and 2 on Magazine St. at Green St.	31	*If bus use of this space is not eliminated,* redesign island to eliminate bus layovers at this space (only pick-up point with one berth) and allow buses to turn right into the single berth	Longer term	City and MBTA
		32	*If bus layovers at this space are not eliminated,* redesign island to allow buses to turn right into the second berth	Intermediate term	City
Operations (Running Times)	Westbound curb lane of Mass Ave. between Essex St. and Norfolk St.	33	Replace taxi stand with bus queue jump lane (for approaching Essex St.)	Intermediate to long term	City
Operations (Dwell Times)	Green St. and Magazine St. westbound (towards Harvard) bus stop	36	Improve Green St at Pearl St stop by providing more wayfinding information in order to partially spread passenger boardings away from Green at Magazine to Green at Pearl.	Intermediate term	City
Rapid Transit Capacity	MBTA Red Line, Kendall-Central	40	Extend bus route 64 to Kendall during off-peak as an alternative	Intermediate to long term	MBTA
Rapid Transit Access/ Egress	access/egress points to/from Red Line (for passengers entering/emerging to/from subway)	42	Relocate bike parking and trash bins away from current location near Central Station elevator access/egress points	Near-term	City
Lane Use	Eastbound curb lane of Mass Ave between Magazine/River St and Pearl St	43	Stricter enforcement of no parking and loading zone rules	Near-term	City
Sidewalk Capacity	Green St. and Magazine St. westbound (towards Harvard) bus stop	45	Create separate berths and shelters for routes stopping at this bus stop.	Intermediate term	City and MBTA
Wayfinding	Red Line Platforms at Central station (for alighting passengers)	47	Suggest MBTA provide signage directing travelers to appropriate exit for each bus route (similar to Harvard station). This could possibly be combined with real-time displays of bus departure times.	Near-term	MBTA
		48	Suggest MBTA provide properly located "You are Here" indicator arrows on station maps	Near-term	MBTA
	Egress points from Red Line Central station (for passengers emerging from subway)	49	Compass orientation for bus routes painted on sidewalk	Near-term	City
		50	Bus route directional signage on poles carrying large 'T' symbol	Intermediate term	City
	Sidewalks/commercial properties between station and stop/stop areas	51	Directional signage to bus routes and Red Line entrances (by direction) on buildings in proximity	Intermediate term	City
		52	Incorporate wayfinding information in sidewalks	Intermediate term	City
	Multi-berth bus stops or bus stop 'clusters' (e.g. Magazine and Green Streets)	53	Summary signs at approach(es) to complex stop areas, informing passengers where they are (map with "You are Here" indicator), bus stop locations within the area, and which routes serve each bus stop.	Intermediate term	City
	Bus stop/shelter	54	Apply MBTA standards for bus stop signs consistently, and augment as necessary to clearly indicate from both sidewalk directions, at a consistent height, which routes serve the stop.	Intermediate term	MBTA
Passenger Information	At each egress point from Red Line Platforms at Central station (for alighting passengers)	55	Real-time next bus arrival/departure prediction displays by route. It may be possible to combine this with a directional arrow to reduce signage.	Intermediate term	MBTA
	Lobbies or other generally accessible locations at public or larger private entities	58	Encourage display of available real-time arrival/prediction information (e.g. by TransitScreen) within the vicinity of Central Square	Near-term	City
	Bus stops/shelters	59	Enhance and update MBTA bus stop information with location of nearest fare product vendor	Near-term	City and MBTA

Category	Location	Idea		Timeframe	Lead Agency (City / Other)
		#	Description		
		60	Enhance MBTA bus stop information with electronic passive high-quality information signs *e.g.* E-paper signs at or near the shelters for schedules, maps, etc.	Intermediate term	MBTA
	MBTA public timetables/website	61	Include the Star Variety store as a Charlie Card source and check whether the other sources shown are still valid. Keep the source information up to date.	Near-term	MBTA

* Intermediate term options that are included in the longer term circulation plans.

4.1 Near-Term

This section describes recommendations based on ideas for which there is little significant planning work required and on which the City can either start implementation design immediately, or suggest to its partner agencies, such as the MBTA, for near-term implementation.

4.1.1 Operations

Idea 42: At present, access to and egress from the elevator to the Central Square Red Line station outbound platform (towards Harvard Square) is hindered by the close proximity of bike parking racks and a trash bin. The efficacious solution is to relocate the bike parking racks and trash bin away from the access and egress pathway in front of the elevator entrance. The placement of such amenities needs to be designed keeping in mind a clear access/egress route for any potential transit customers who may access the elevator, including wheelchair-bound riders.

Idea 43: The Eastbound curb lane of Mass Ave between Magazine/River St and Pearl St was noticed to often be occupied by vehicles private vehicles despite the no parking and loading zone restrictions. Stricter enforcement of these restrictions is necessary to ensure that this lane is not occupied other than by allowed vehicles.

4.1.2 Wayfinding

Idea 47: For passengers transferring from Red Line trains to bus routes at Central Square, there is a lack of clear wayfinding information. Since different bus routes pick-up passengers from multiple locations which are not located in close proximity, passengers can tend to get confused in the absence of clear wayfinding. It is recommended that the City suggest asking the MBTA to provide signage directing travelers to appropriate exits for each individual bus route, similar to the signs at Harvard station. *E.g.* as per current routing, Route 83 and 91 signage might indicate to passengers that exiting at the two Northernmost exits in either direction would lead them to these routes, while for passengers transferring to Routes 1, CT1, 64, 70, 70A route signage might indicate the two Southernmost exits. This could potentially be combined with real-time displays of bus departure times for passengers alighting at the Central Square Red Line platforms.

Idea 48: The "You are Here" indicator arrows on station maps near the central exits from either platform at Central Square station currently indicate the wrong exit locations. The map at the exit from the Northbound platform (towards Harvard) suggests that passengers would exit on the Southern side of Mass Ave, rather than the correct location which would be the Northern side. The same issue was noticed at the map near the opposite platform as well. The City needs to ask the MBTA to replace these maps with ones which indicate the correct exit locations.

Idea 49: A potential wayfinding tool for passengers exiting the Central Square Red Line station includes painting a directional compass orientation (North-South-East-West) or a bus route stop directional indicator on the sidewalks near the exit points from the station. This would allow transit users to easily orient themselves once they exit the station. Such signs however need to be designed to be easily visible and placed in such a location that the exiting pedestrian traffic is not blocked by any passengers trying to orient themselves. Further consideration needs to be given to the placement, number, size and maintenance of such wayfinding tools.

4.1.3 Passenger Information

Idea 58: One of the ways to encourage more commuters and visitors to Central Square to use transit is to involve local private entities in providing multi-modal real-time arrival/prediction information through large display signs. Such display signs could be installed in various locations including lobbies or other generally accessible locations at public or larger private entity buildings where they are prominently visible to commuters and visitors. Providing such information might encourage their use of transit and also reduce the pressure to provide parking and/or reduce parking costs for private employers. The City of Cambridge is already in discussions with a private company to provide such real-time transit information displays at a few locations near Central Square.

Idea 59: Currently, the MBTA bus stops do not provide easily visible information on the location of nearest fare product vendor. The only information is available on the paper schedules pasted within bus stop shelters, within the route maps and in a small font. The location of the nearest fare product vendor could be better highlighted through displaying this information more prominently, through the use of more prominent icons on the map, or directions to the nearest location, etc.

Idea 61: At present, the Star Variety store provides MBTA fare products but is not referenced on any of the paper schedules stored at local bus stops, and instead other stores (e.g. 7-Eleven) are referenced. The paper schedules need to be updated to reference the Star Variety store as a source for fare products and the other fare source information needs to be verified. The electronic schedules provided online also need to be checked for accuracy. In the future, such information needs to be kept up to date.

4.2 Intermediate Term

This section describes recommendations based on ideas which require further development and design prior to implementation. In a few cases, further development may uncover obstacles or costs that may make them impractical. Some intermediate term ideas initially identified as potential recommendations were not advanced because of specific challenges already identified, but may be revisited in the future:

- Idea 23 – Mass. Ave and Sidney St. westbound (towards Harvard) bus stop – Move bus stop to farside of intersection. Although as a general rule ‘farside’ stops are preferable operationally because they reduce the change a bus may have to stop twice, relocation of this stop would require buses to move out of the travel lane to make a curb stop, making it more difficult to re-enter the traffic stream.

- Idea 24 – Mass. Ave and Prospect St. westbound (towards Harvard) bus stop - Move bus stop to farside of intersection. The intention is to move the stop closer to a wide stairway to/from the Red Line, and to facilitate the typically preferable ‘farside’ location. Relocation of this stop would require buses to make a curb stop in a relatively short space between bulbouts, making it difficult to re-enter the traffic stream.

- Idea 60: The schedules, maps, and other passenger information at bus stops need to be manually updated whenever a new service plan is implemented or other changes are made. It was noticed that this update is not always performed or on occasion the wrong information is put up. An idea that the City might consider suggesting to the MBTA is to provide enhanced stop information through the use of electronic passive E-paper information signs. These signs would display static information such as schedules, maps, and fare vendor location information, and provide the benefit of being wirelessly updateable. Such signs use E-ink displays (similar to those used in E-readers) and therefore require minimal electrical power, typically only when information is updated, and also use minimal wireless capacity. However, a preliminary opinion of the cost for implementing this at seven principal bus stops is $90,000, and these units would be subject to theft or vandalism. This idea might be worth further exploration in the future should the technology become less expensive.

4.2.1 Routing, Stop Locations, and Layovers

Idea 4 – Route 47 is currently required to layover on Green St near Magazine St (which is an active bus stop and also currently over capacity), but also tends to frequently layover on Mass Ave between Magazine St and Pearl St. In addition, bus drivers frequently route buses turning right from Green St onto Magazine St via Magazine St at Green St Berth 2. Since the current turn is not designed for this movement, buses are expected

to turn right onto River St, which then merges with Magazine St. In the absence of any design changes to better accommodate the right turn from Green St to Magazine St, it is recommended that the Route 47 layover be relocated to layover on Magazine St between Franklin St and Green St. This would prevent buses from directly turning right onto Magazine St and will also reduce the excessive usage of the Green St at Magazine St stop. Locating layovers on Magazine Street could affect parking and loading zones (see Appendix D: Central Square Curb Use Map). Note that recommended layover locations for Route 47 are different if other longer term routing changes are pursued (see Section 4.3).

Idea 15 – The layover location for Routes 83 and 91 at Magazine St at Green St Berth 1 is currently over capacity in the peak periods. Relocating layovers for these routes would resolve issues with stop usage. In the absence of any rerouting, the potential locations for these layovers would include Magazine St between Franklin St and Green St (as shown in the 'Modest Improvements' longer term plan), or Franklin St between Western Ave and Magazine St (as shown in the 'Massachusetts Ave Stop Relocation' longer term plan). Relocating layovers to these locations might, however, affect parking spaces or loading zones at these locations (see Appendix D: Central Square Curb Use Map) and identifying a potential bio-break location that bus operators may be able to easily access.

Idea 17 - The layover location for Route CT1 is currently at Magazine St at Green St Berth 2 and the recommended routing from Green St requires buses to turn left on to Western Ave, then left onto Franklin St, and finally left onto Magazine St before pulling into the layover location. However, operators frequently route buses turning right from Green St onto Magazine St, despite the turn not currently being designed for this movement and the bus' turning radius. Relocating layovers for Route CT1 to Magazine St between Franklin St and Green St (as shown in the 'Modest Improvements' longer term plan), or Franklin St between Western St and Magazine St (as shown in the 'Massachusetts Ave Stop Relocation' longer term plan) would resolve this routing movement by forcing buses to complete the required routing. Relocating layovers to these locations might, however, affect parking spaces or loading zones at these locations (see Appendix D: Central Square Curb Use Map) and identifying a potential bio-break location that bus operators may be able to easily access.

Idea 18 – For MBTA Route 64, in the Outbound direction, there are different bus stops by time of day. During the peak customers access buses from the Western Ave at Green St bus stop, and during the off-peak customers access buses from the Green St at Magazine St bus stop. If the routing is not changed, it is recommended that Route 64 not stop at Green St and Magazine St during off-peak. This would reduce potential confusion stemming from the different peak and off-peak stop locations. Passengers from Central Square traveling outbound on Route 64 would, however, still be able to access buses from either the Western Ave at Green St bus stop or the Green St at Pearl St bus stop.

Idea 19 – Passengers traveling inbound on Routes 83 and 91 and desiring to transfer to the Red Line at Central Square are currently required to either egress from the bus at Prospect St and Bishop Allen Dr and then walk to the station entry locations on Mass Ave or wait for the buses to loop around from Western Ave to Magazine St before egressing at Magazine St at Green St and then walk to the station entry locations. It is recommended to explore moving the Prospect St and Bishop Allen Dr bus stop closer to the Central Square Red Line station to reduce the access distances. Potential locations might be on Mass Ave. at Temple St. or on Prospect St/Western Ave closer to Central Square. This idea has not been included in either of the two circulation plans and might need further exploration.

Idea 21 – The eastbound stop at Mass Ave and Pearl St (towards Boston) serves many bus routes (1, CT1, 47, 64, 70, 70A) and the bus shelter is currently overcapacity in the peak periods. When multiple buses arrive at the same time, buses often wait in line for the current bus to leave or tend to drop-off/pick-up passengers earlier on Mass Ave prior to the shelter. This causes cross-pedestrian traffic amongst the customers for different routes. It is recommended that this de facto experience is adapted and improved upon by formally expanding bus stop locations along the curb lane on Massachusetts Ave between Essex St. and Pearl St. This would include establishing specific locations to one or more bus routes at different spots along the Mass Ave stretch and also providing formal bus shelters at each of the spots. A potential example would be assigning Route 1, CT1 to the current location near Pearl St, assigning Route 70, 70A closer to Essex St (in front of the Chipotle's restaurant), and assigning other routes between the two locations (in front of the Sleepy's storefront). The design would need to consider various factors, such as the transfer volumes between routes, and routing after the stop (e.g. the

continuation of Route 1, CT1 on Mass Ave and the turning movement by Route 47, 64, 70, 70A onto Pearl St), etc.

Idea 40 – The Red Line suffers from significant passenger crowding during peak periods, and this issue is particularly noticeable for passengers at the Central Square Red Line station, who are often unable to board the first train. This is a particularly frustrating issue for passengers trying to travel one stop to Kendall in the morning peak period. An alternative currently exists in the form of Route 64 which travels between Central Square and Kendall Square in the peak periods. However Route 64 has a different routing during the off-peak and terminates near Mass Ave and Sidney St, with a median load of around one (1) passenger traveling on the bus between Mass Ave and Pearl St and the termination location. Extending this bus route to Kendall during the off-peak would ensure consistent service and might encourage passengers to choose this alternative more frequently. The impact might be increased even further if the routing were changed to serve more office locations west of Kendall station. The idea could be introduced independent of any of the longer-term improvements that might be made. The idea of extending Route 64 to Kendall Square through the day has been incorporated into both of the two circulation plans alongside the potential routing changes, but it's cost-effectiveness as a standalone solution warrants further study before implementation.

4.2.2 Bus Stop Design and Amenities

Idea 27 – The bus stop shelters at Mass Ave and Pearl St and Mass Ave and Prospect St were found to have insufficient capacity to adequately accommodate the present number of transit riders in the peak periods (refer to Appendix C). Therefore the City needs to consider increasing the capacity of these shelters, either by extending the existing bus stop shelters or redesigning to ensure better usage of existing space.

Idea 28 – The bus stop at Green St and Magazine St westbound is located around a corner and restricted from easy view from primary pedestrian and vehicle travel corridors on Magazine St, which might give the perception of insecurity. One recommendation is to improve the lighting at this bus stop.

Idea 29 – The shelter design for bus stops at Mass Ave and Pearl St and Mass Ave and Prospect St do not currently include side panels for weather protection and some users have expressed concern about this. The solution for this is to consider designing and incorporating side panels on shelters for inclement weather conditions.

Idea 32 – The design of the Magazine St at Green St bus stop includes two berths which are used as layover locations for three routes (CT1, 83, 91). The second bus berth is frequently used as a shortcut by other routes which need to turn from Green St onto Magazine St, despite not being designed for this turn. *If bus layovers at this space are not eliminated* as indicated in other recommendations, then the island should be redesigned to allow buses to more easily turn right here. This would reduce the running or deadhead time for buses turning from Green St onto Magazine St and channelize buses turning onto Mass Ave, while at the same time not endangering the island's structure.

Idea 45 – The bus stop at Green St and Magazine St westbound serves bus routes with significant number of passengers alighting at this stop (Routes 47, 64, 70, 70A). The bus stop consists of two small Cemusa shelters built along a narrow sidewalk. The shelter's size and configuration, combined with the high utilization results in a severe restriction on sidewalk capacity for transit customers. In order to improve the capacity of the sidewalk and relieve the overloaded shelter, multiple separate berths and shelters could be created for different routes stopping at this bus stop along Green Street.

4.2.3 Operations

Idea 33 – Route 1 buses traveling Eastbound towards Harvard Square were found to suffer from significant running delays in the segment from Mass Ave and Sidney St (Westbound) and Mass Ave and Prospect St. A potential solution to reducing delays is to replace the taxi stand south of Essex St with a bus queue jump lane. This would reduce delay for buses and allow them to easily pull in to the bus stop at Mass Ave and Prospect St.

Idea 36 - During the peak periods, buses stopping at the Green St. and Magazine St. westbound stop experience long dwell times. This is primarily due to this location being a major boarding point for westbound routes, but the dwell times are also increased due to the stop being extremely crowded with waiting passengers.

A potential improvement might be to attract some passengers to board from the Green St at Pearl St stop instead. This could be encouraged by providing better wayfinding information and would be particularly useful for passengers exiting the Red Line station near the Pearl St exit. Wayfinding information might include signage within or outside the Central Square Red Line station. Adding features such as a bench or shelter appear to be precluded by the narrow width of the sidewalk (approximately 5'3").

4.2.4 Wayfinding

Idea 50: A potential wayfinding tool for passengers on Mass Ave is to provide bus route directional signage on poles which are currently carrying the large 'T' symbol. These poles are prominently placed and are widely visible, including from some of the major egress points from the Red Line Central station. Providing summary signs which direct passengers to the different bus stops for each route might be beneficial for wayfinding.

Idea 51: Similar to the previous idea, if approved by property owners, directional signage to bus routes and Red Line entrances (by direction) could be placed on buildings in proximity. Signs would need to be located at an optimal height and location to ensure the widest viewing angles, and the design would need to ensure clear visibility. Installing such signage might however require the City to collaborate with local commercial entities who own buildings.

Idea 52: Similar to Idea 49, another potential wayfinding tool for passengers traveling from the Central Square Red Line station to bus stops includes incorporating wayfinding information in sidewalks in a way that requires minimal or no maintenance. These would provide route direction information for transit users to orient themselves as they are walking towards bus routes. The specifics of the wayfinding information would need to be designed but might include information on streets, bus stops, major locations, etc. This wayfinding should not be fully relied upon, however, in case of snow covering them.

Idea 53: As passengers are approaching complex stop areas (Multi-berth bus stops or bus stop 'clusters' such as near Magazine and Green Street), a useful wayfinding tool might be to provide summary signs informing passengers where they are (map with "You are Here" indicator), bus stop locations within the area, and which routes serve each bus stop. This would negate the need for passengers to walk to each individual stop and check which buses serve that specific stop before proceeding to the next one.

Idea 54: At present, signage across bus stops in the Central Square area is not consistently implemented. Route signage tends to occasionally be installed at different heights, and also tends to be facing only in one direction. This is particularly an issue for routes whose signage faces away from customers approaching stops from Central Square. The signage needs to be augmented to ensure they are visible from all the major directions of approach, are at a consistent height, and visibility is not impeded by other objects/signs.

4.2.5 Passenger Information

Idea 55: For passengers transferring from Red Line trains to bus routes at Central Square, there is a lack of readily available passenger information. Although real-time bus arrival/departure predictions are available over web and mobile applications, the City might suggest to the MBTA that they provide real-time displays of bus departure times for passengers alighting at the Central Square Red Line platforms. Such signs would need to be located close to egress points from the platforms.

4.3 Longer Term

IBI Group has considered the entire set of ideas identified as 'Longer Term' in Table 4 and has compiled the inter-compatible ideas into two distinct circulation plans. The circulation plans also incorporate some elements of the ideas explored in Section 4.2. Each circulation plan would require further development and consensus-building prior to implementation. These plans are:

- The 'Modest Improvements' plan. This plan focuses on addressing the deficiencies of the present arrangements relative to stop capacities for both buses and passengers, and layover locations. The overall circulation plan for routes is not changed substantially through Central Square, with Green Street continuing in use of outbound routes 47, 64, 70, 70A. Walking distances for bus passengers transferring to and from the Red Line would not be substantially changed.

- The 'Massachusetts Avenue Stop Relocation' plan focuses on reducing the time for passengers transferring to/from the Red Line by relocating many of the bus stops to Massachusetts Avenue, and making several changes to the established bus routings to do so, while also assuring there is adequate bus stop and layover capacity.

These two plans should not be regarded as mutually exclusive, and therefore neither is recommended over the other. The 'Modest Improvements' plan could likely be implemented sooner, but would not preclude a shift to the 'Massachusetts Avenue Stop Relocation' plan at a later date.

Some longer term ideas initially identified as potential recommendations were not advanced because of challenges identified below, but may be revisited in the future:

- Idea 6 – This idea considered a potential change to CT1 bus routing that would reduce the vehicular conflict with passengers at Mass Ave at Pearl St by moving the existing left turn from Mass Ave. onto Pearl St. to a left turn from Mass Ave. onto Landsdowne St. However this idea was discarded in favor of Idea 5 which solves the same issue and also has the advantage of having the last stop be situated closer to the Central Square Red Line station.

- Idea 7 – This idea was considered in order to minimize the intermodal transfer distances by dropping passengers off closer to Central Square but was discarded in favor of retaining the current configuration.

- Ideas 20 and 22 – Each of these ideas considered separating stops for drop-off and pick-up for Route 1, in order to reduce the dwell times at Mass Ave. and Pearl St. stop and Mass Ave. and Prospect St. The ideas were discarded in favor of reassigning bus stops for different routes.

- Idea 31 – This idea considered a redesign of the island at Magazine St. at Green St to allow buses to safely turn right from Green St into Berth 2 on Magazine St. at Green St. The idea was discarded in favor of redesigning the island to relocate the layovers away from this location.

The following sections describe the two circulation plans, and are followed by some observations regarding possible further developments.

4.3.1 'Modest Improvements' plan

The focus of the 'Modest Improvements' plan is on improving waiting conditions for passengers by relieving congestion at bus stops, as well as minor reallocation of space. This involves a number of stop changes, routing changes, and layover location changes. Expanding some bus stops and installing additional shelters will improve the experience of passengers by reducing crowding, speeding up boarding and alighting, and also enabling a smoother flow of passengers transferring between bus routes. '

The 'Modest Improvements' Plan involves the following stop changes in the Study Area, as shown in Figure 6:

- Route 1
    - Eastbound direction: The location of the Mass Ave at Pearl bus stop for this route would not be changed.
    - Westbound direction: The location of the Mass Ave at Prospect St bus stop for this route would not be changed.
- Route CT1
    - Eastbound direction: The location of the Mass Ave at Pearl St stop for this route would not be changed (collocated with Route 1 Eastbound bus stop).
    - Westbound direction: Relocation of the last stop at Magazine St at Green St Berth 2 to Mass Ave and Prospect St (collocated with Route 1 Westbound bus stop).

- Route 47
    - Eastbound direction: Relocation of the last stop at Green St at Magazine St bus stop a few feet upstream, further away from Magazine St and closer to 291 Green St.
    - Westbound direction: The location of the first stop for this route at Mass Ave at Pearl St would be relocated a few feet upstream, closer to Mass Ave at Essex St.
- Route 64
    - Eastbound direction: Location of stop at Mass Ave at Essex St for both peak and off-peak time periods (collocated with Route 47 Westbound bus stop).
    - Westbound direction: Relocation of Green St at Magazine St bus stop a few feet upstream, further away from Magazine St (collocated with Route 47 Eastbound bus stop).
- Route 70/70A
    - Eastbound direction: Relocation of Mass Ave at Pearl St bus stop a few feet upstream, closer to Mass Ave at Essex St (collocated with Route 47 Westbound bus stop and Route 64 Eastbound bus stop).
    - Westbound direction: The location of the Green St at Magazine St bus stop for this route would not be changed.
- Route 83/91: There are no recommended changes to the stops for these routes.

The ‘Modest Improvements’ Plan involves routing changes for the following routes:

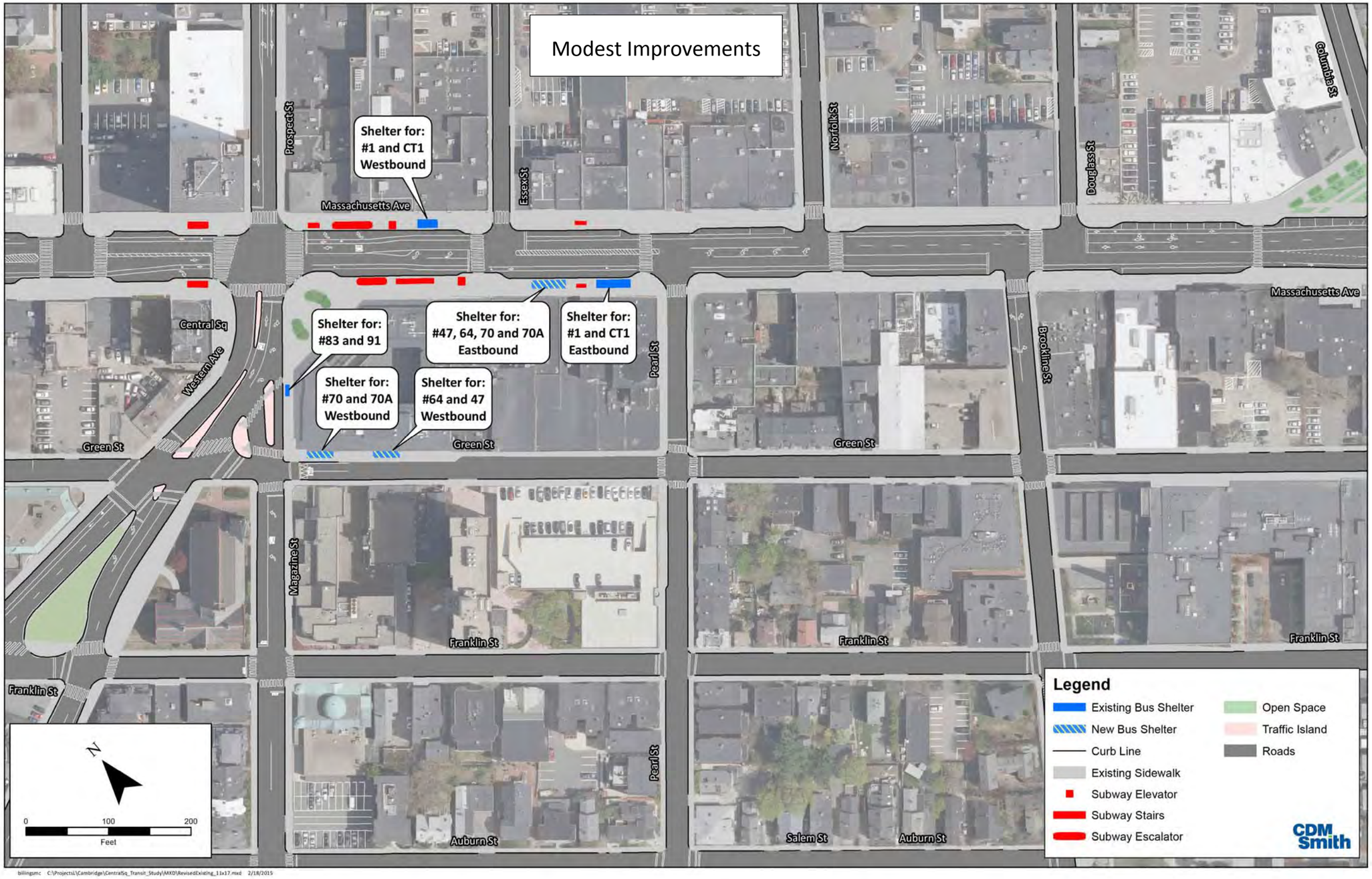
- Route CT1: The current routing for Route CT1 Westbound (towards Central Square) involves buses turning left from Mass Ave onto Pearl St before turning right onto Green St. Instead of this, the bus routing will change to continue down Mass Ave, turn left onto Pleasant St, left onto Franklin St, and left onto Magazine St (see Figure 5)
- Route 64: The current routing for Route 64 differs between peak and off-peak periods. This will be changed to have a common routing regardless of the time period (see Figure 7).

The "Modest Improvements' Plan does not involve any routing changes for Route 47 (Figure 6), Route 70/70A (Figure 8), and Route 83/91 (Figure 9).

The ‘Modest Improvements’ Plan involves changing the layover locations for the following routes:

- Route CT1: The layover for Route CT1 is suggested to be moved to Magazine St between Franklin St and Green St.
- Route 47: The layover for Route 47 is suggested to be moved to Mass Ave at the loading zone between Magazine St and Essex St.
- Route 64: The layover for Route 64 is suggested to be moved to the Kendall Sq station vicinity during the peak and off-peak periods.
- Route 83/91: The layovers for Routes 83 and 91 are suggested to be moved to Magazine St between Franklin St and Green St.

Figure 4: Modest Improvements Plan - Bus Stop Changes



Modest Improvements: Bus Routes

Figure 5: Route CT1

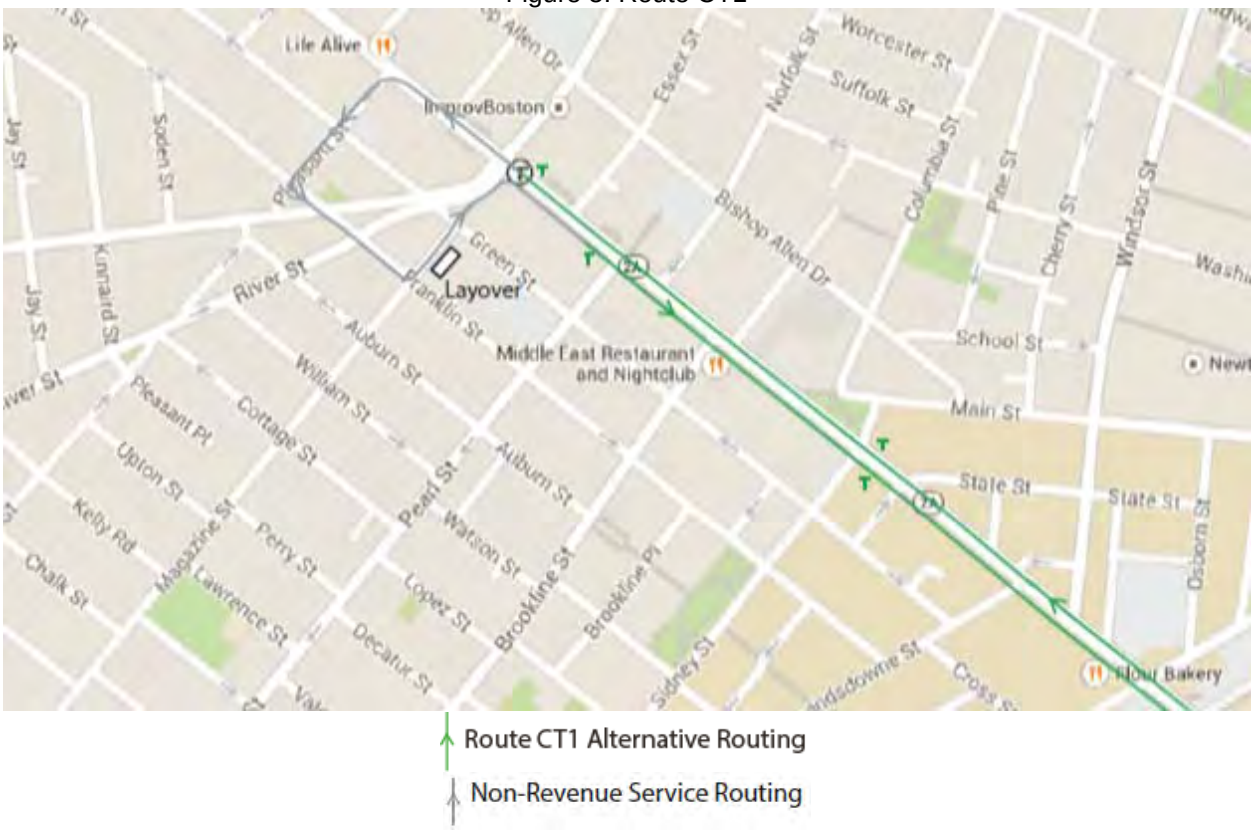


Figure 6: Route 47

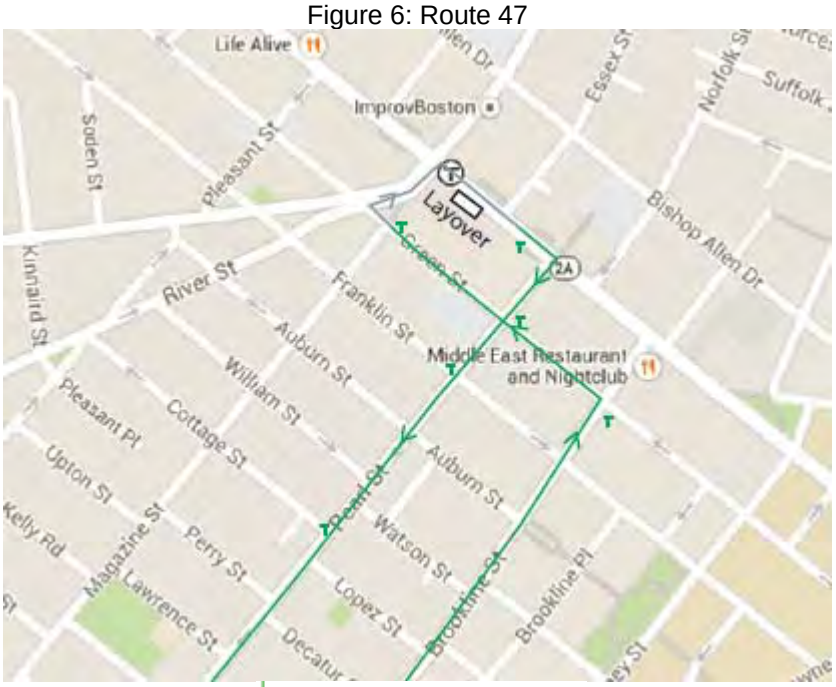


Figure 7: Route 64

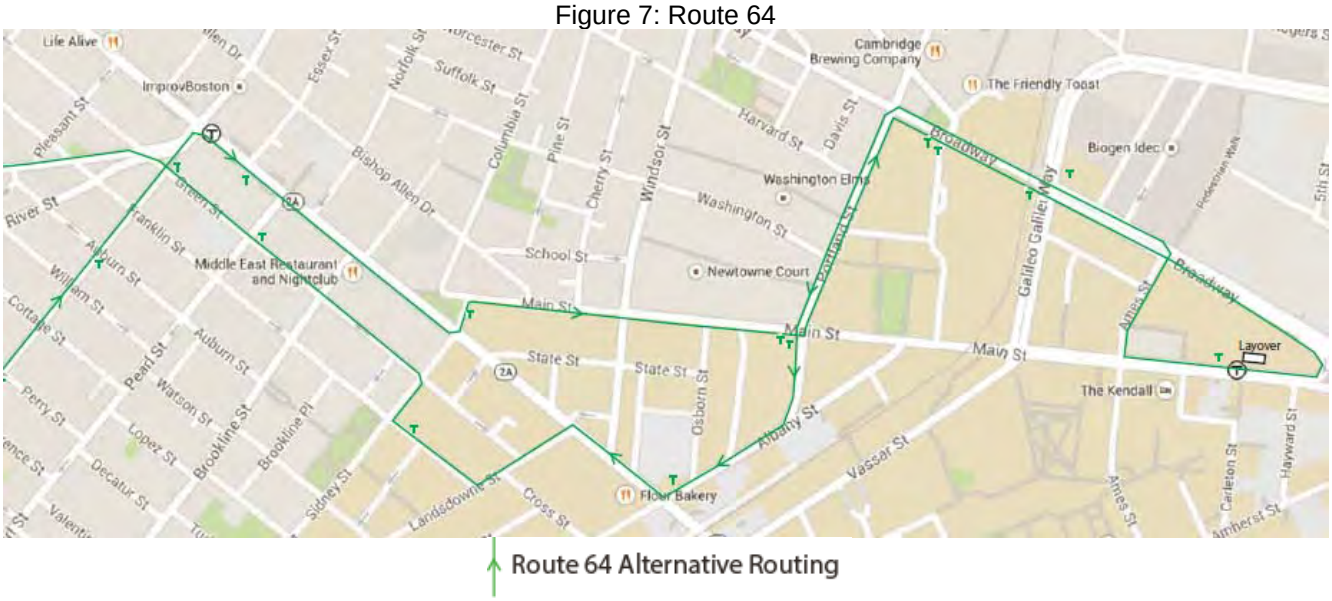


Figure 8: Route 70/70A

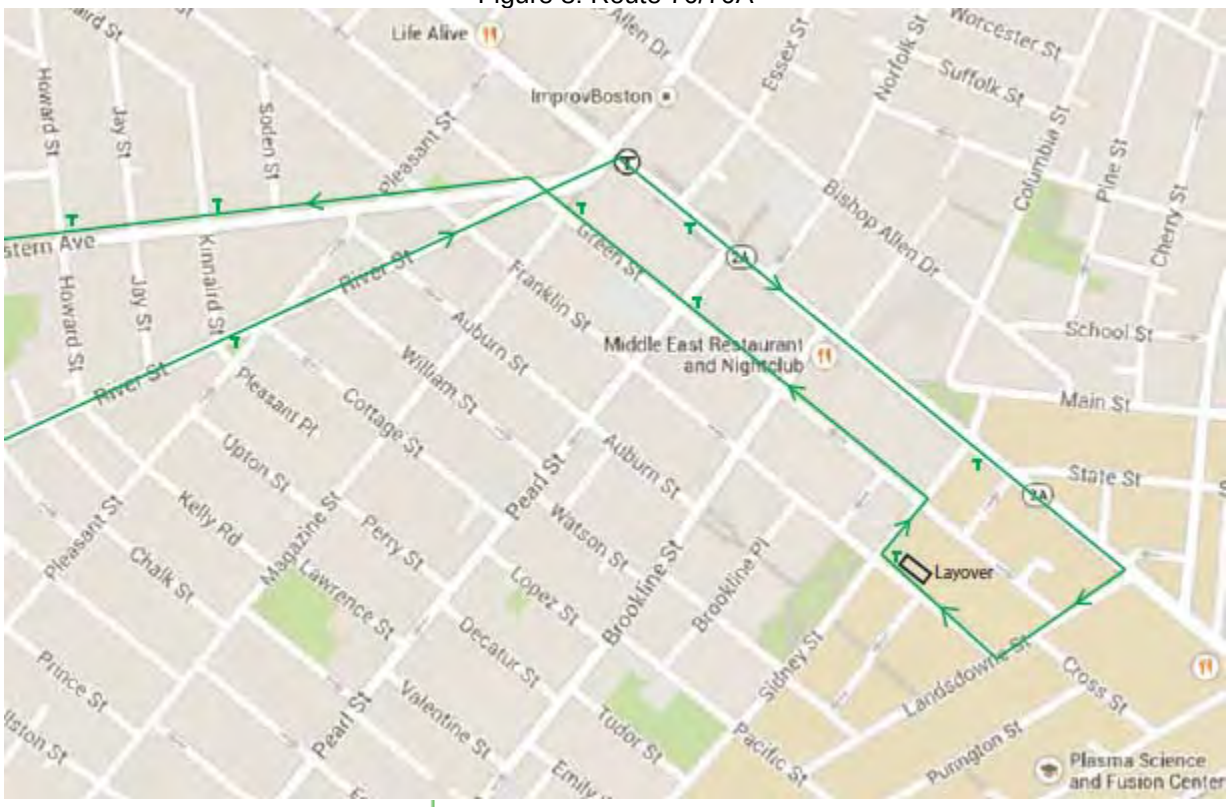
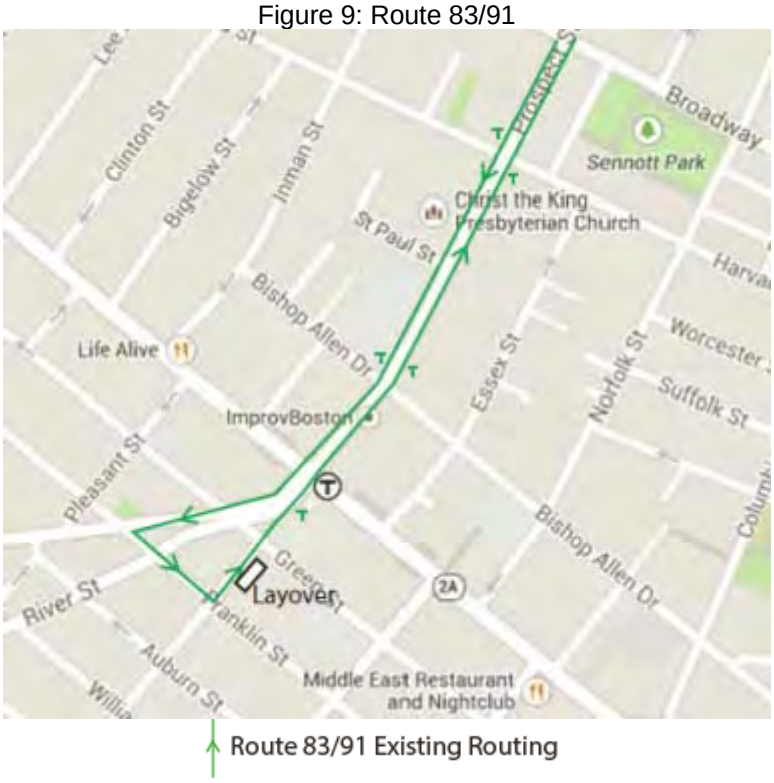


Figure 9: Route 83/91



4.3.2 'Massachusetts Avenue Stop Relocation' plan

The 'Massachusetts Avenue Stop Relocation' plan is more focused on reducing the time for passengers transferring to/from the Red Line by relocating many of the bus stops to Massachusetts Avenue. This involves a number of stop changes, routing changes, and layover location changes. The plan include locating stops for the majority of routes traversing through Central Square closer to the Central Square subway station entrances and also closer to each other. Passengers will be able to transfer faster, more easily and conveniently between transit modes. Some elements of the 'Modest Improvements' plan described in Section 4.3.1 have also been included in this plan, such as adding bus shelters and spreading stop locations among multiple bus stops.

The 'Massachusetts Avenue Stop Relocation' Plan involves the following stop changes in the Study Area, as shown in Figure 10:

- Route 1
    - Eastbound direction: The location of the Mass Ave at Pearl bus stop for this route would not be changed.
    - Westbound direction: Relocation of Mass Ave at Prospect St stop from a nearside stop at Mass Ave at Prospect St to a farside stop, closer to Temple St. This might require the relocation/removal of 1-2 parking spots or removal of a bulb-out in the sidewalk.
- Route CT1
    - Eastbound direction: The location of the Mass Ave at Pearl St stop for this route would not be changed (collocated with Route 1 Eastbound bus stop).
    - Westbound direction: Relocation of the last stop at Magazine St at Green St Berth 2 to a nearside stop at Mass Ave and Essex St.

- Route 47
    - Eastbound direction: Relocation of the last stop at Green St at Magazine St to a Mass Ave at Prospect St nearside stop.
    - Westbound direction: The location of the first stop for this route at Mass Ave at Pearl St would be relocated a few feet upstream, closer to Mass Ave at Essex St.
- Route 64
    - Eastbound direction: Location of stop at Mass Ave at Essex St (collocated with Route 70/70A Eastbound stop) for both peak and off-peak periods.
    - Westbound direction: Location of stop at Mass Ave at Essex St nearside.
- Route 70/70A
    - Eastbound direction: Relocation of Mass Ave at Pearl St bus stop a few feet upstream, closer to Mass Ave at Essex St (collocated with Route 47 Westbound bus stop and Route 64 Eastbound bus stop).
    - Westbound direction: Relocation of stop at Green St at Magazine St to Mass Ave at Prospect St nearside.
- Route 83/91: There are no recommended changes to the stops for these routes.

The ‘Massachusetts Avenue Stop Relocation’ Plan involves routing changes for the following routes:

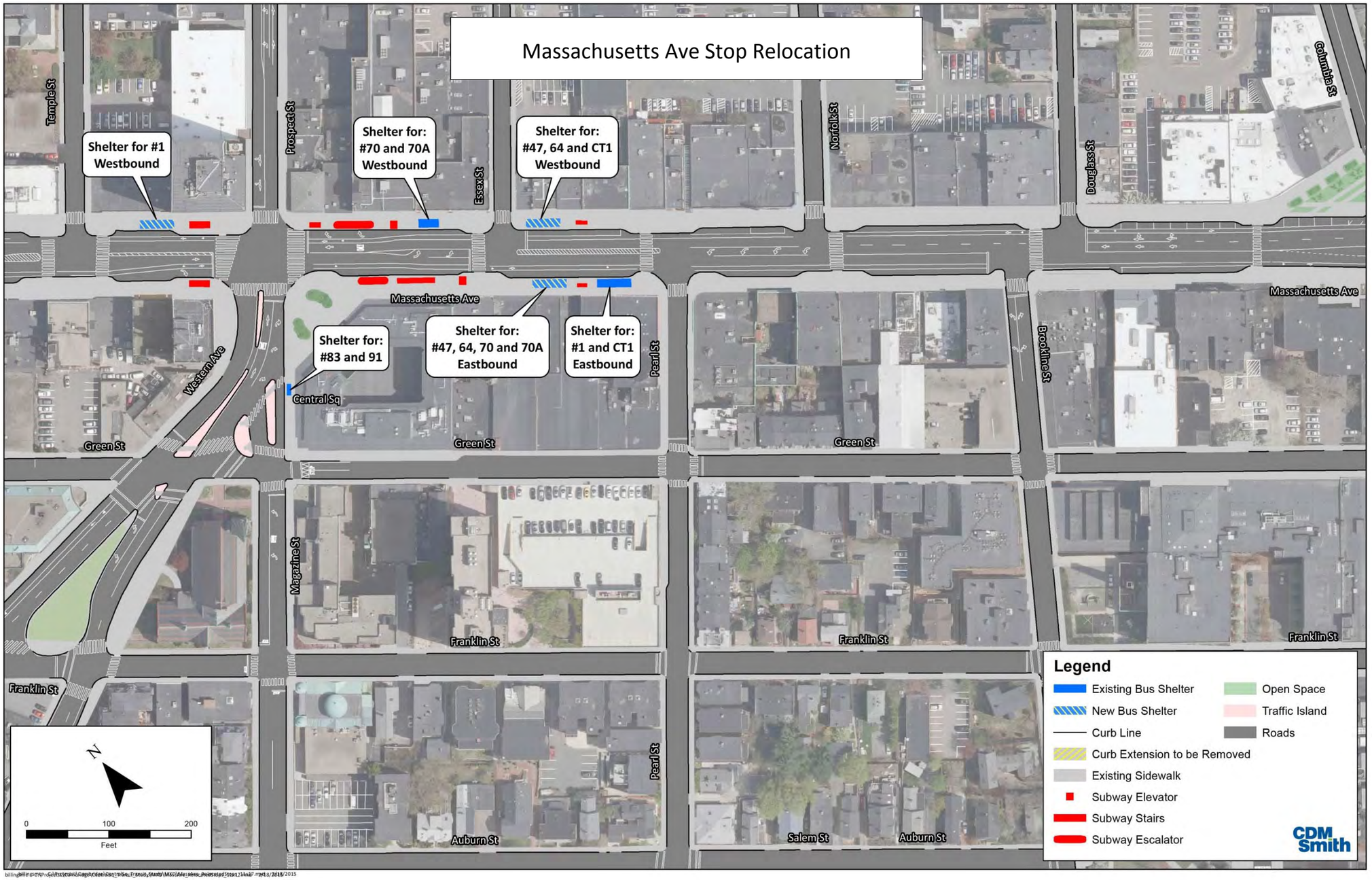
Route CT1: The current routing for Route CT1 Westbound (towards Central Square) involves buses turning left from Mass Ave onto Pearl St before turning right onto Green St. Instead of this, the bus routing will change as per **Massachusetts Avenue Stop Relocation: Bus Routes**

- Figure 11.
- Route 47: The current routing for Route 47 involves buses heading in the Eastbound direction traveling along Brookline St before turning left onto Green St. This will be changed to require buses to turn left onto Mass Ave and drop passengers off directly near the Central Square T station, as per Figure 12.
- Route 64: The current routing for Route 64 differs between peak and off-peak periods. It is recommended that there be a common routing regardless of the time period as per Figure 13.
- Route 70/70A: The current routing for Route 70/70A involves buses traveling in the Westbound direction traveling along Green St before turning left onto Western Ave. It is recommended to require buses to pick-up passengers from Mass Ave before turning onto Western Ave via Pleasant St, as per Figure 14.
- Route 83/91: There are not anticipated to be any changes to the routing for these routes (Figure 15).

The ‘Massachusetts Avenue Stop Relocation’ Plan involves changing the layover locations for the following routes:

- Route CT1: The layover for Route CT1 is suggested to be moved to Franklin St between River St and Magazine St.
- Route 47: The layover for Route 47 is suggested to be moved to Franklin St between River St and Magazine St.
- Route 64: The layover for Route 64 is suggested to be moved to the Kendall Sq station vicinity during the peak and off-peak periods.
- Route 83/91: The layovers for Routes 83 and 91 are suggested to be moved to Magazine St between Franklin St and Green St.

Figure 10: Massachusetts Avenue Stop Relocation Plan - Bus Stop Changes



Massachusetts Avenue Stop Relocation: Bus Routes

Figure 11: Route CT1

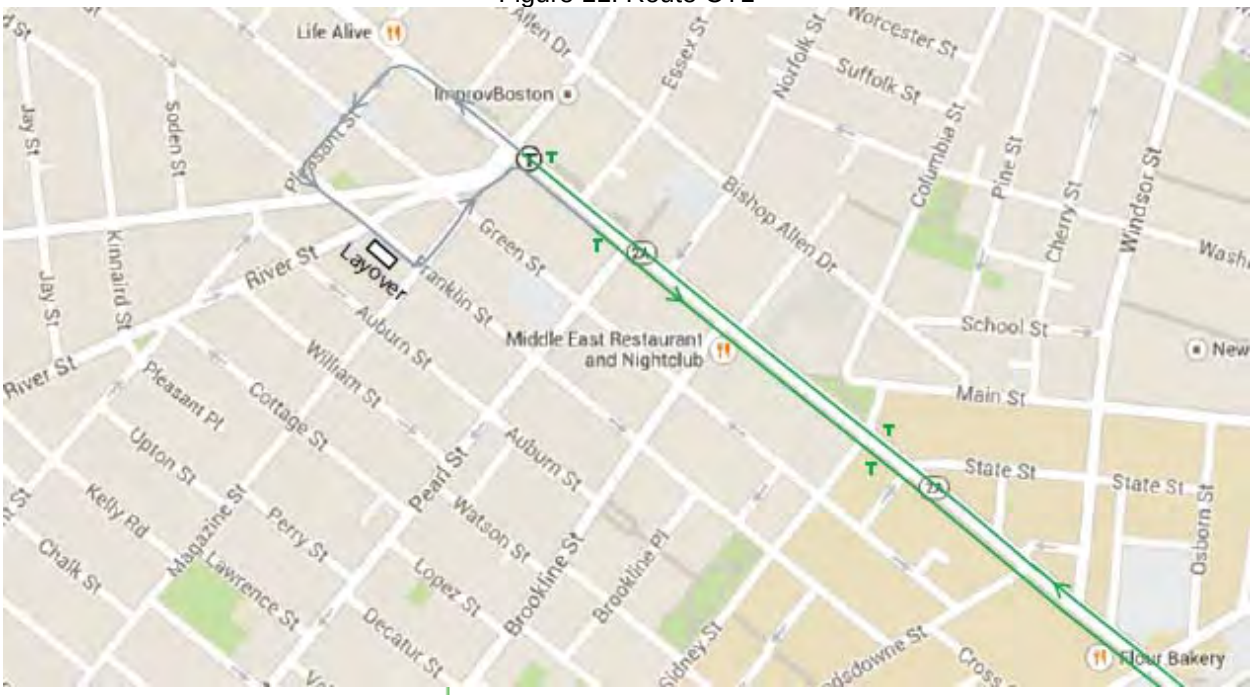


Figure 12: Route 47

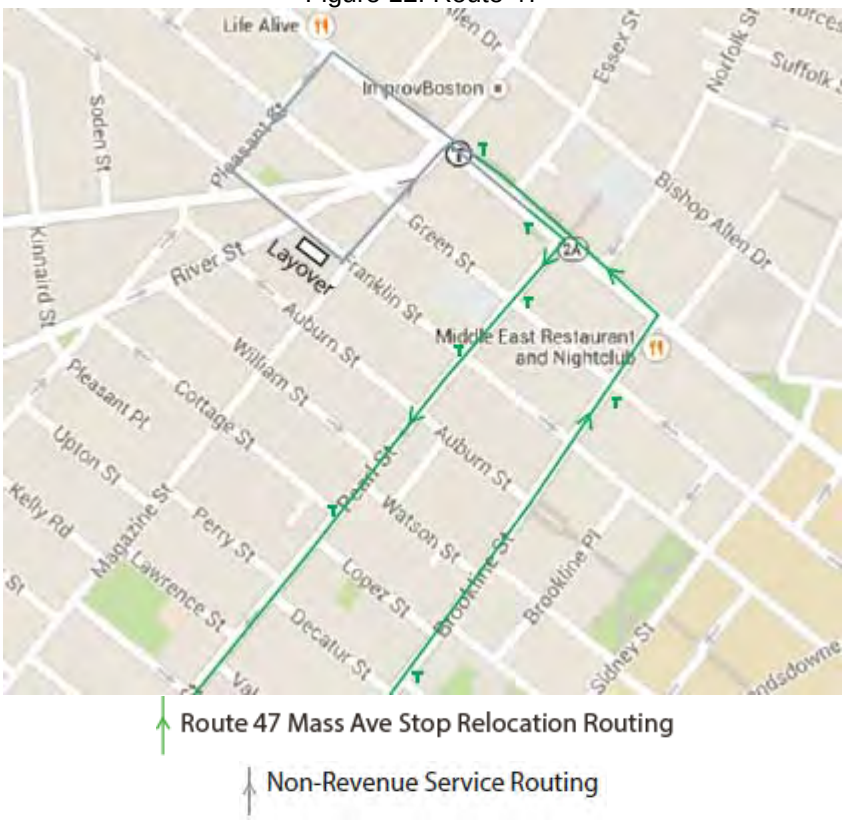


Figure 13: Route 64

Figure 14: Route 70/70A

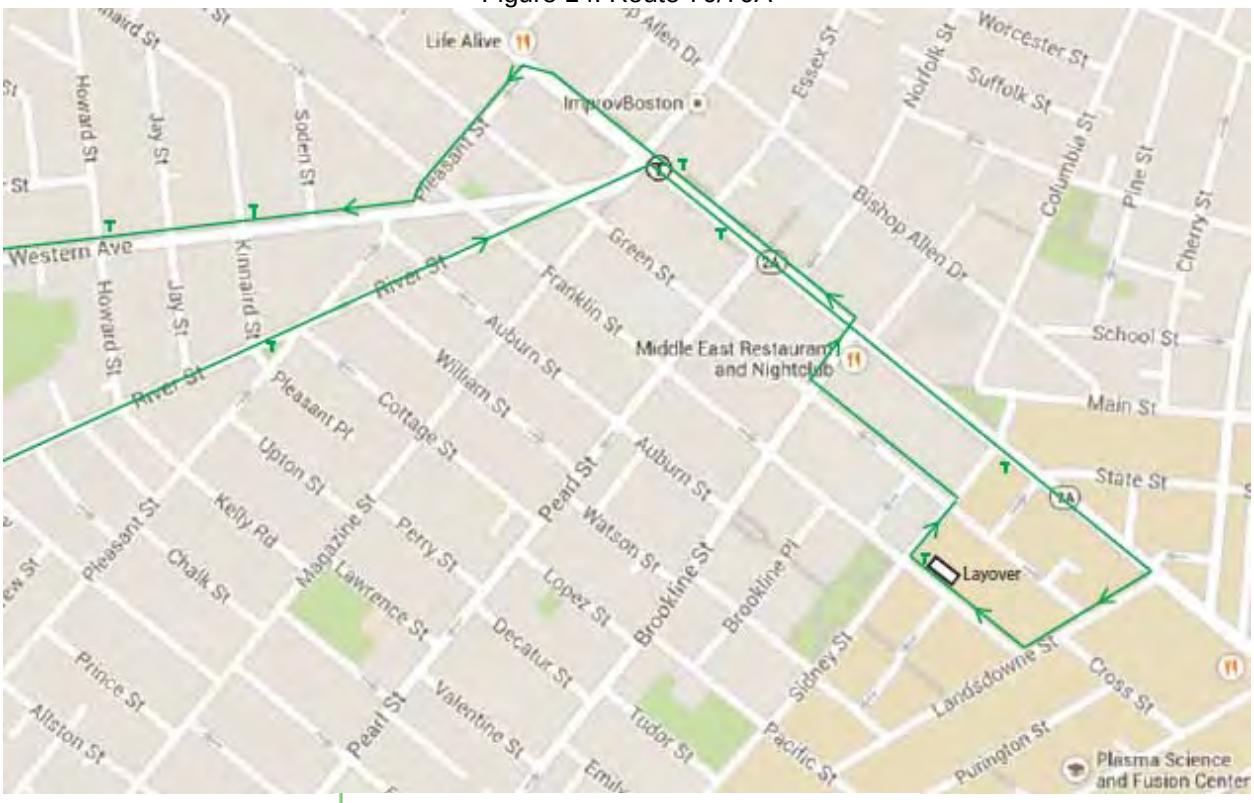
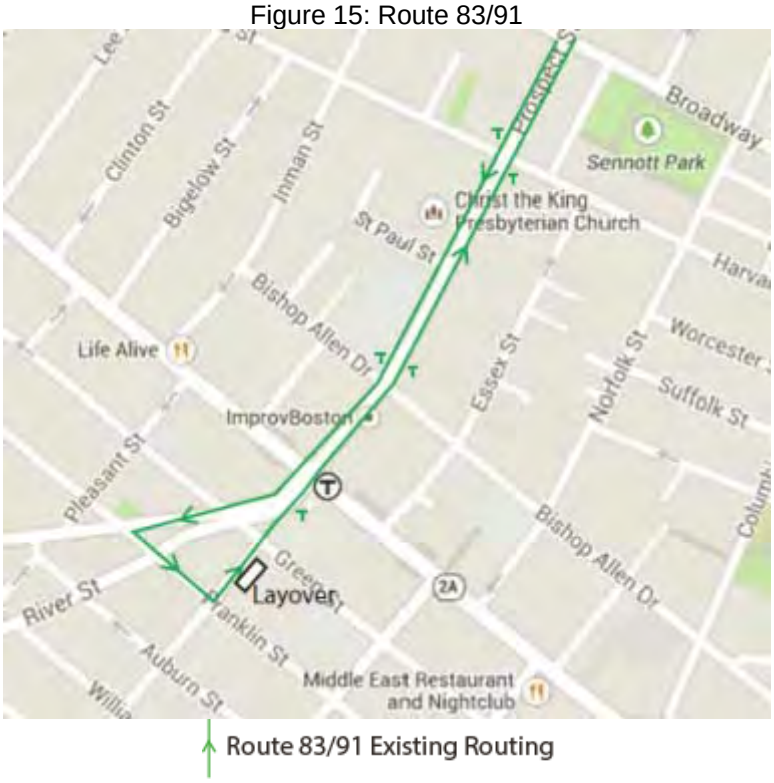


Figure 15: Route 83/91



4.3.3 Future Considerations

The 'Modest Improvements' and 'Massachusetts Avenue Bus Stop Relocation' plans both articulate a possible future configuration for bus operations in and around Central Square which remedy issues of the existing situation at bus stops. The 'Massachusetts Avenue Bus Stop Relocation' plan goes further towards bringing bus passengers closer to the Red Line, but would require some changes in how curb space is used on Massachusetts Avenue. Neither plan is likely to substantially reduce bus delays, because both conform to the overall balance of street space use among the various modes of travel and uses such as parking and loading.

Neither plan precludes a further development which might have the objective of improving transit operating speed by making an alternative allocation of road space, especially on Massachusetts Avenue. For example, the idea of creating exclusive bus lanes on Massachusetts Avenue was raised. This would require further study and street design work considering users of the street.

Appendix A: Referenced Documents

The following documents were referenced as part of this report:

- MBTA Systemwide Passenger Survey: Rapid Transit 2008–2009 - Red Line, 2010*, prepared for* MBTA Planning and Development*, by* Central Transportation Planning Staff
- MBTA Systemwide Passenger Survey: Bus System 2008–2009 - Albany Garage, 2010*, prepared for* MBTA Planning and Development*, by* Central Transportation Planning Staff
- MBTA Systemwide Passenger Survey: Bus System 2008–2009 - Cabot Garage, 2010*, prepared for* MBTA Planning and Development*, by* Central Transportation Planning Staff
- MBTA Systemwide Passenger Survey: Bus System 2008–2009 – Charlestown and Fellsway Garages, 2010*, prepared for* MBTA Planning and Development*, by* Central Transportation Planning Staff
- MBTA Systemwide Passenger Survey: Bus System 2008–2009 - Somerville Garage, 2010*, prepared for* MBTA Planning and Development*, by* Central Transportation Planning Staff
- Kendall Square Central Square (K2C2) Planning Study, 2013, prepared for Cambridge Community Development Department, by Goody Clancy, Nelson Nygaard, Carol R. Johnson Associates, MJB Consulting, wZHA.

Appendix B: Vehicle Curb Utilization Analysis

The following table presents the vehicle curb utilization (in minutes during every hour) by each bus stop or layover location during both the AM and PM peak periods. These values were derived from bus operations data from the MBTA's APC system. The table presents, for each location during an average period of 60 minutes, the following:

- the total layover time (sum for all routes that layover at that location),
- the total dwell time (sum for all routes that dwell at that location),
- the total curb utilization (sum of layover and dwell times), and
- the associated note in case the curb utilization is high, near, or over capacity.

The curb utilization represents the minutes that a bus spends occupying a curb space during an hour in that peak period. For example, if the curb utilization is 60 minutes, one bus length of curb space is occupied for 60 minutes. If only one bus length of curb space is available at that location, then a curb utilization of more than 60 minutes would indicate that curb utilization is over capacity and that sometimes buses stop outside the designated berth or have to wait for a berth.

Bus Stop/Layover Location	Layover Time (minutes per hour)		Dwell Time (minutes per hour)		Curb Utilization (minutes per hour)		Note
	AM Peak	PM Peak	AM Peak	PM Peak	AM Peak	PM Peak	
Green St & Magazine St	41.3	57.6	7.3	6.0	**48.5**	**63.6**	Over capacity PM
Franklin St & Sidney St	94.9	124.8	0.0	0.0	**94.9**	**124.8**	Within capacity due to availability of multiple berths
Magazine & Green Berth 1	56.4	73.6	0.8	0.9	**57.2**	**74.5**	Over capacity PM
Magazine & Green Berth 2	34.4	44.8	0.0	0.0	**34.4**	**44.8**	
Mass Ave & Bigelow St	0.0	0.0	1.1	2.7	**1.1**	**2.7**	
Mass Ave & Pearl St	0.0	0.0	30.7	25.4	**30.7**	**25.4**	High utilization due to de facto Route 47 layover
Mass Ave & Pleasant St	0.0	0.0	1.6	3.3	**1.6**	**3.3**	
Mass Ave & Prospect St	0.0	0.0	2.2	5.3	**2.2**	**5.3**	
Mass Ave & Sidney	0.0	0.0	1.4	2.2	**1.4**	**2.2**	
Mass Ave & Sidney IN	0.0	0.0	2.4	4.5	**2.4**	**4.5**	
Mass Ave & Sidney OUT	0.0	0.0	1.9	3.8	**1.9**	**3.8**	
Prospect St & Bishop Allen Dr IN	0.0	0.0	1.4	1.5	**1.4**	**1.5**	
Prospect St & Bishop Allen Dr OUT	0.0	0.0	1.3	1.8	**1.3**	**1.8**	
Prospect St & Bishop IN	0.0	0.0	0.8	1.3	**0.8**	**1.3**	
Prospect St & Bishop OUT	0.0	0.0	0.7	0.9	**0.7**	**0.9**	

Appendix C: Bus Stop Space Consumption Analysis

A bus stop space consumption analysis was conducted for the major stops in the Study Area. For each stop location, the total number of median boardings was calculated using APC data. This includes the median number of boardings from each route that serves the stop. Thereafter, based on an ideal design area of 10 square feet per boarding person, the total design space required for serving passengers was calculated and compared against the actual bus shelter area. The ideal area of 10 square feet per person is the lower bound of Level of Service 'C' for passenger waiting areas according to the *Transit Capacity and Quality of Service Manual.*

The following table presents the shelter area by bus stop location.

Stop	Shelter Dimensions		Shelter Area (square feet)
	Width (feet)	Depth (feet)	
Mass Ave & Pearl St	40	10	400
Mass Ave & Prospect St	25	10	250
Green St & Magazine St	30	6	180
Magazine St & Green St Berth 1	13.5	6	81
Magazine St & Green St Berth 2	24	8	192

For each stop, a bus stop space consumption analysis table is presented. Each table includes the following:

- the time period being considered (including the AM Peak, the PM Peak, and Maximum from any other time period of the day),
- the sum of all median boardings (calculated using APC data) from each route picking up passengers at that stop location,
- the total design area based on the median boardings and the assumed design space per alighting person,
- the approximate shelter area as calculated above, and
- the associated note in case the bus stop currently has inadequate space.

Mass Ave and Pearl St

Time Period	Total Median Boardings	Total Design Area (sq feet) Needed	Approx. Shelter Area (sq feet)	Note
AM Peak	53.0	530	400	Inadequate Space
PM Peak	23.5	235		
Max. Other Period	43.1	431		Inadequate Space

Mass Ave and Prospect St

Time Period	Total Median Boardings	Total Design Area (sq feet) Needed	Approx. Shelter Area (sq feet)	Note
AM Peak	2.4	24	250	
PM Peak	7.3	73		
Max. Other Period	6.5	65		

Green St at Magazine St

Time Period	Total Median Boardings	Total Design Area (sq feet) Needed	Approx. Shelter Area (sq feet)	Note
AM Peak	36.5	365	180	Inadequate Space
PM Peak	32.0	320		Inadequate Space
Max. Other Period	54.0	540		Inadequate Space

Magazine St at Green St Berth 1

Time Period	Total Median Boardings	Total Design Area (sq feet) Needed	Approx. Shelter Area (sq feet)	Note
AM Peak	21.0	210	81	Inadequate Space
PM Peak	39.0	390		Inadequate Space
Max. Other Period	34.0	340		Inadequate Space

Magazine St at Green St Berth 2

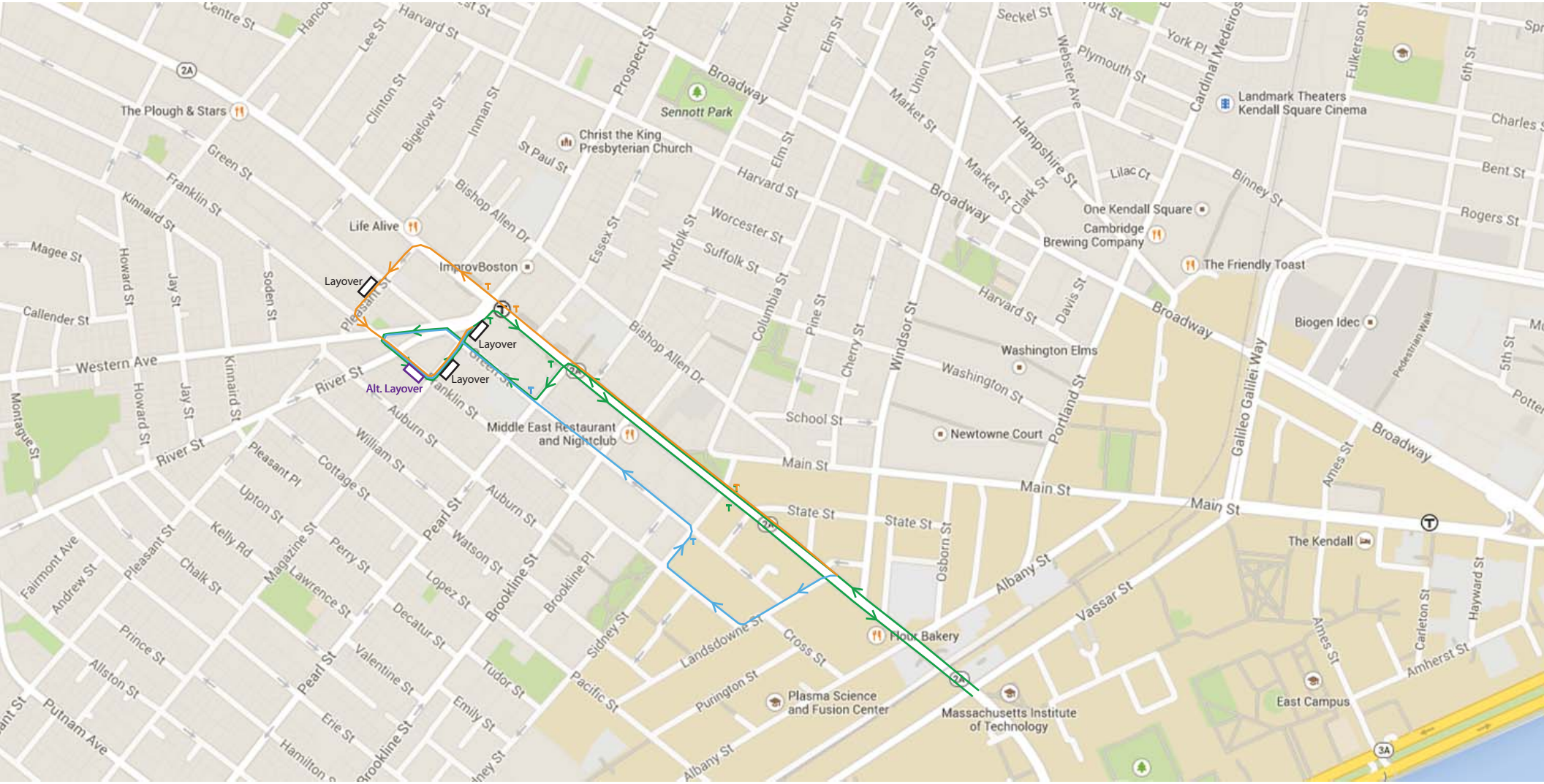
Time Period	Total Median Boardings	Total Design Area (sq feet) Needed	Approx. Shelter Area (sq feet)	Note
AM Peak	11.0	110	192	
PM Peak	1.0	10		
Max. Other Period	2.0	20		

Appendix D: Central Square Curb Use Map


Curb uses
Central Square
No Parking
No Stopping
Loading Zone 30-min
Loading Zone
Taxi Stand
Valet
MBTA Bus Stop
City Senior Shuttle
Disability
Hubway
Bike Stall
Metered Parking - 30 Min
Metered Parking - 1 Hr
Metered Parking - 2 Hr
Unmetered Parking
Unmetered Parking - 1 Hr
Permit Only Parking
New Bulb Out
Soden
Western
Pleasant
Magazine
River
Central
Franklin
Auburn
Brookline
Green
Sidney
Blanche
Pearl
Salem
Massachusetts
Douglass
Temple
Essex
Prospect
Inman
Doyle
Austin
Vail
Bishop Allen
St Paul
Ashburton
Norfolk
Washington
Fiske
Renz
Columbia
Pine
Eaton
Sidney St
Main
School

Appendix E: Potential Route Ideas

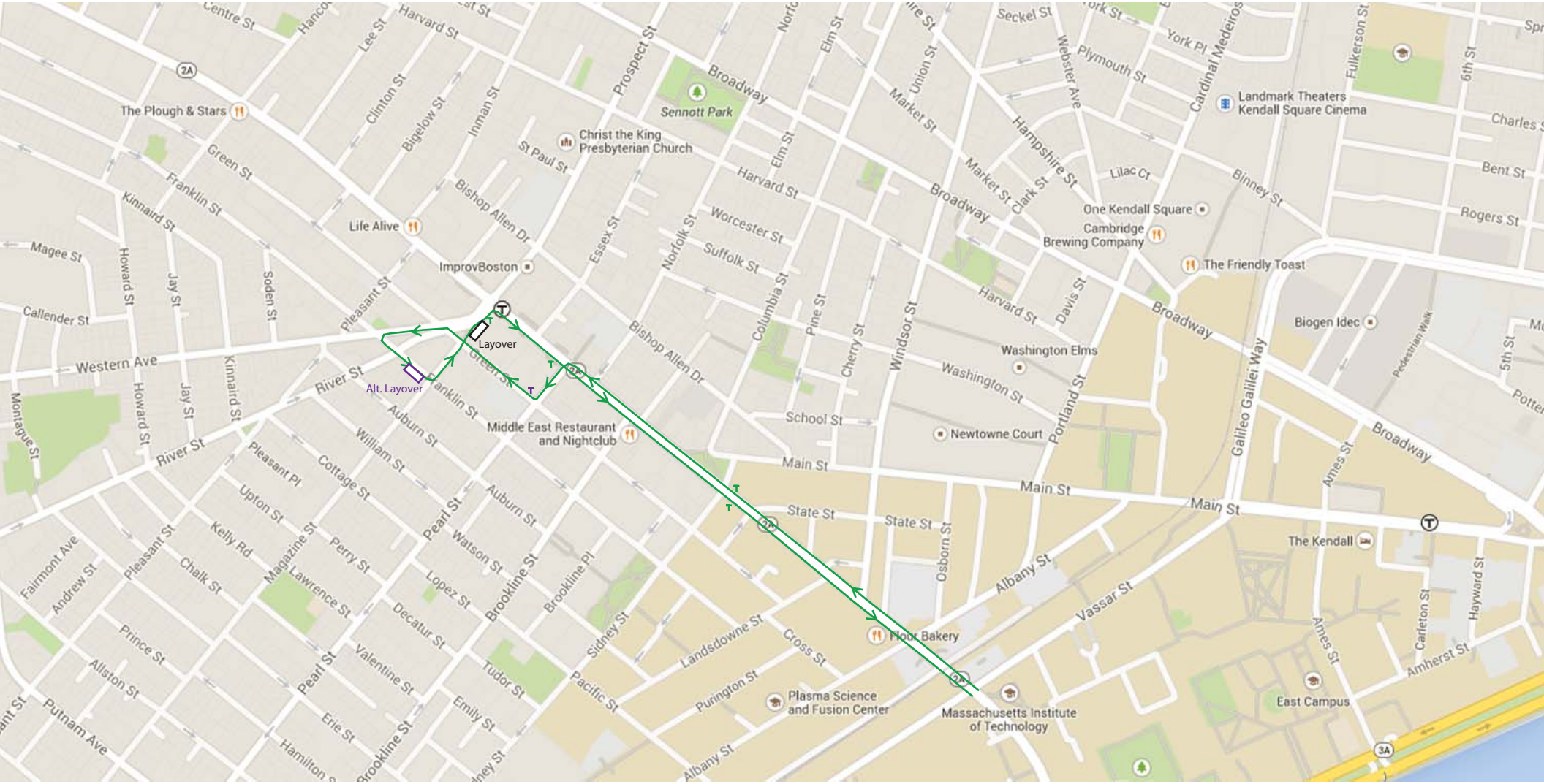
Route CT1
Existing and Alternatives



Existing Route Alternative Route 1 Alternative Route 2

Route CT1

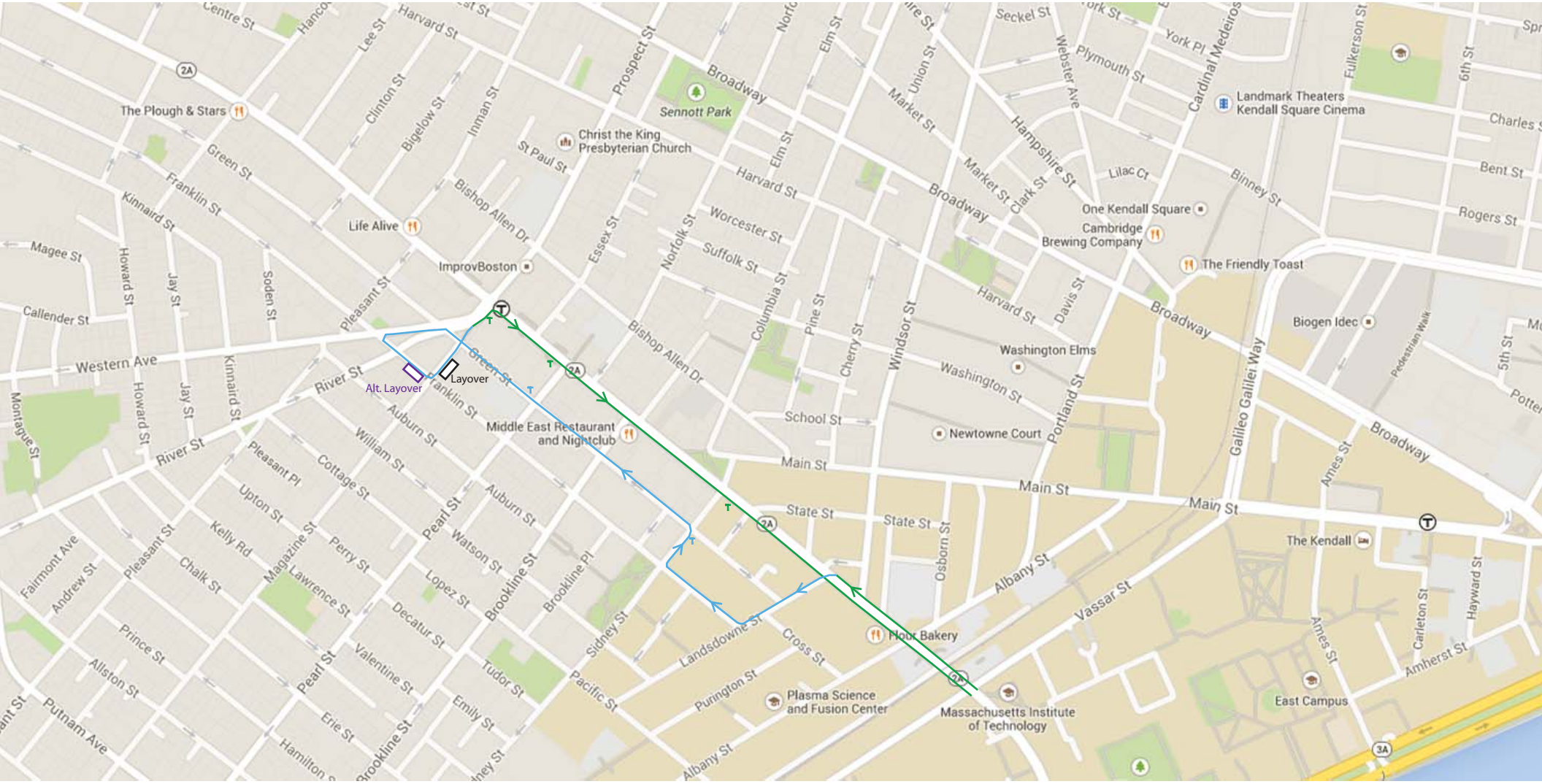
Existing



Existing Route Alternative Route 1 Alternative Route 2

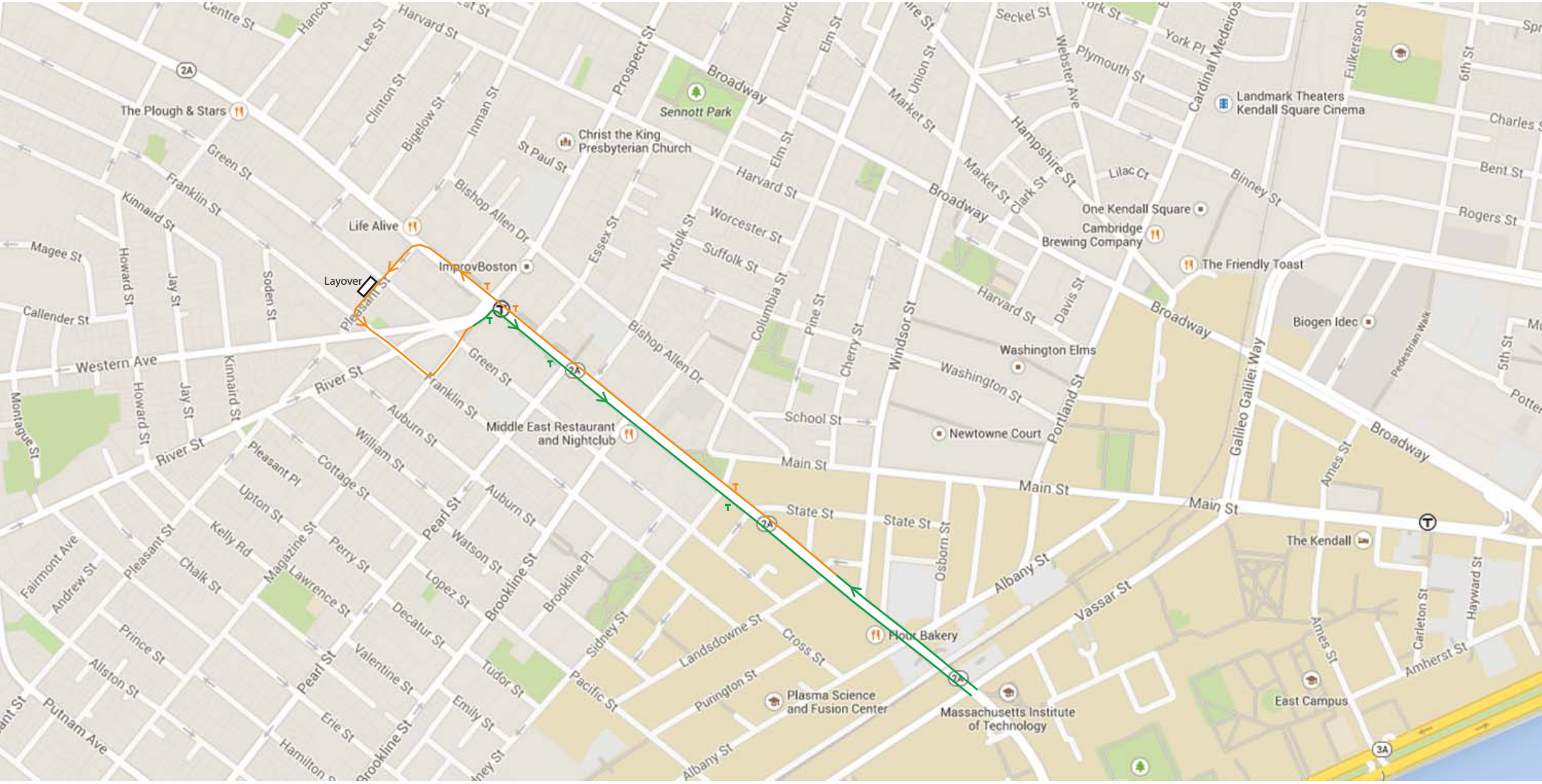
Route CT1

Alternative 1



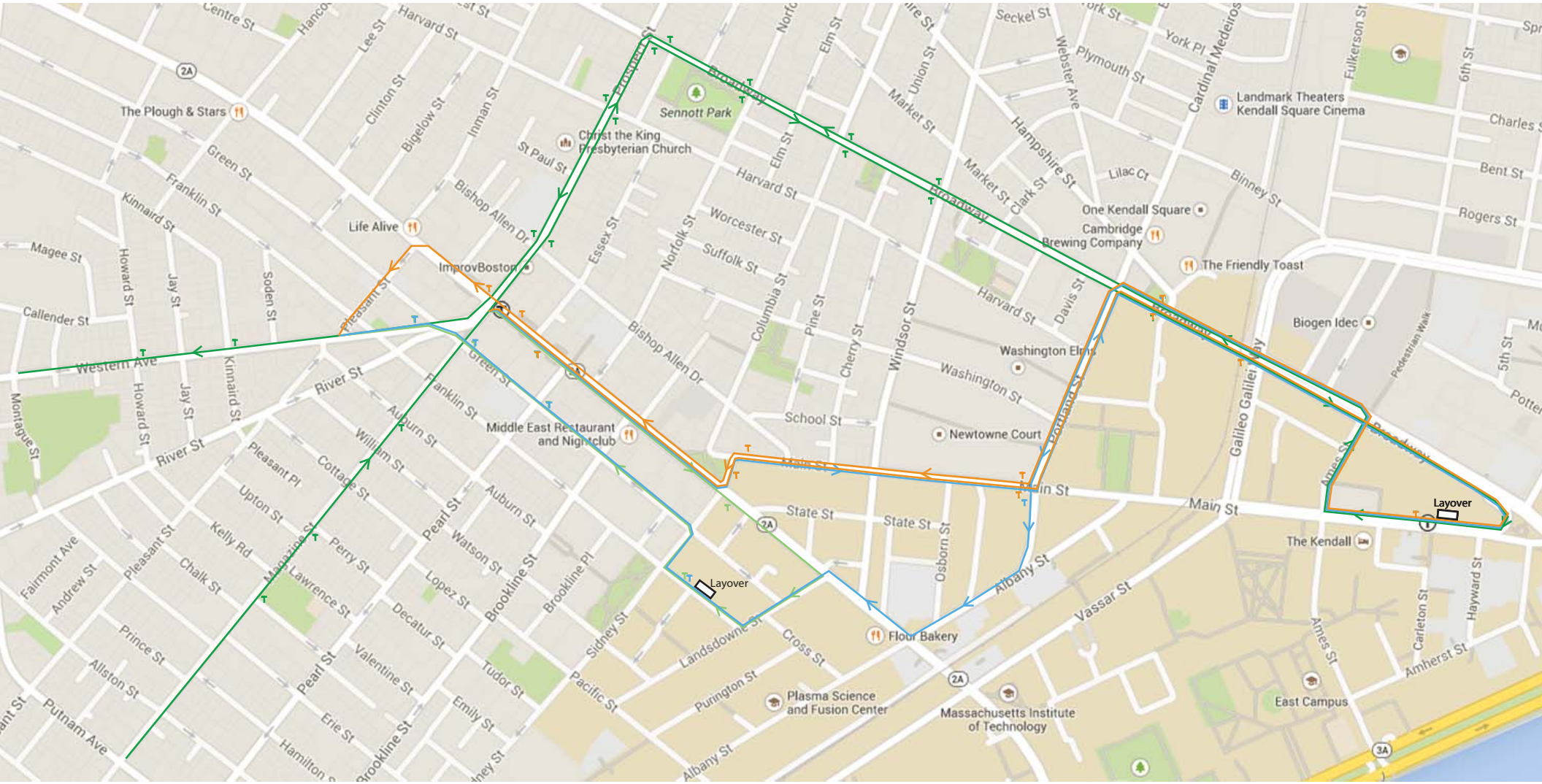
Route CT1

Alternative



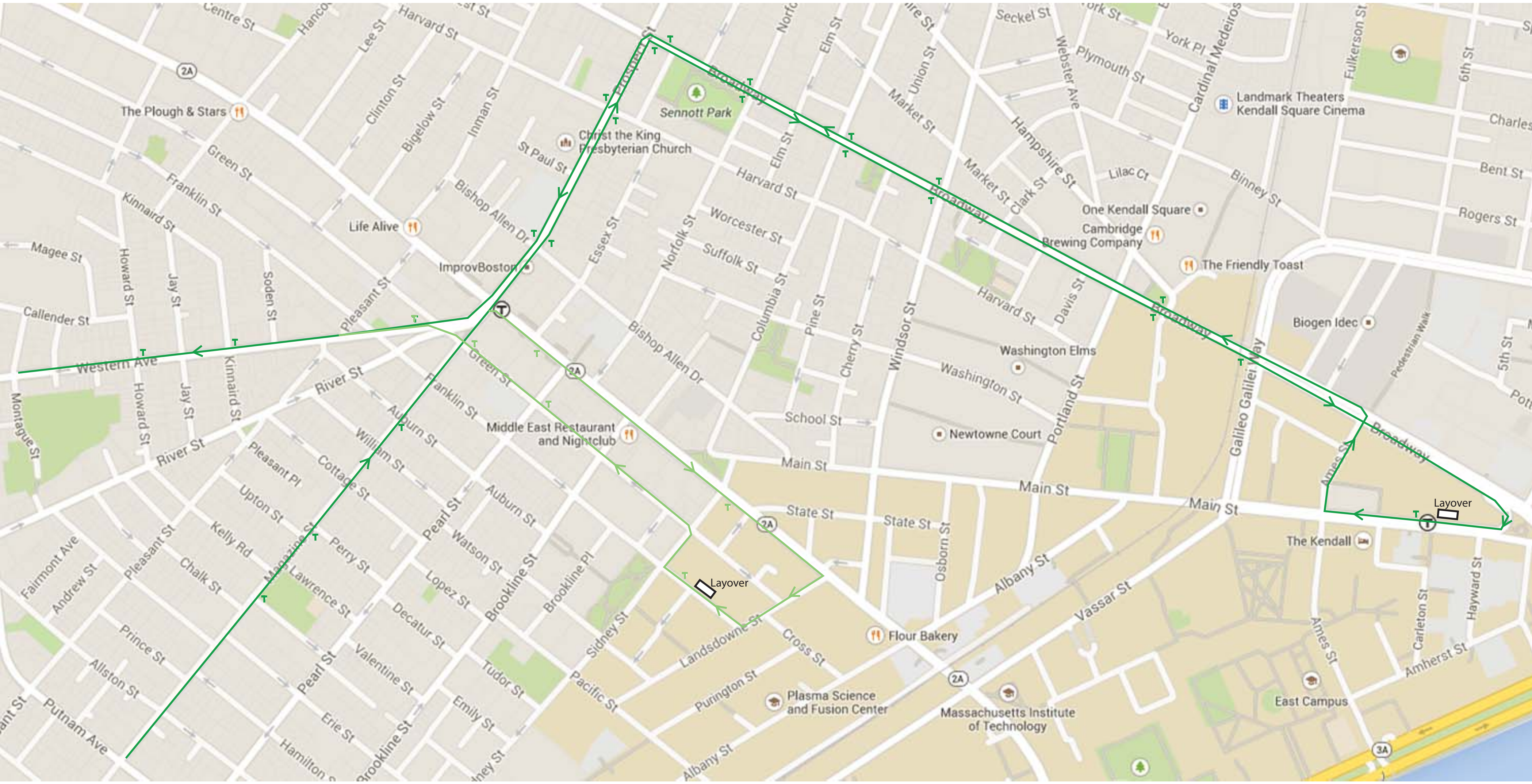
Route 64

Existing and Alternatives



Route 64

Existing



Existing Route - Peak

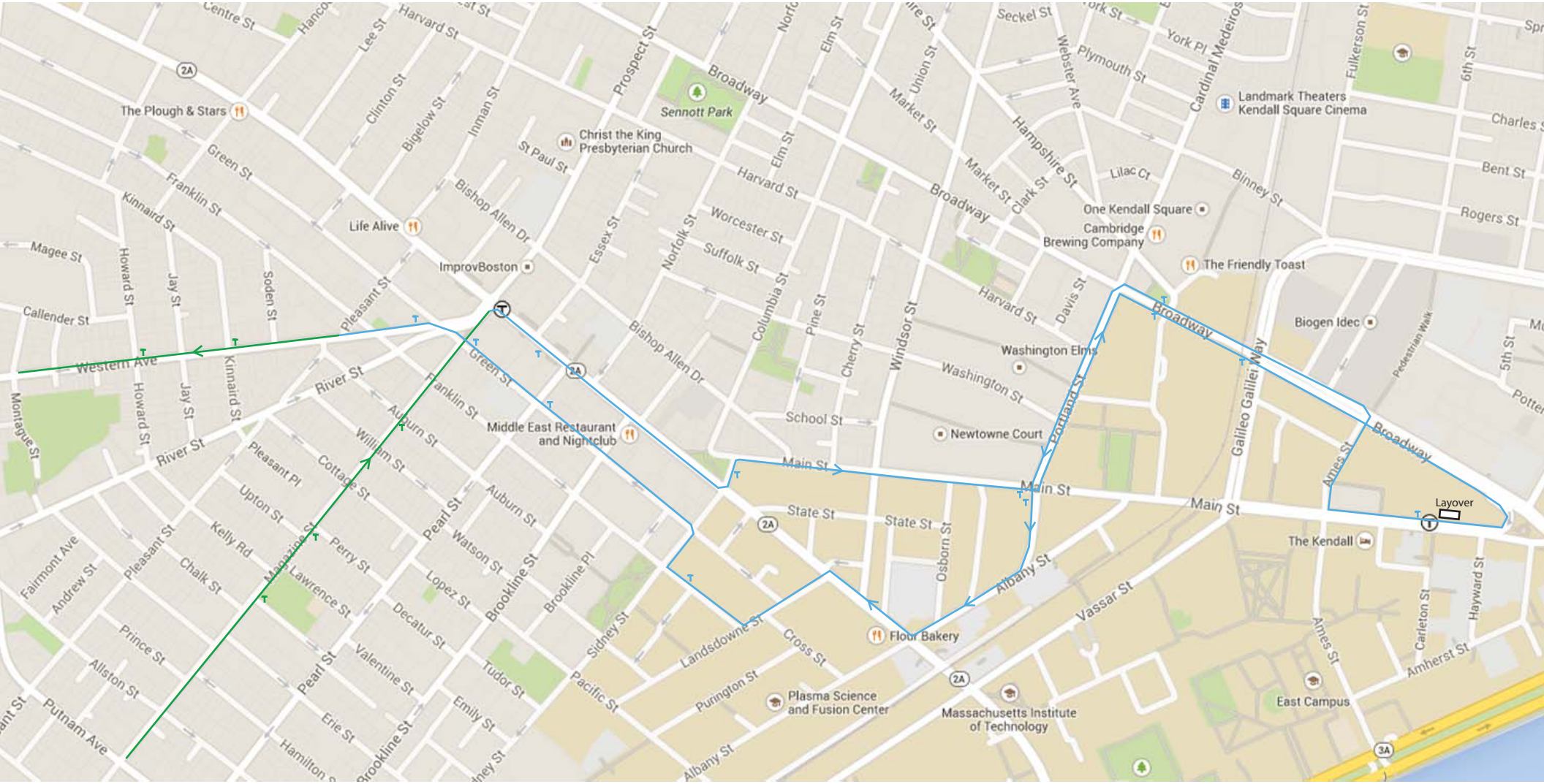
Alternative Route 1

Alternative Route 2

Existing Route - Off Peak

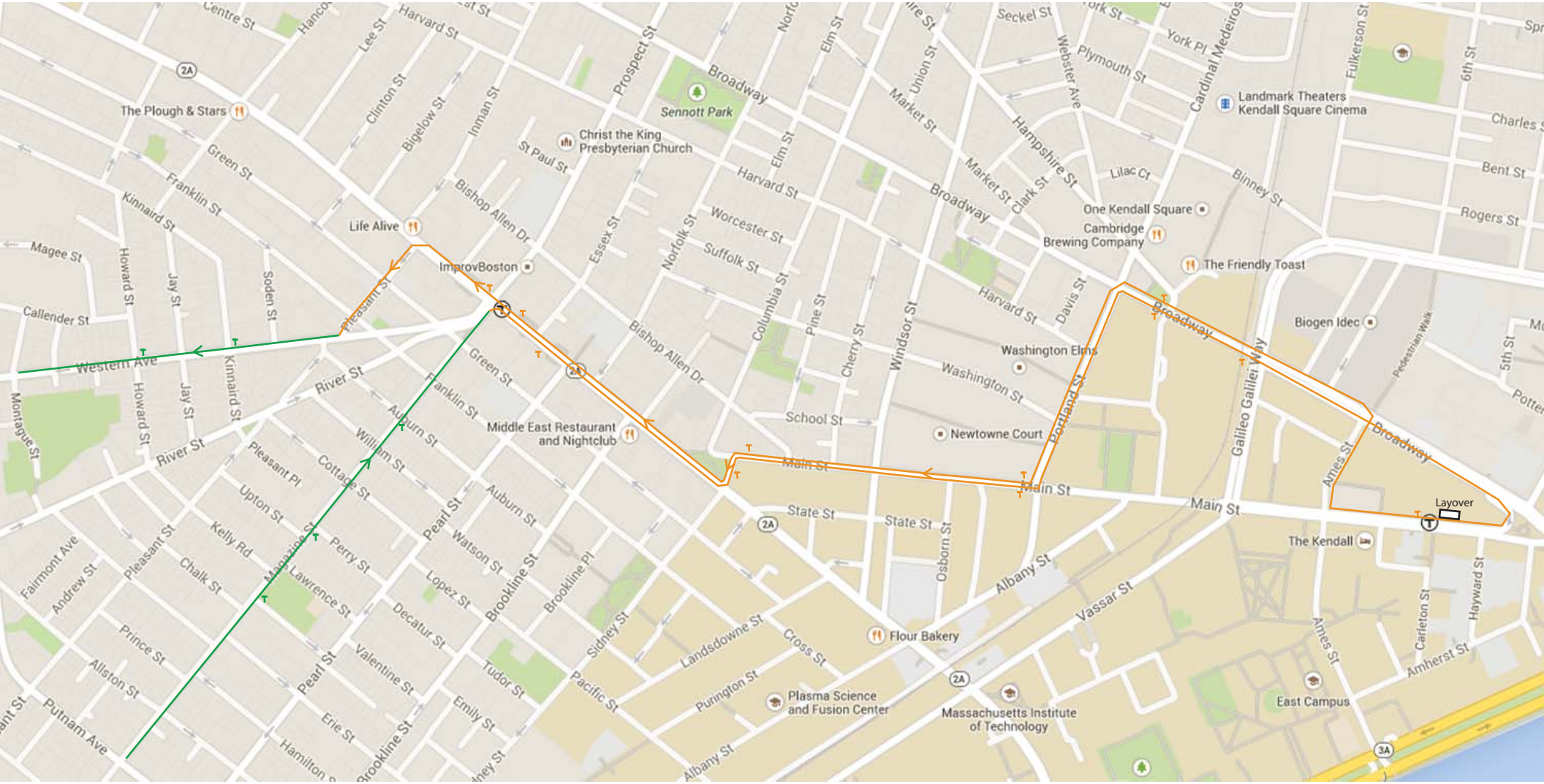
Route 64

Alternative 1



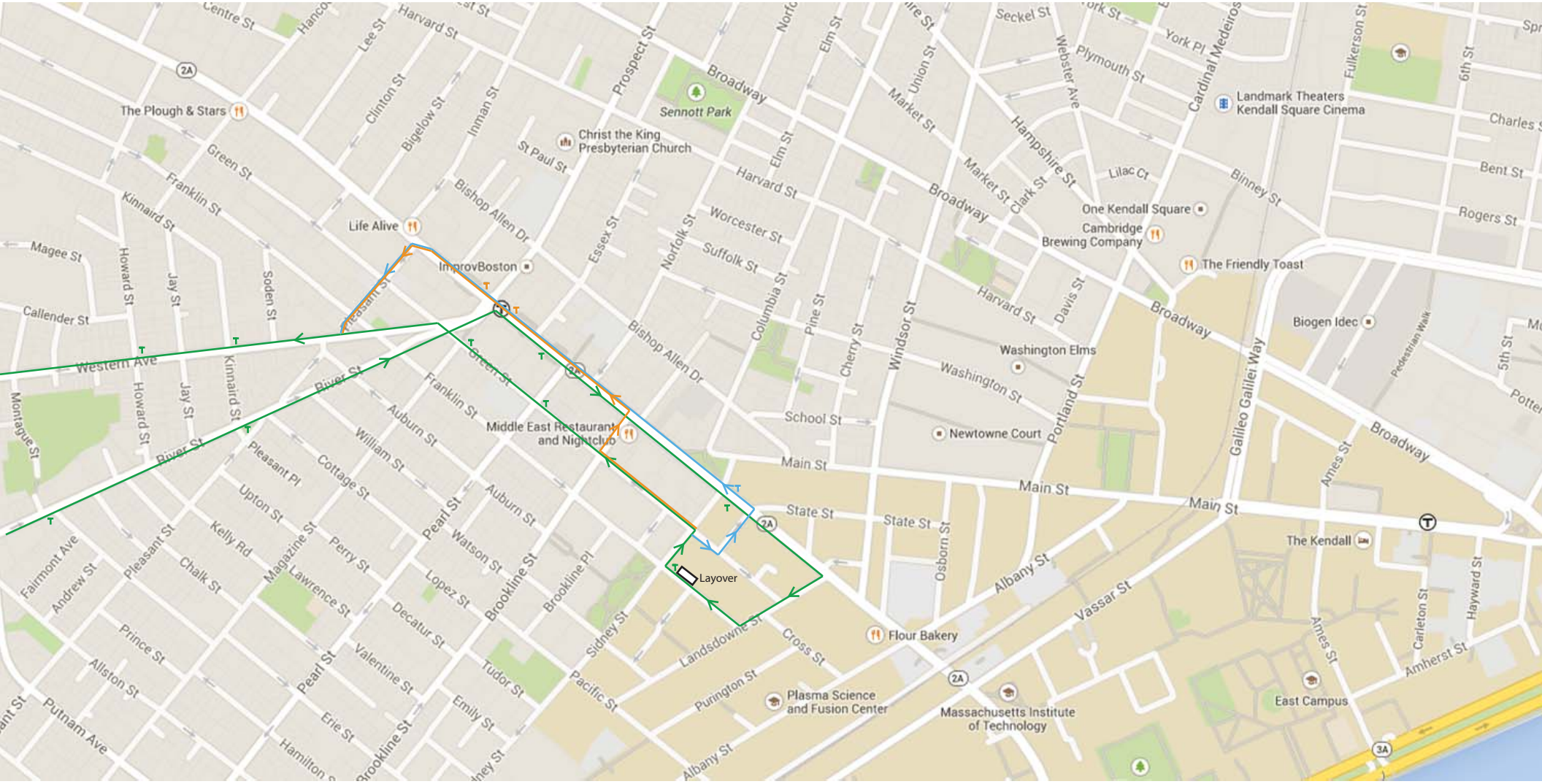
Route 64

Alternative 2



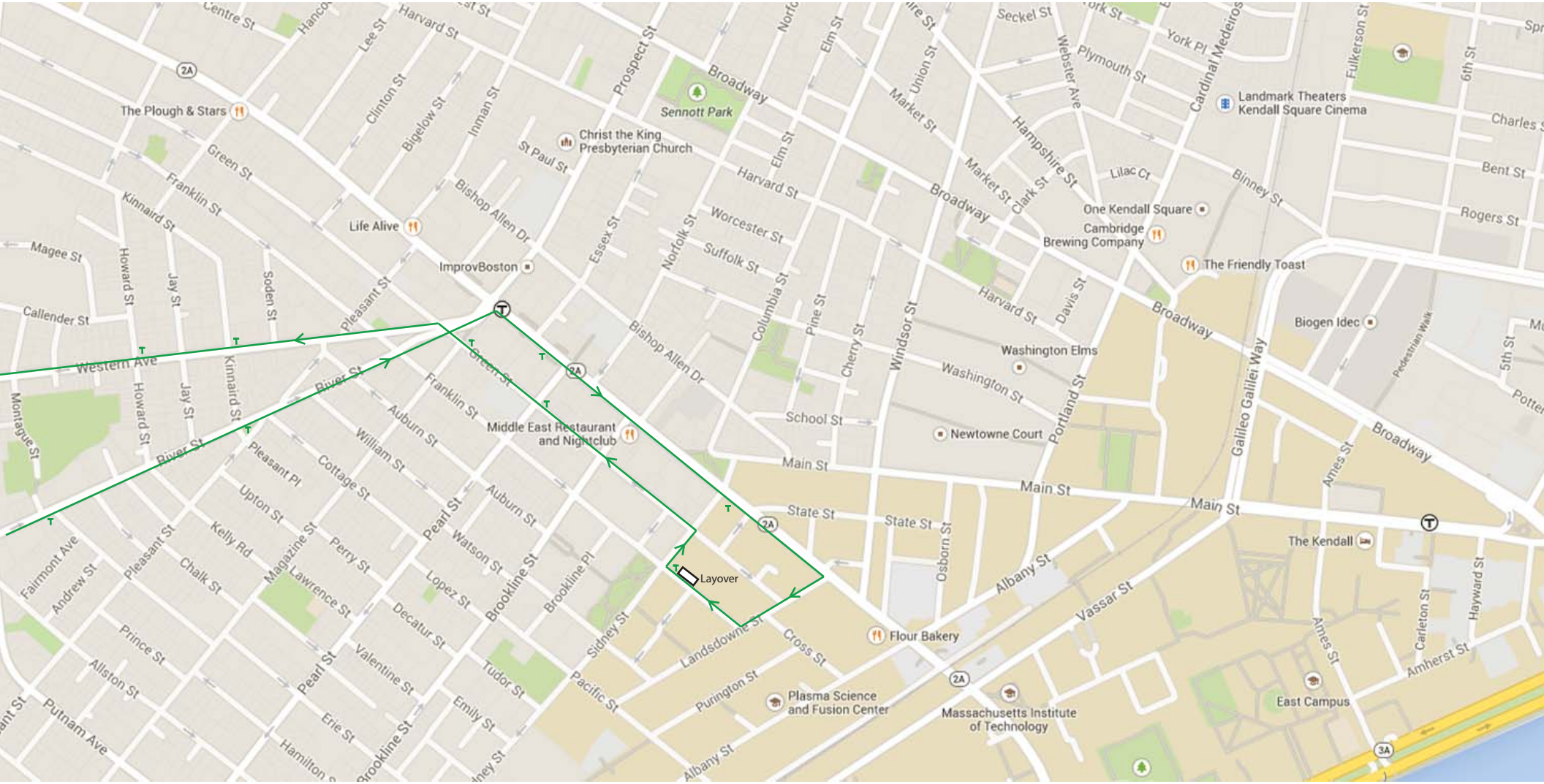
Route 70/70A

Existing and Alternatives



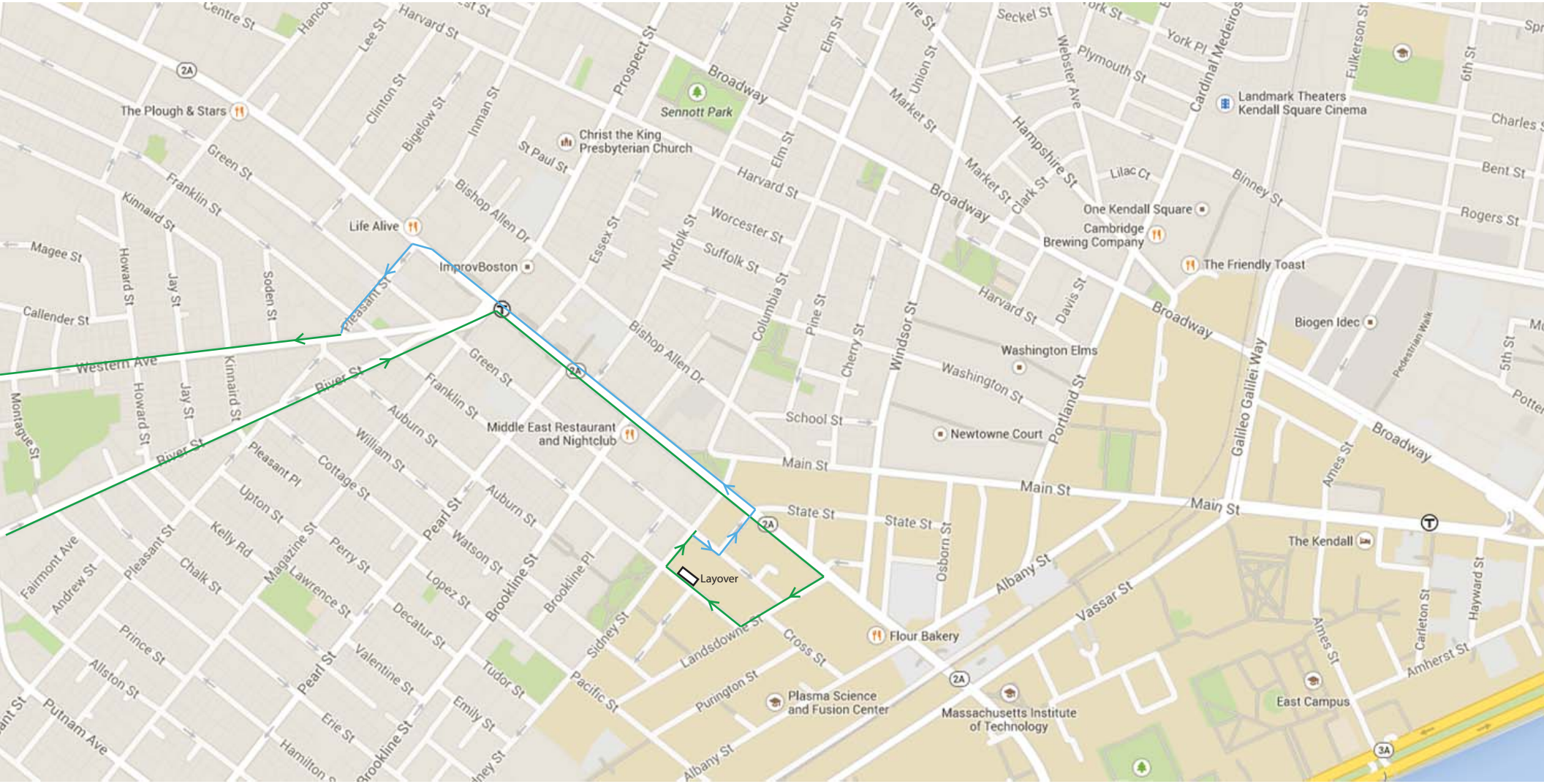
Route 70/70A

Existing



Route 70/70A

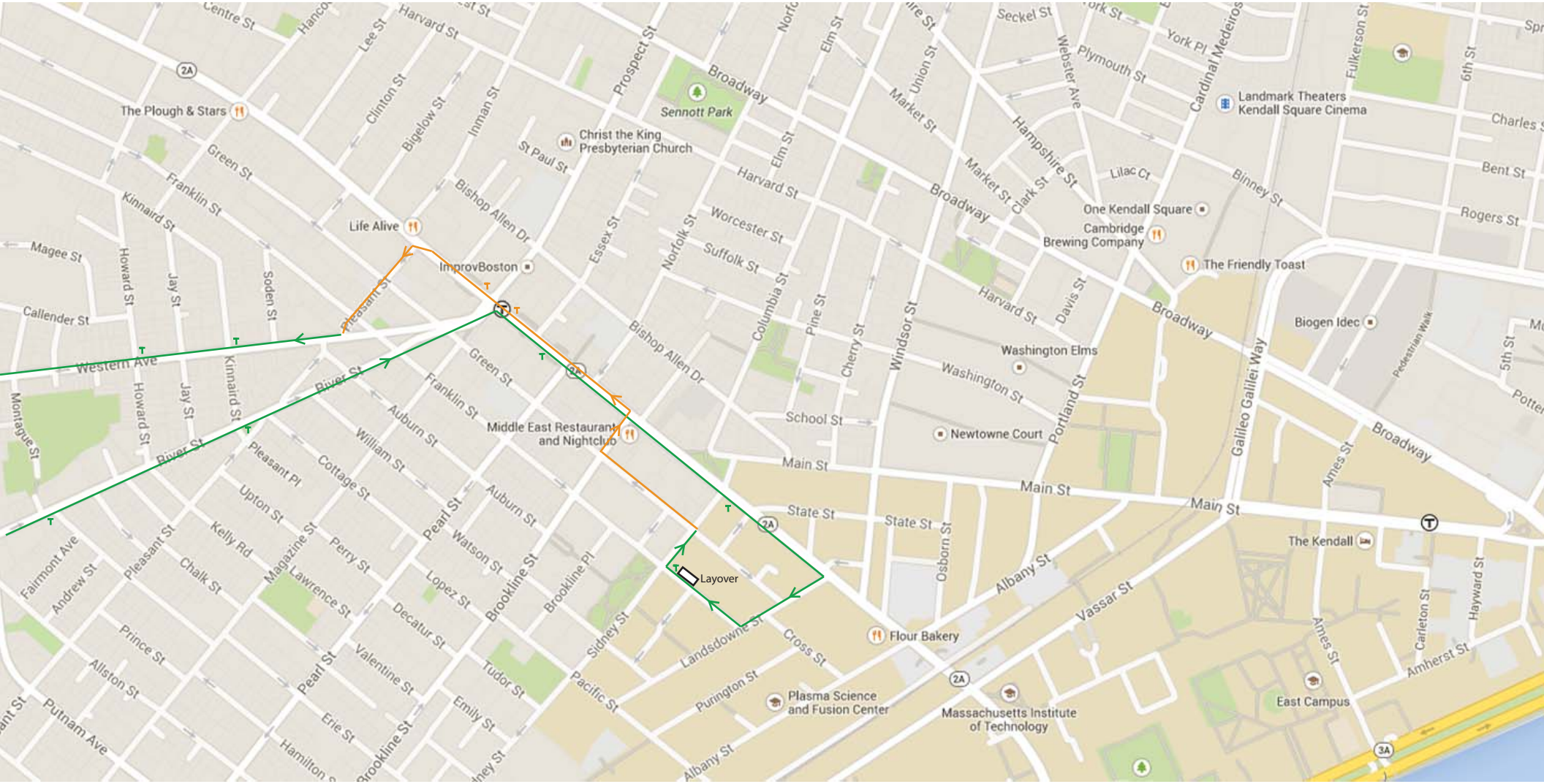
Alternative 1



Existing Route Alternative Route 1 Alternative Route 2

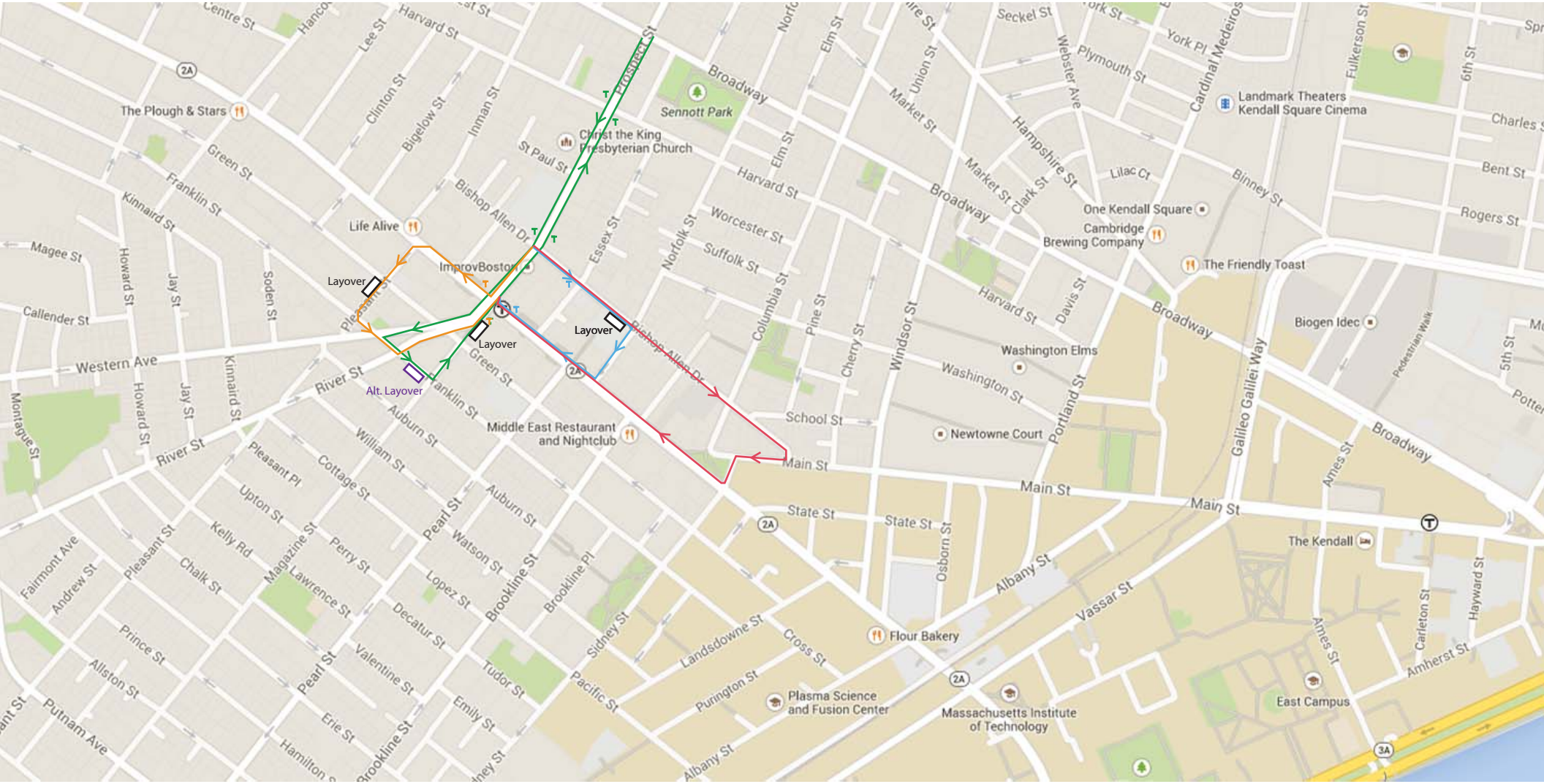
Route 70/70A

Alternative 2



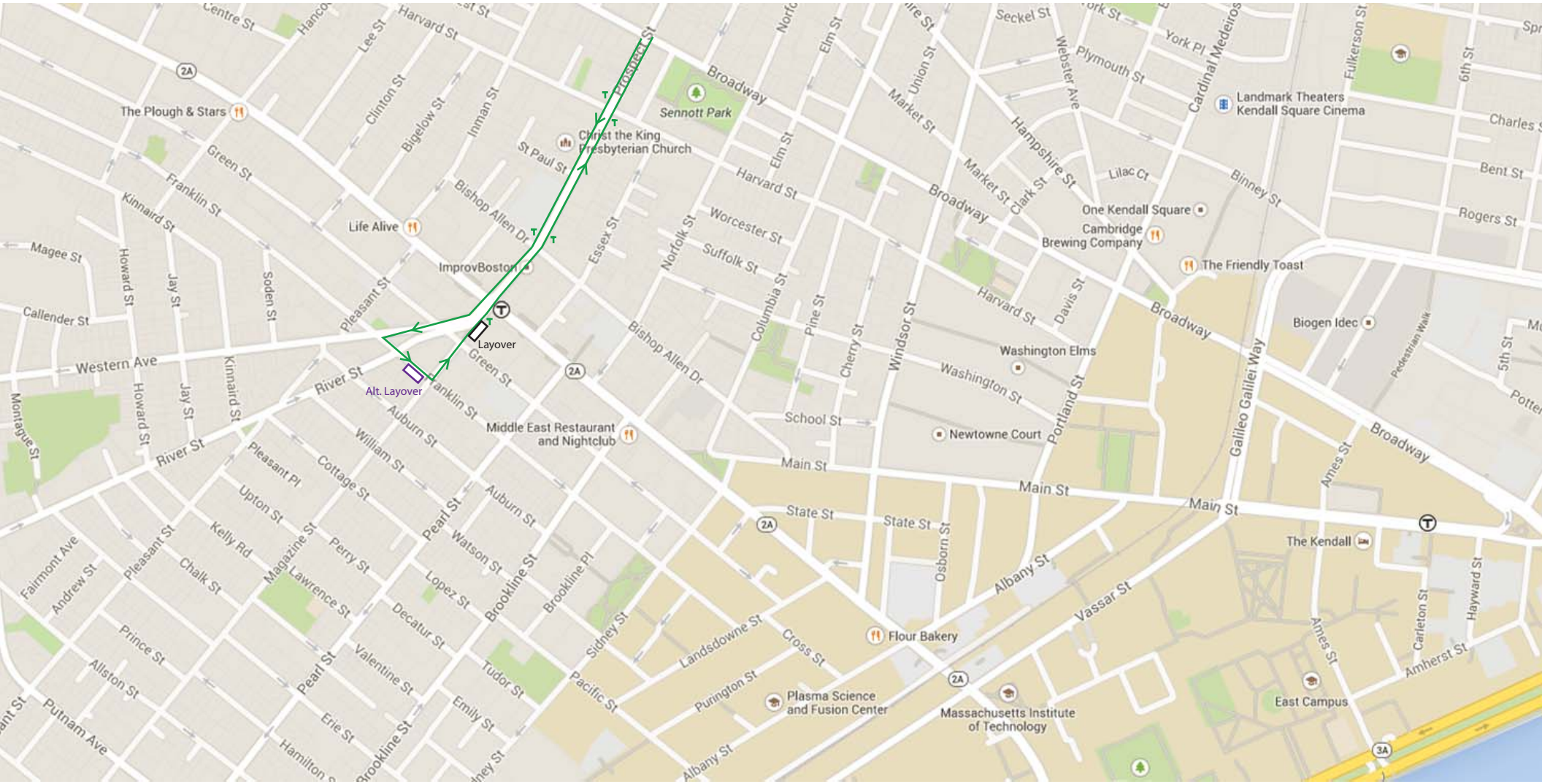
Route 83,91

Existing and Alternatives



Route 83,91

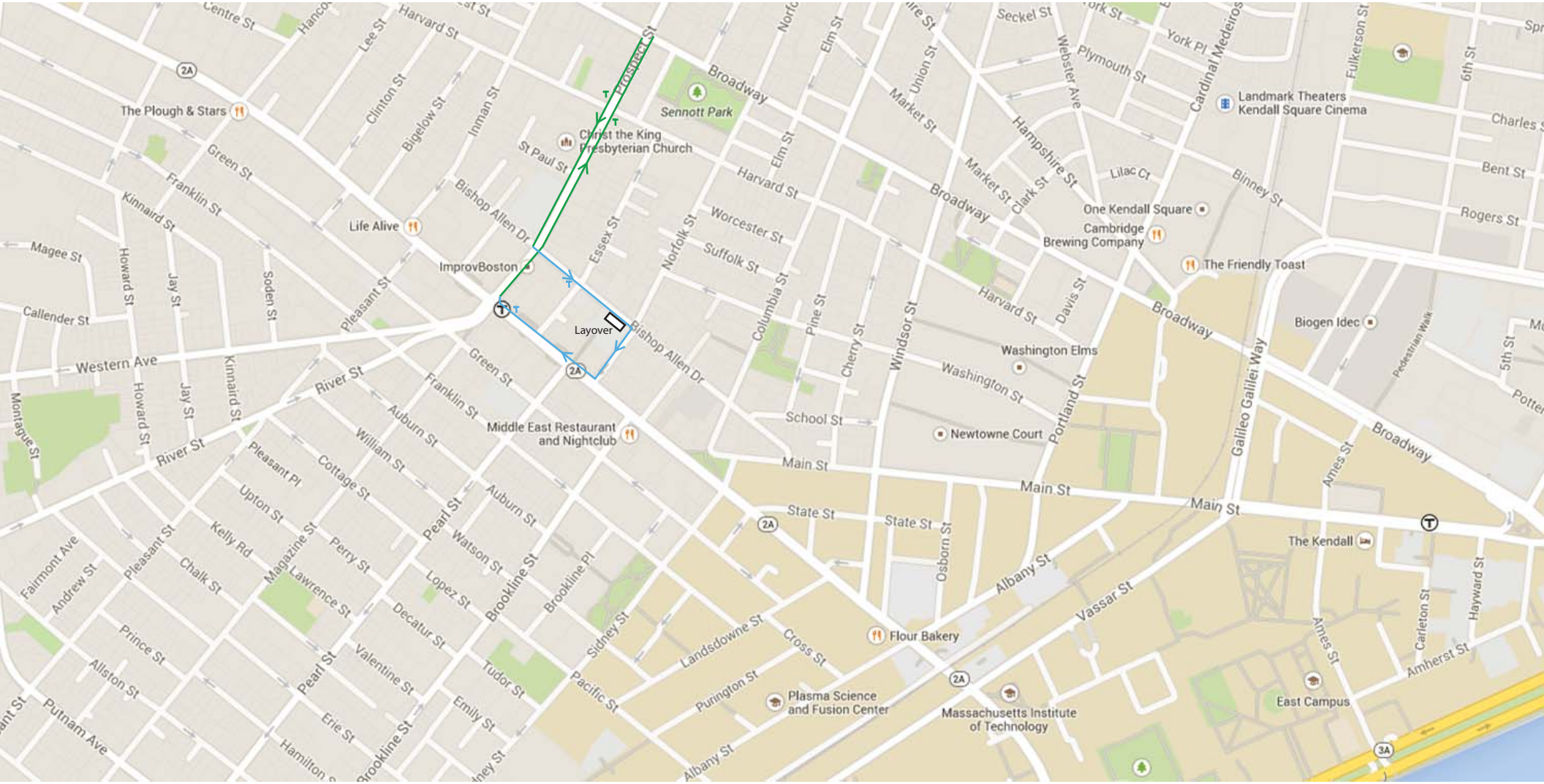
Existing



Existing Route Alternative Route 1 Alternative Route 2 Alternative Route 3

Route 83,91

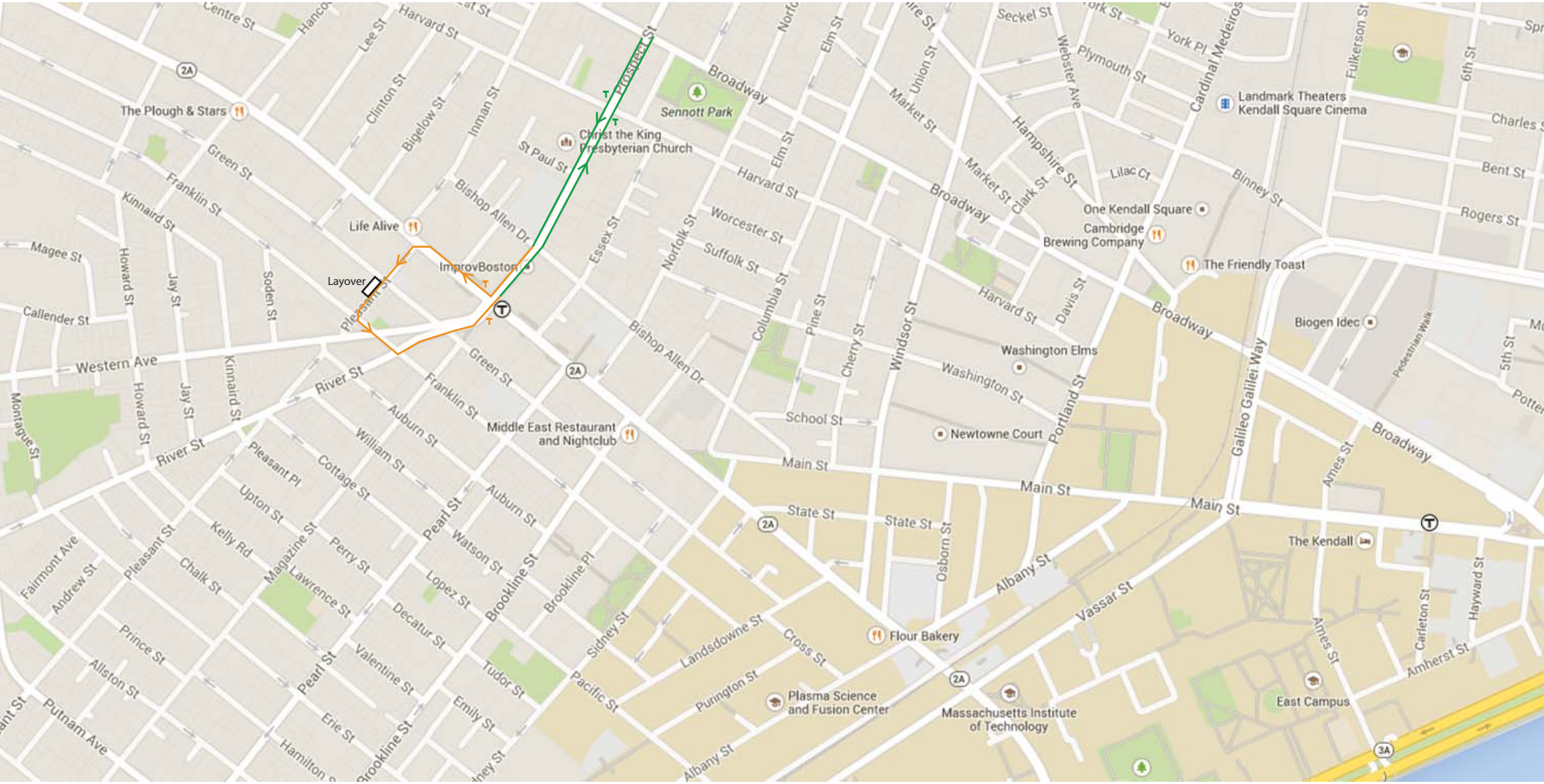
Alternative 1



Existing Route Alternative Route 1 Alternative Route 2 Alternative Route 3

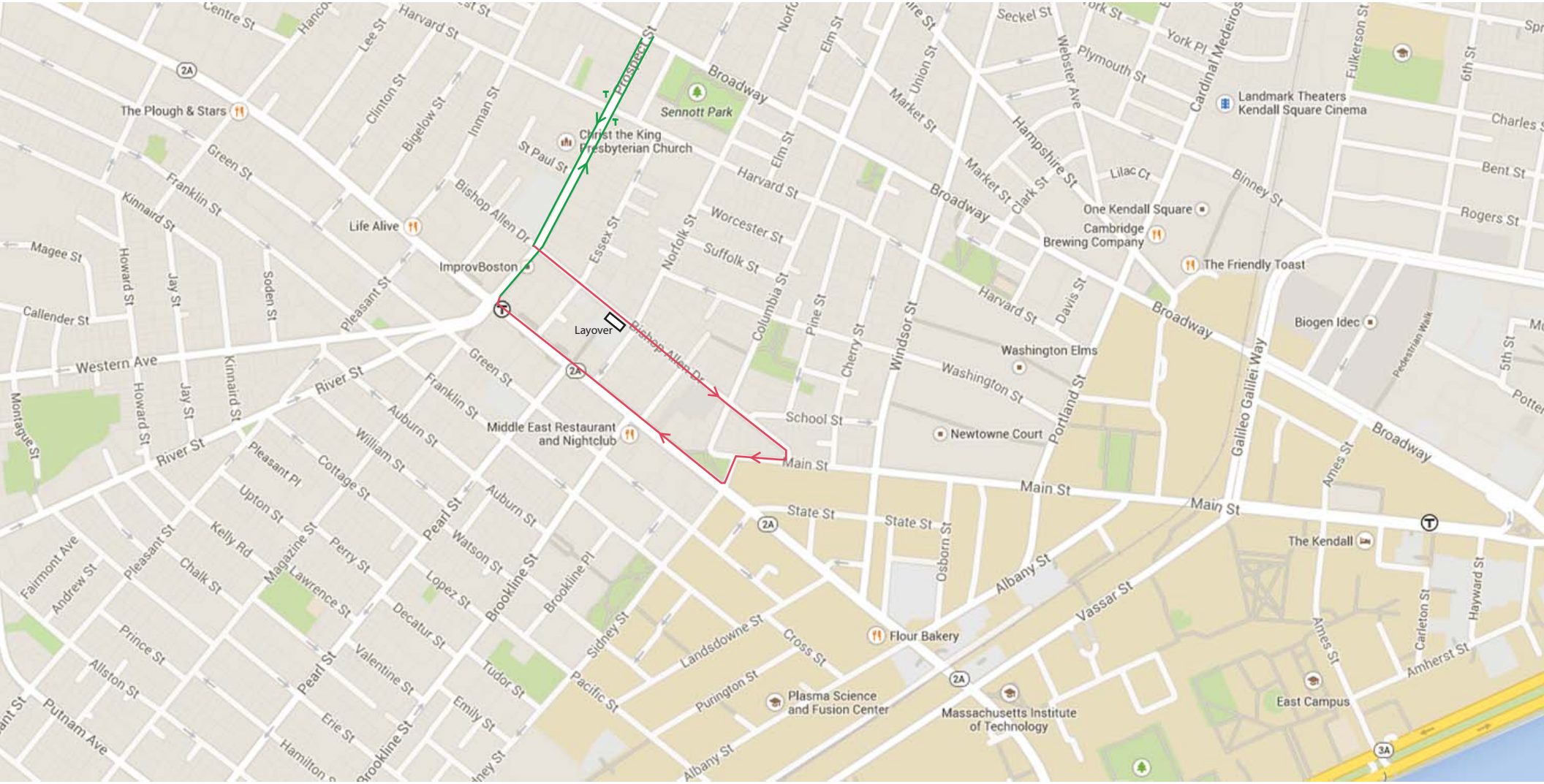
Route 83,91

Alternative 2



Route 83,91

Alternative 3



Existing Route Alternative Route 1 Alternative Route 2 Alternative Route 3

Appendix F: Existing Conditions Analysis

Central Square Access and Circulation Study
Existing Conditions Analysis

Prepared for City of Cambridge
by IBI Group
with CDM Smith
August 25, 2014

Document Control Page

CLIENT:	City of Cambridge
PROJECT NAME:	Central Square Access and Circulation Study
REPORT TITLE:	Central Square Existing Conditions Analysis
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REVIEWER:	Tegin Teich, Duncan Allen
AUTHORIZATION:	
CIRCULATION LIST:	
HISTORY:	1.1 Draft submitted on 2014-08-25 1.2 Updated as an Appendix in response to City of Cambridge comments

Table of Contents

1 Introduction

IBI Group has been engaged by the City of Cambridge (hereinafter referred to as the 'City') to study the transit routing, circulation, and access for MBTA routes around Central Square and to develop recommendations for reducing crowding for people waiting for the bus on narrow sidewalks and to improve access to and circulation around Central Square.

This project consists of the following tasks:

- Task 1 includes data collection and analysis activities to provide information on the existing conditions for transit around Central Square.
- Task 2 involves creating a list of issues, starting with those identified by Cambridge staff in the Request for Proposals (RFP), and added to or refined based on background information developed in Task 1 and a review of the 2013 K2C2 Central Square Final Report. The aim of this task is to provide a list of issues to consider while developing ideas for improving bus circulation and access in Central Square.
- Task 3 is intended to develop a list of potential ideas to improve the bus circulation, routing, stops, and layover locations, and refines the list with to include up to three (3) conceptual bus circulation plans.
- Task 4 is intended to develop a draft report, which provides more detail on the conceptual design level for the selected three (3) bus circulation plans, along with high level opinions of probable cost estimates.

This Task 1 Report summarizes the existing conditions for transit routing, layover, and stops around Central Square.

1.1 Background

Central Square is an important mixed-use downtown district in the City of Cambridge, and is located at the center of the Cambridgeport, Riverside, Mid-Cambridge, and Area 4 neighborhoods, and is in close proximity to the Massachusetts Institute of Technology (MIT) and Harvard University. It is a major transportation hub that serves all the surrounding residential communities and the commercial, entertainment, and retail spaces.

In order to encourage further development of this area and ensure that Central Square (along with Kendall Square) continues to be an important multi-use area and transportation hub, the Cambridge City Manager commissioned a comprehensive development study. The final report from this study, titled the Kendall Square Central Square (K2C2) Planning Study was released in 2013. One of the recommendations of the K2C2 Planning Study with respect to transit was "to look at routing, layover, and stop changes for the Central Square buses" along with the associated goal to "look at ways to reduce the crowding from people waiting for the bus on narrow sidewalks". The objective of this study is to further investigate and come up with recommendations to achieve this goal.

1.2 Document Structure

This document is structured as follows:

- Section 1 provides an overview of the study, the structure of this document, and related information.
- Section 2 presents a summary of the Study Area, including the basemapping and transportation facilities, the MBTA bus routes which are routed through Central Square, and an audit of the associated bus stops within the Study Area.
- Section 3 presents a summary of the transit access and transfer situation in the Central Square Study Area. The analysis in this section is primarily based on the Red Line and Bus Passenger surveys conducted by the Central Transportation Planning Staff (CTPS) in 2008-2009.
- Section 4 presents an analysis of Automatic Passenger Counter (APC) Data collected from the bus routes operating in the Central Square Study Area. The APC data are analyzed to delve deeper into the existing route-level and stop-level conditions for bus routing, layover, schedules, and crowding.

- Section 5 presents a summary of the observations from a field survey of the Central Square Study Area. The field observation verifies and supplements the information gathered in the previous sections, with further information on bus routing, stop locations, layovers, signage, and wayfinding.
- Section 6 identities the next steps in the study process.

1.3 Referenced Documents

The following documents were referenced as part of this report:

- MBTA Systemwide Passenger Survey: Rapid Transit 2008–2009 - Red Line, 2010*, prepared for* MBTA Planning and Development*, by* Central Transportation Planning Staff
- MBTA Systemwide Passenger Survey: Bus System 2008–2009 - Albany Garage, 2010*, prepared for* MBTA Planning and Development*, by* Central Transportation Planning Staff
- MBTA Systemwide Passenger Survey: Bus System 2008–2009 - Cabot Garage, 2010*, prepared for* MBTA Planning and Development*, by* Central Transportation Planning Staff
- MBTA Systemwide Passenger Survey: Bus System 2008–2009 – Charlestown and Fellsway Garages, 2010*, prepared for* MBTA Planning and Development*, by* Central Transportation Planning Staff
- MBTA Systemwide Passenger Survey: Bus System 2008–2009 - Somerville Garage, 2010*, prepared for* MBTA Planning and Development*, by* Central Transportation Planning Staff
- Kendall Square Central Square (K2C2) Planning Study, 2013, prepared for Cambridge Community Development Department, by Goody Clancy, Nelson Nygaard, Carol R. Johnson Associates, MJB Consulting, wZHA.

2 Study Area Basemapping and Transportation Facilities

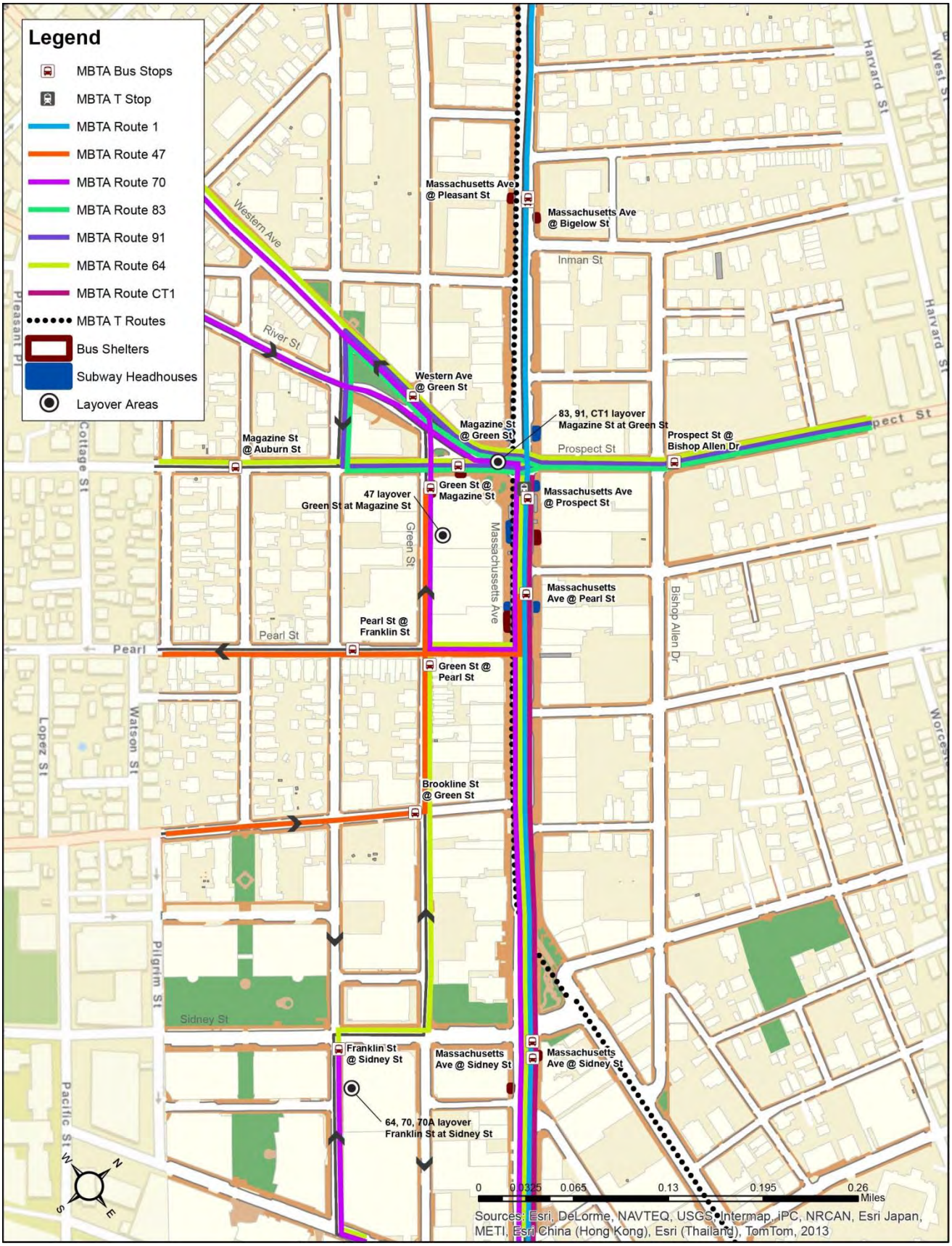
The Study Area is a rectangular area around Central Square, roughly bounded by Bishop Allen Drive, Landsdowne St, Auburn St., and Bigelow St, with Massachusetts Avenue (or 'Mass Ave') running through the Study Area parallel to the longer edge of the rectangle. Figure 1 illustrates the Study Area bounded by the rectangle.

Figure 1: Central Square Study Area

There are a variety of transit related features within the Study Area, including the Central Square subway station headhouses, bus stops, bus shelters, Hubway stations, bicycle facilities, street lights, benches and other facilities as shown in Figure 2. The following MBTA bus routes operate within the Study Area: 1, CT1, 47, 64, 70, 70A, 83, and 91. Figure 3 shows the routing of the buses and the associated bus stops and bus shelters. In addition, there are other non-MBTA routes which also operate in the Study Area, particularly the Medical Academic and Scientific Community Organization (MASCO) M2 shuttle between Harvard and the Boston Longwood medical area, which is routed along Mass Ave.

Figure 2: Central Square Study Area Transit Amenities

Figure 3: Central Square Study Area MBTA Service Audit



The results of the audit of the facilities associated with each bus stop in the Study Area is presented in the following table.

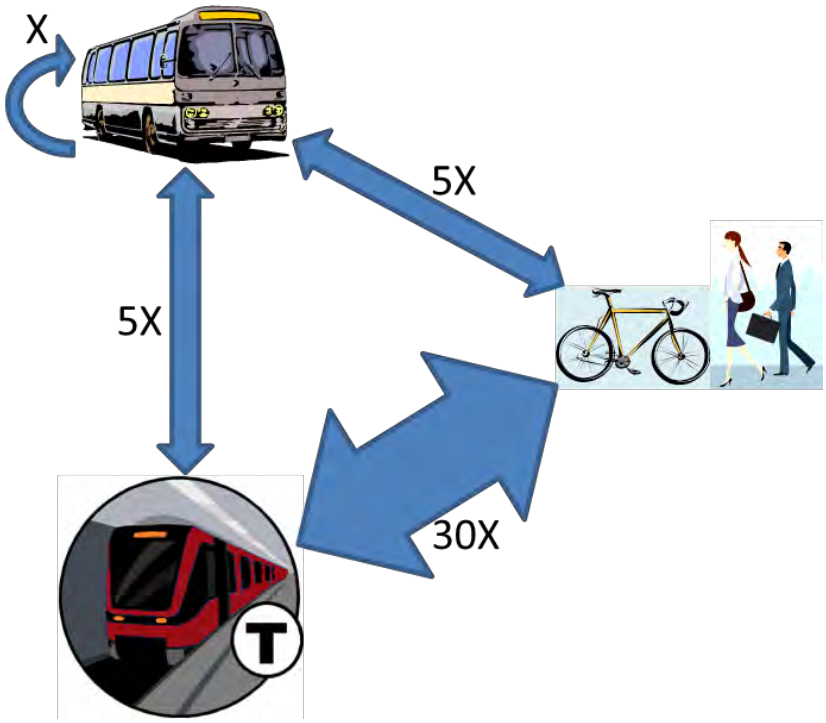
BUS STOP	ROUTES SERVED	SHELTER	SEATING	LIGHTING	ROUTE SIGNAGE	SCHEDULE INFO
Mass Ave at Prospect St	1, CT1 (and MASCO M2 shuttle)	✓	✓	✓	✓	
Mass Ave at Pearl St	1, 47, 64, 70, 70A, CT1 (and MASCO M2 shuttle)	✓	✓	✓	✓	
Mass Ave at Sidney St (Eastbound)	1, CT1, 64, 70, 70A	✓	✓	✓	✓	1, CT1, 64, 70, 70A
Mass Ave at Sidney St (Westbound)	1, CT1	✓	✓	✓	✓	1, CT1
Mass Ave at Pleasant St	1	✓	✓	✓	✓	1
Mass Ave at Bigelow St	1	✓	✓	✓	✓	1
Franklin St at Sidney St	64, 70, 70A				✓	
Brookline St at Green St	47				✓	
Green St at Pearl St	47, 64, 70, 70A				✓	
Pearl St at Franklin St	47				✓	
Prospect St at Bishop Allen Dr (Northbound)	64, 83, 91				✓	
Prospect St at Bishop Allen Dr (Southbound)	64, 83, 91				✓	
Green St at Magazine St	47, 64, 70, 70A	✓	✓	✓	✓	64, 83, 91, CT1
Magazine St at Green St Berth 1	64, 83, 91, CT1	✓	✓	✓	✓	CT1, 83, 91
Magazine St at Green St Berth 2	CT1	✓	✓	✓	✓	
Magazine St at Auburn St	64				✓	
Western Ave at Green St	64, 91				✓	

3 Central Square Transit Access and Transfer Summary

It is estimated that approximately 35,000 daily person-trips (journeys) by transit originate, terminate, or make transfers in the Study Area. Approximately a quarter of these make a transfer between MBTA services within the Study Area and more than three-quarters of these journeys access or egress from the MBTA services on foot or by bicycle.

Central Transportation Planning Staff (CTPS) conducted a system-wide survey of Massachusetts Bay Transportation Authority (MBTA) riders for the MBTA in 2008–09. This survey covered all of the modes operated by the MBTA: bus (including trackless trolley), rapid transit or 'heavy rail' (the Blue, Red, and Orange Lines), light rail (the Green Line and the Mattapan High-Speed Line), commuter rail, and boat. The results were summarized in a series of summary reports. These summary reports were consulted to gain an understanding of the transit and transfer activity within the Central Square area. Figure 4 provides a summary of the approximate relative proportions of intermodal transit transfer activity near Central Square as estimated from these survey reports. The base here is the lowest proportionate value for bus to bus transfers, labeled as X. As an example of how to read this diagram, the transfers between MBTA buses and the Red Line (shown as '5X') are five times the number of bus to bus transfers (shown as 'X'). Transfers between bicycles and other modes are significantly smaller than other modal transfers and have therefore been shown included along with walk-access transfers.

Figure 4: Approximate Relative Proportions of Intermodal Transfer Activity near Central Square



The diagram illustrates the relative importance of the various modal transfers in the Study Area, with the majority of transit users walking or biking to the Central Square Red Line station, a smaller number transferring between buses and the Red Line, and a further smaller number transferring between buses. This is not unusual for a major subway station situated close to multiple bus routes and with significant residential and commercial land use in proximity.

Further relevant detailed results from the survey reports are summarized in the following subsections. Section 3.1 presents the results from the Red Line Passenger Surveys and Section 3.2 presents the results from the Bus Passenger Surveys.

3.1 Red Line Passenger Survey Results for Central Square Station

3.1.1 Methodology

The results presented in this section are based on the Red Line survey. CTPS' survey methodology included provision of survey forms to all riders entering each Red Line station between 6:00 AM and 3:00 PM on a typical weekday in 2008 or 2009. According to CTPS, "this distribution strategy was designed to provide approximately 85% of the weekday riders on the Red Line with an opportunity to receive a survey form during what would be considered typical travel conditions". Surveys were not given to riders transferring to the Red Line at Park Street or Downtown Crossing Stations because CTPS staff felt that such riders would be covered at the station at which they first entered the rapid transit system.

The survey responses were collected and the survey data were expanded to cover 100% of results by weighting them to equal typical boardings during the survey hours using the most recently available ridership figures.

3.1.2 Modal Distribution for Passengers Accessing or Egressing at Central Square

Figures 5 and 6 present the modal distribution of passengers accessing or egressing from the Red Line at Central Square station. Figure 5 presents the combined results for both access and egress, while Figure 6 distinguishes between the access and egress results through two separate pie charts.

Figure 5: Modal Distribution for Red Line Access and Egress at Central Square

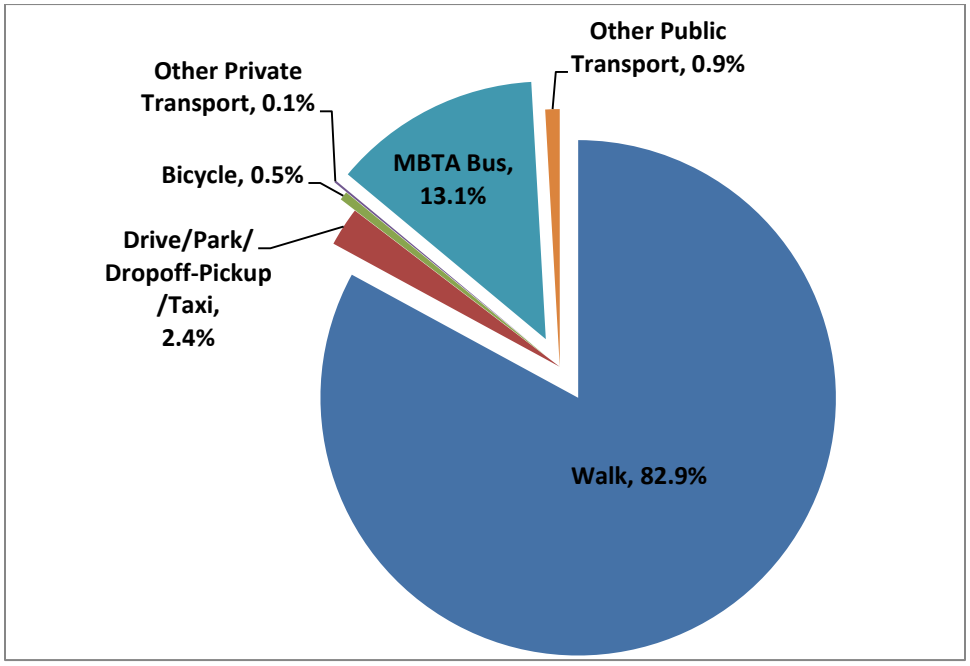
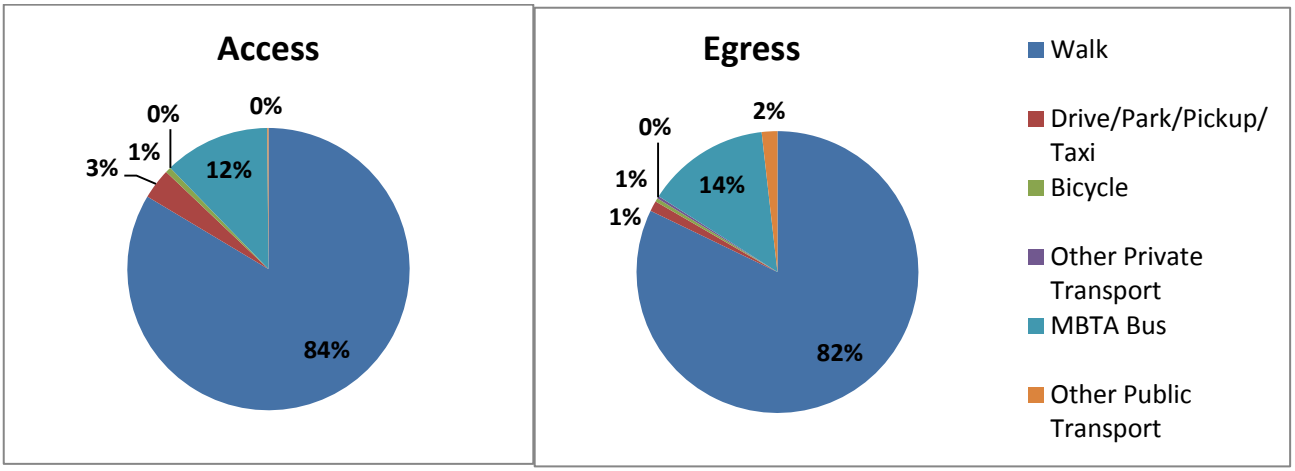


Figure 6: Modal Distribution for Red Line Access or Egress at Central Square

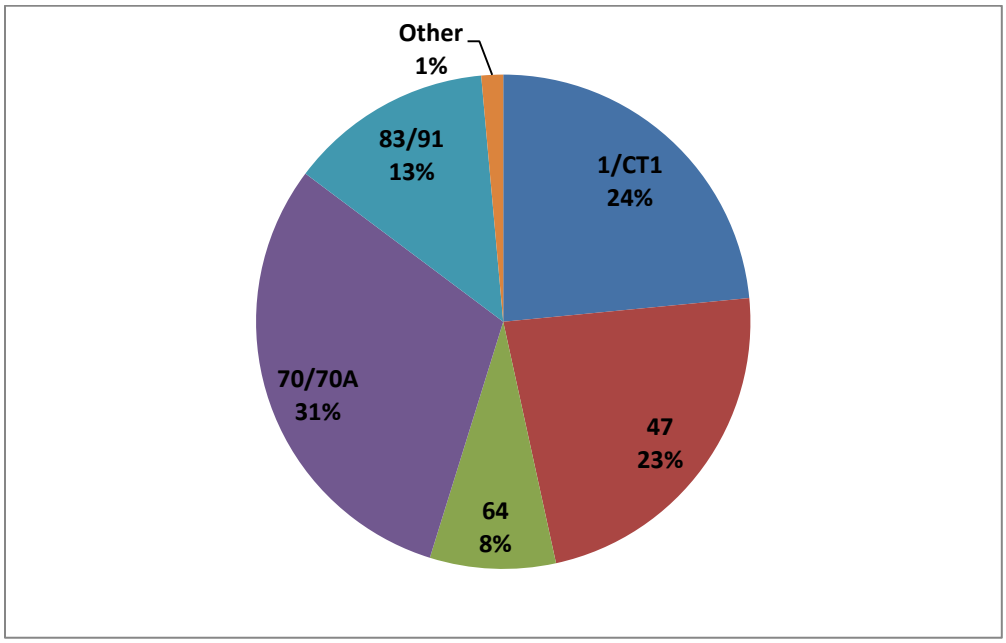


As evident from the two figures, the majority of passengers, equivalent to around 82-84%, walk to or from the Red Line at Central Square Station. There is no significant difference between passengers accessing or egressing. Approximately 12-14% passengers transfer between MBTA buses and the Red Line at Central Square Station.

3.1.3 Intermodal Transfers between Red Line Station and MBTA Bus Routes

The 13% of passengers transferring between the Red Line and MBTA buses can be further distinguished based on the bus route taken either to access the Red Line or after egressing from the Red Line. Figure 7 presents the survey results for passengers transferring between the Red Line at Central Square and the various MBTA bus routes.

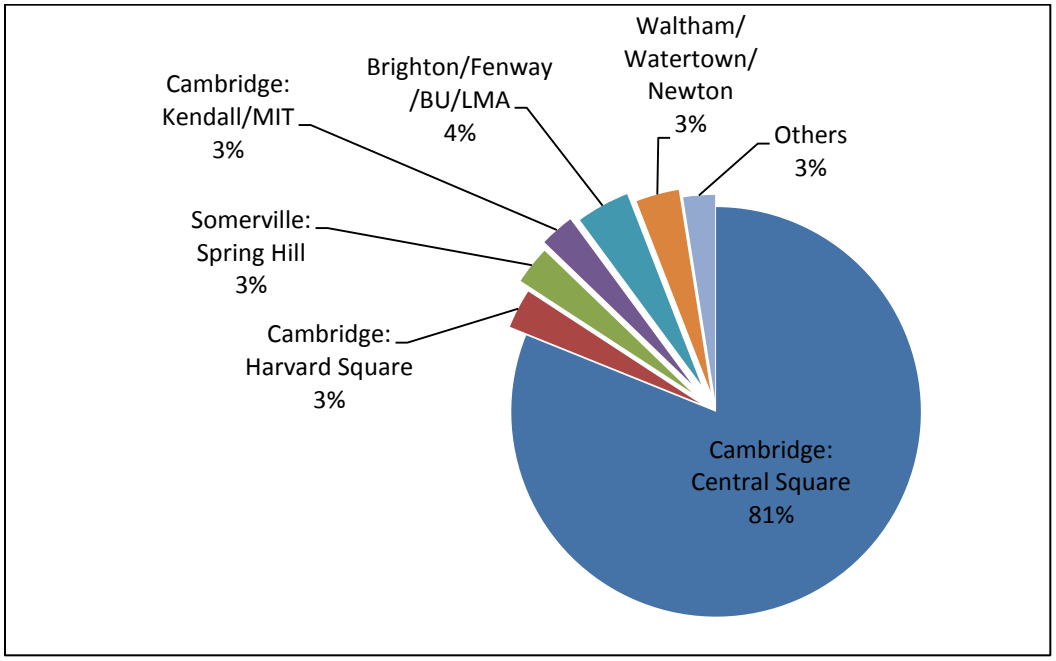
Figure 7: Intermodal Transfer between Red Line and MBTA Bus Routes at Central Square Station



3.1.4 Origin Locations for Passengers Entering Red Line at Central Square Station

The Red Line Passenger survey presents the origin locations for passengers accessing the Red Line at Central Square Station. Figure 8 presents the summary of these origin locations.

Figure 8: Origin Locations for Passengers Entering Red Line at Central Square Station



3.1.5 Destination Locations for Passengers Exiting Red Line at Central Square Station

The Red Line Passenger survey presents the destination locations for passengers exiting the Red Line at Central Square Station. Figure 9 illustrates the boundaries of the destination locations while Figure 10 presents the summary of the destination locations.

Figure 9: Origin-Destination locations from CTPS Red Line Survey

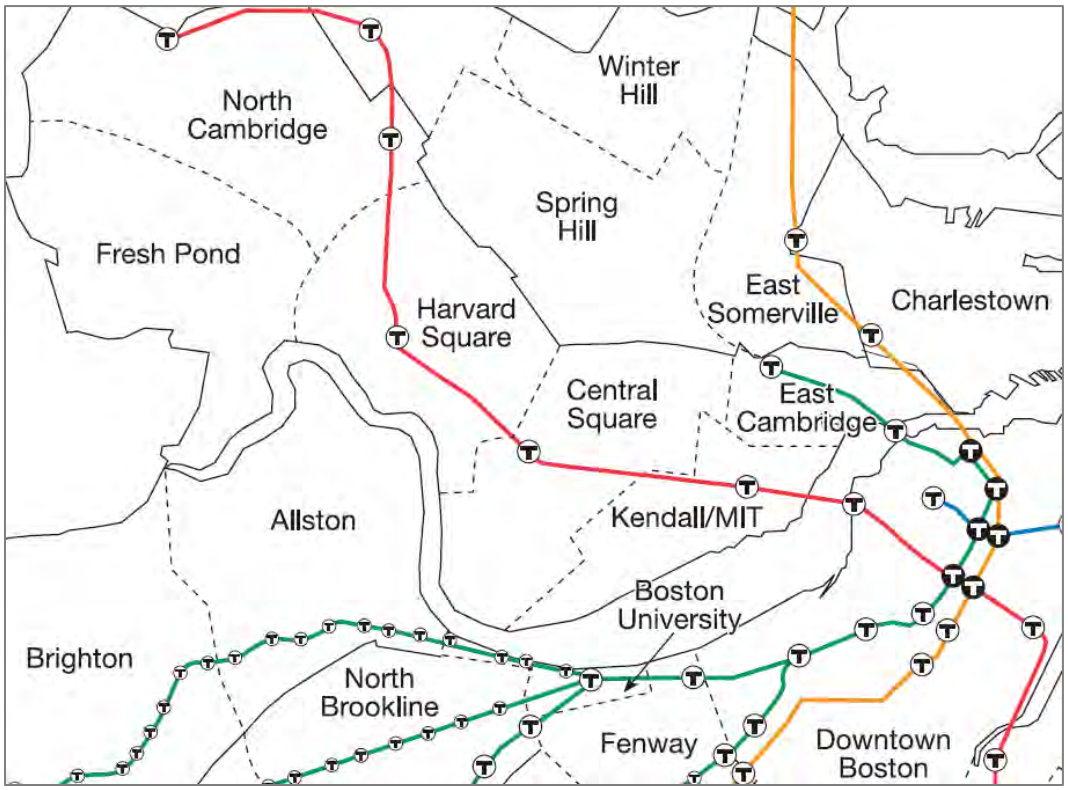
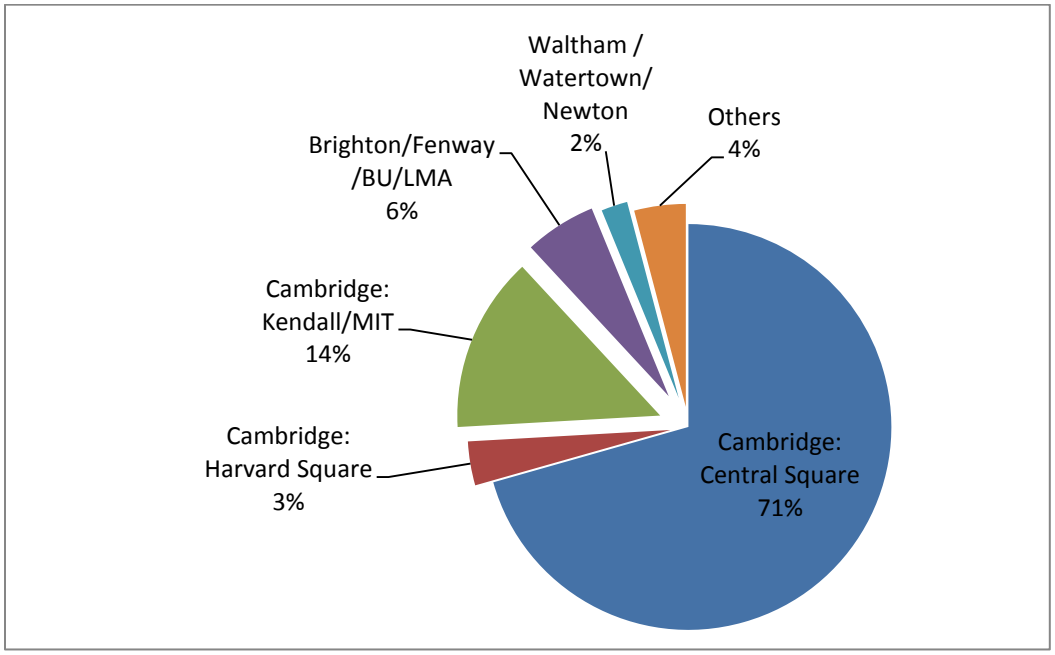


Figure 10: Destination Locations for Passengers Exiting Red Line at Central Square Station



3.2 Bus Passenger Survey Results for Routes Serving Central Square Station

3.2.1 Survey Methodology

The results presented in this section are based on the bus survey. CTPS' survey methodology for buses was similar to that for the Red Line and included the provision of survey forms to all riders riding the various MBTA bus routes between 6:00 AM and 3:30 PM on a typical weekday in 2008 or 2009. According to CTPS' Passenger survey reports, "this distribution strategy was designed to provide approximately 85% of the weekday riders on the buses with an opportunity to receive a survey form during what would be considered typical travel conditions".

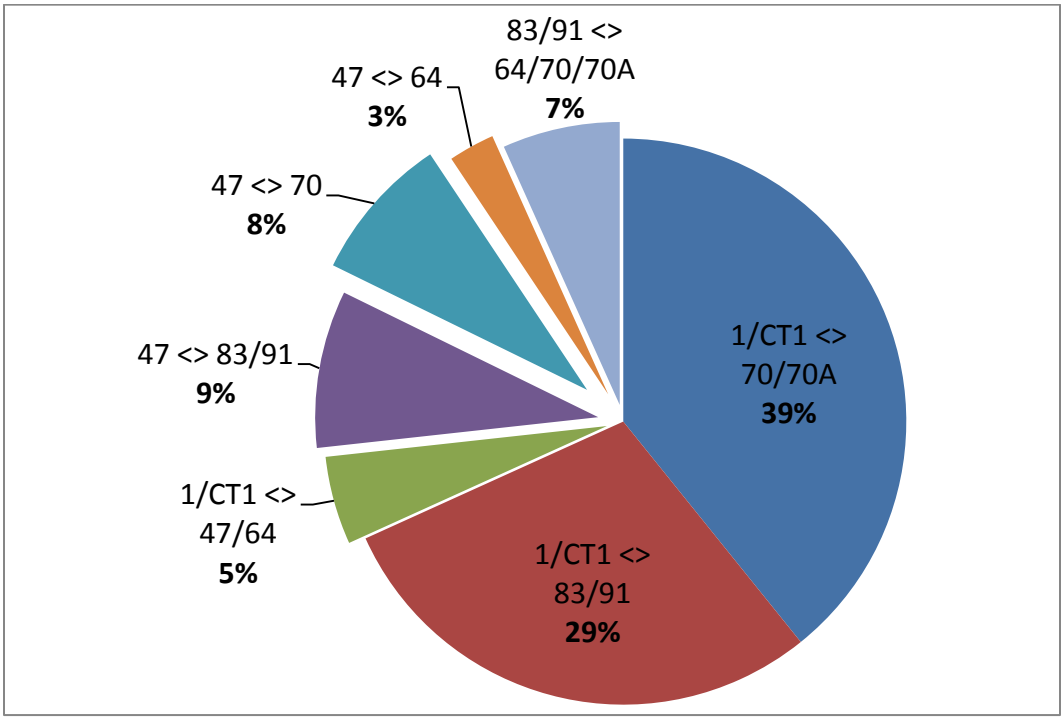
The survey responses were collected and the data collected from the survey were expanded to cover 100% of results by weighting them to equal typical boardings during the survey hours using the most recently available ridership figures.

The following sections present a summary of results for the following routes: 1, CT1, 47, 64, 70, 70A, 83, 91.

3.2.2 Intermodal Transfers between MBTA Bus Routes

The bus survey provides a summary of passengers transferring between MBTA bus routes, but does not explicitly describe the location at which the transfers take place. However, because the majority of the bus routes considered here only intersect or meet at Central Square Station, it is reasonable to assume that that these passengers transfer within the Central Square Study Area. Figure 11 presents the summary of intermodal transfers between the different bus routes.

Figure 11: Intermodal Transfers between MBTA Bus Routes near Central Square



If we group routes together, it is evident that the majority of people, 73%, transfer between routes running along Mass Ave (1/CT1) and routes running effectively perpendicular to Mass Ave (all other routes).

4 APC Travel Time and Load Analysis

This section presents the results of the following four analyses:

- Dwell Time Analysis at Route 1 and CT1 stops in the Study Area
- Duration between Scheduled Arrival and Departure Times for Routes in the Study Area (indicative of scheduled layover time)
- Passenger Loads Analysis for Routes 64, 70, and 70A
- Crowding at Stops in the Study Area

4.1 APC Data Overview

Data from the MBTA's Automatic Passenger Counters (APCs) were analyzed to understand bus operating conditions in and around Central Square. These on-board devices count the number of passengers boarding and alighting a bus at each stop and provide the time at which the bus makes movements and opens/closes its doors. Specifically the devices provide:

- Bus travel time – the time from when the bus starts moving away from a stop to the time when the door opens at the next stop
- Bus dwell time – the time from when the bus opens its doors at a stop to the time the bus closes its doors at a stop
- Bus wait time – the time from when the bus closes its doors at a stop to the time when the bus starts moving away from the stop
- Overall travel time – the sum of the bus travel time, dwell time, and wait time
- Passenger load – the boarding and alighting information also allows calculation of the passenger load (i.e. the number of passengers in the bus) after each stop.

There are APC data for trips in both the AM and PM weekday periods, providing a dataset for bus performance during these times.[1] The routes analyzed were:

- Route 1 – operating between Harvard Square and Dudley Square (via Central Square)
- Route CT1 – operating between Central Square (at Magazine St at Green St) and B.U. Medical Center
- Route 47 – operating between Central Square (at Massachusetts Ave and Pearl St) and Broadway Station in South Boston
- Route 64 – operating between Central Square (at Franklin St at Sidney St) and Oak Square in the off-peak and Kendall Square and Oak Square in peak times
- Routes 70 and 70A– operating between Central Square (at Franklin St at Sidney St) and Cedarwood, North Waltham or Watertown Square
- Route 83 – operating between Central Square (at Magazine St at Green St) and Rindge Ave
- Route 91 – operating between Central Square (at Magazine St at Green St) and Sullivan Square Station

The following sections further describe the data analysis done for each bus route.

4.2 Dwell Time Analysis at Route 1 and CT1 Stops in the Study Area

The APC data provide the times when the buses' doors open at a stop and the time when the buses' doors close at a stop. This allows the dwell time of the bus at a stop to be determined. The dwell times at stops on

[1] Data were collected for trips made during the spring of 2014. Approximately 25 percent of MBTA buses are equipped with APCs. AM peak is 7am – 9am and PM peak is 4pm – 6:30pm.

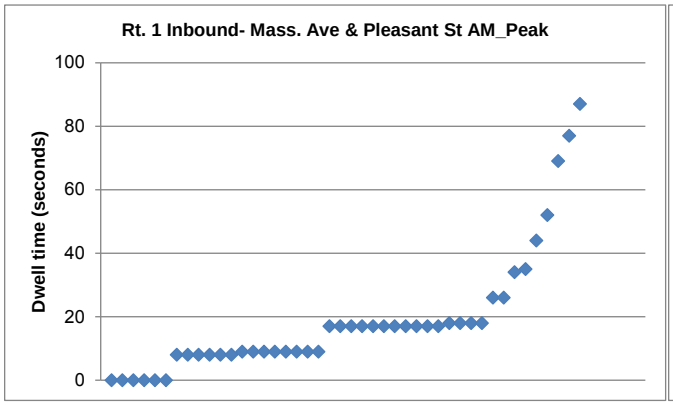
Massachusetts Ave within the study area during the AM and PM peaks were calculated for Routes 1 and CT1. The stops are shown in the figure below. The dwell time for each stop for each trip in the AM and PM peaks were calculated and are shown in the plots below. The dwell times are arranged in increasing order on the y-axis (the x-axis has no value because it is just the relative (ordinal) position of the dwell times). Dwell times will vary throughout the course of the day depending on how many passengers board the bus. A dwell time of up to 20 seconds is typical for buses in normal operations without overcrowding. Dwell times consistently over 20 seconds are a sign that buses are overcrowded at that location.

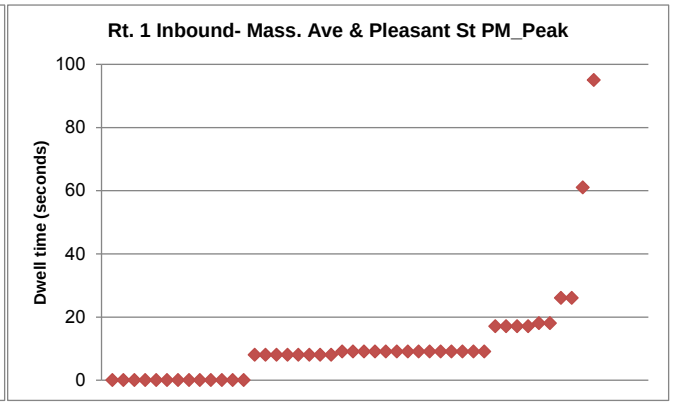
Figure 12: Stops on Massachusetts Ave in Study Area

Based on this analysis, it was found that the dwell times at Mass Ave at Pearl St and Mass Ave at Prospect St are highly variable. This is to be expected because both stops are located at the center of the Central Square area and near the entry and exit points for the subway. The dwell times at Mass Ave at Pleasant St and Mass Ave at Bigelow St show low variability and the majority of dwell times are below 20 seconds, indicating that the extent of passenger boardings and alightings at stops is not typically problematic. The stops in both directions at Mass Ave at Sidney St however exhibit a greater degree of dwell time variability in the PM peak, with dwell times quite often greater than 20 seconds. Further details of the analysis are presented in Sections 4.2.1-4.2.6, which address individual locations

4.2.1 Massachusetts Ave and Pleasant St

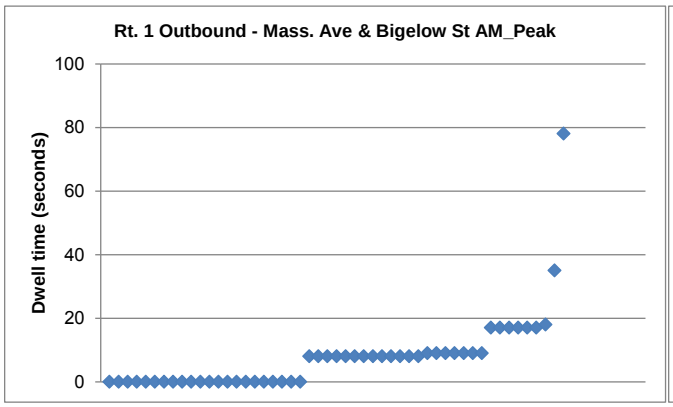
The stop at Massachusetts Ave and Pleasant St (Route 1 in the Inbound direction from Harvard to Dudley) has a typical distribution of a bus stop without indicatons of overcrowding or other dwell time issues with most (~84%) of the dwell times in the peaks being below 20 seconds.

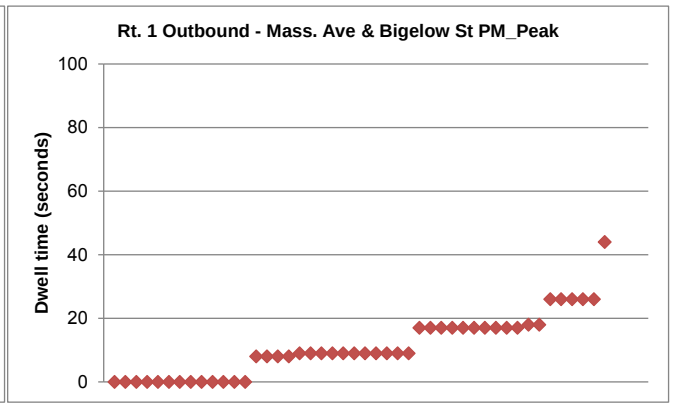




4.2.2 Massachusetts Ave and Bigelow St

The stop at Massachusetts Ave and Bigelow St (Route 1 in the Outbound direction to Harvard from Dudley) has a typical distribution of a bus stop without indication of overcrowding or other dwell time issues with most (92%) of the dwell times in the peaks below 20 seconds.

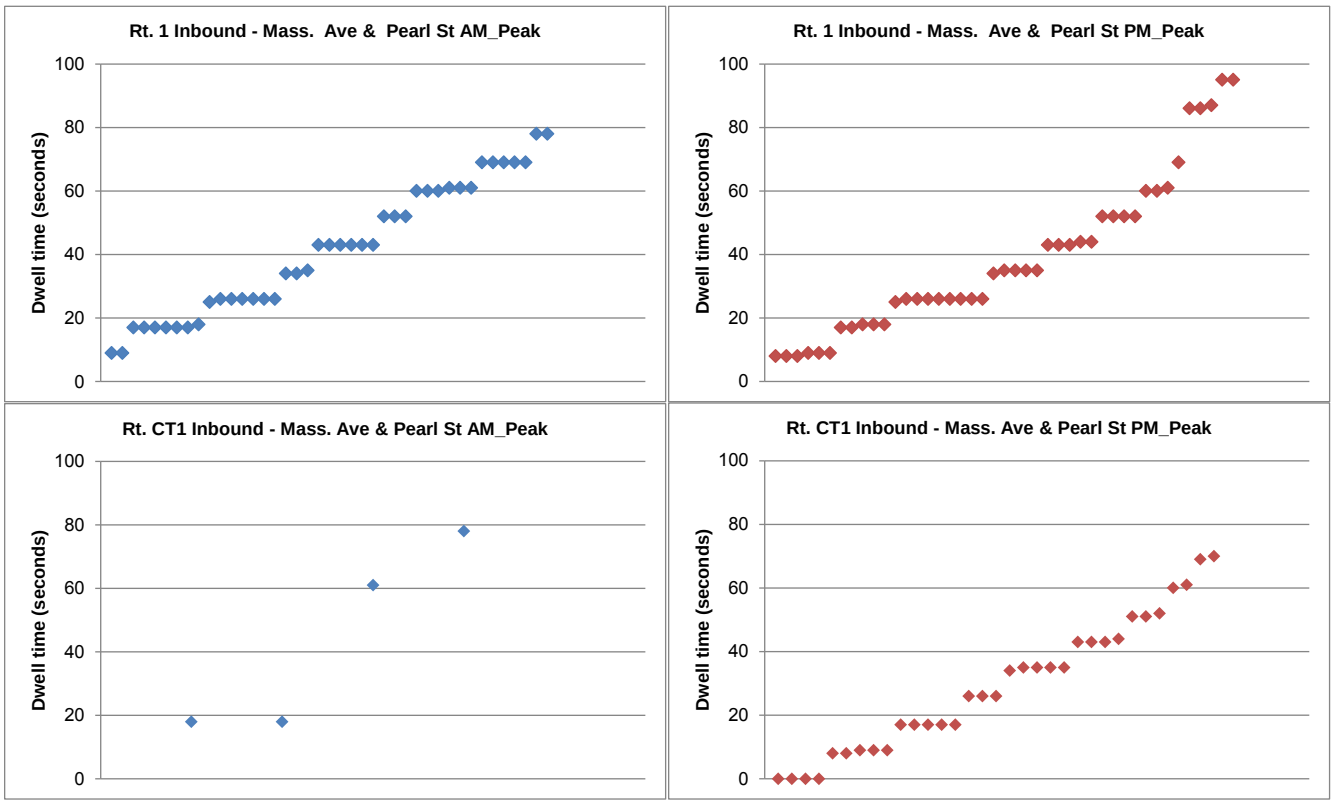




4.2.3 Massachusetts Ave and Pearl St

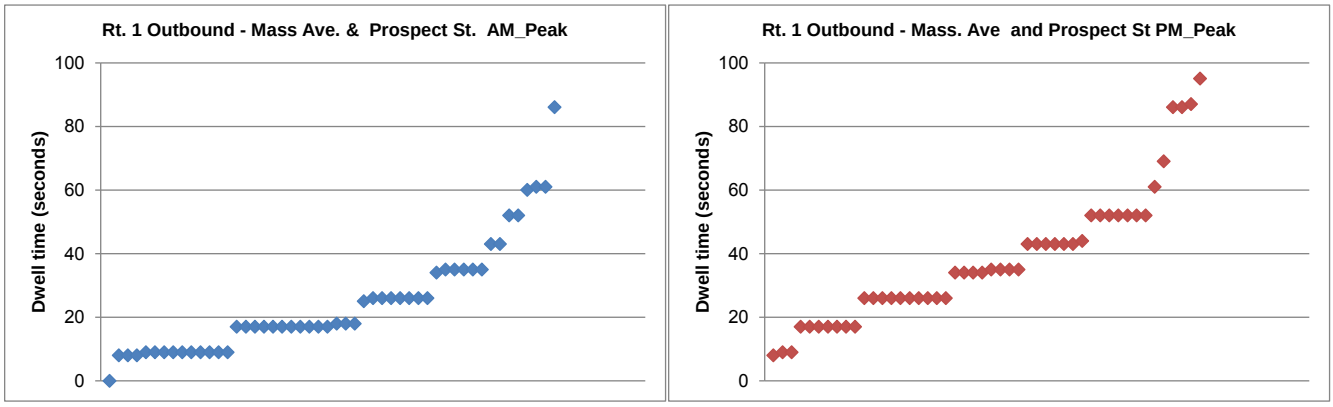
The stop at Massachusetts Ave and Pearl St (Route 1 in the Inbound direction from Harvard to Dudley and Route CT1 in the Inbound Direction from Central to B.U. Medical Center) has a typical distribution of a bus stop with a high level of passenger activity. This is the stop that is right outside the Central Square Red Line subway station. Only 22% of the dwell times in the peaks for Route 1 and 40% for Route CT1 are below 20 seconds.

This suggests that the high passenger volumes (likely people transferring to or from the Red Line) are causing the long dwell times for both routes.



4.2.4 Massachusetts Ave and Prospect St

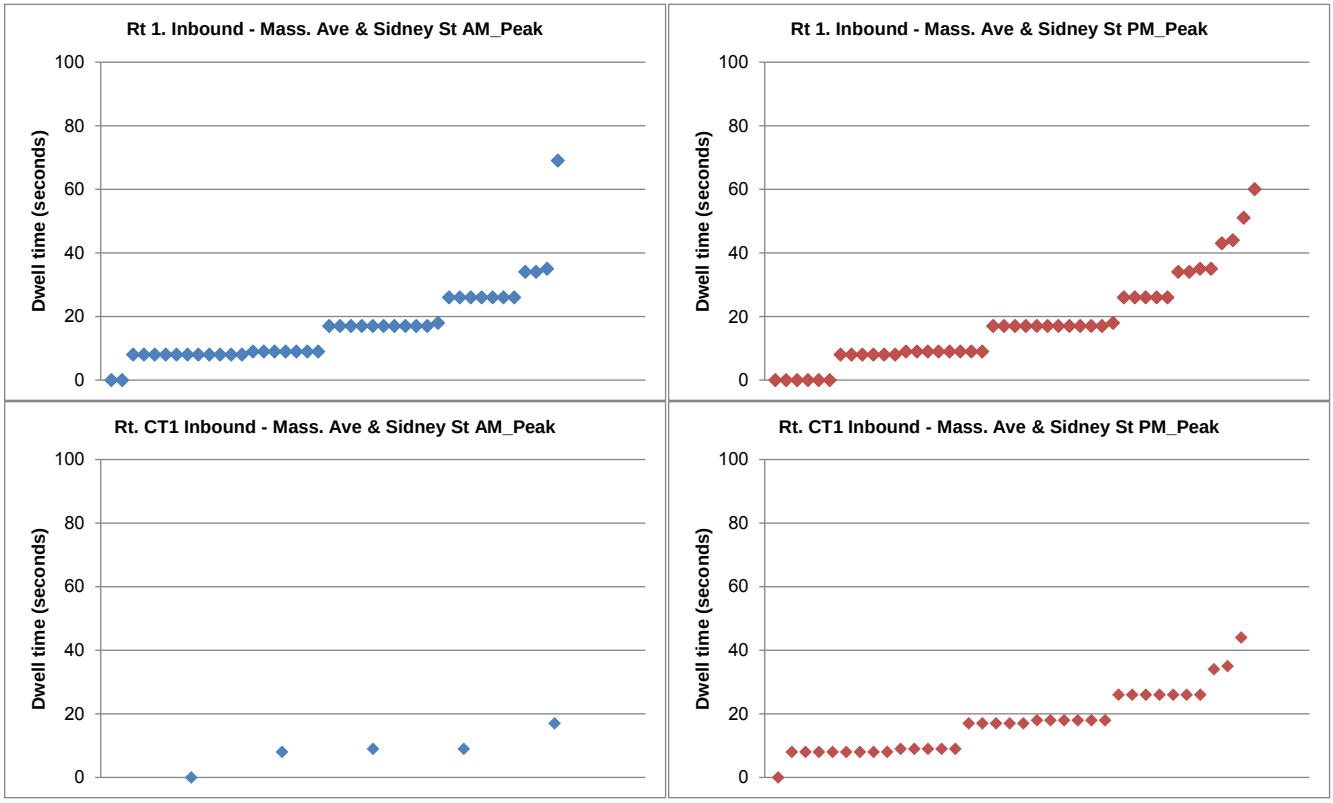
The stop at Massachusetts Ave and Prospect St (Route 1 in the Outbound direction from Dudley to Harvard) has a typical distribution of a bus stop with some overcrowding or other dwell time issues. Only 38% of the dwell times in the peaks are below 20 seconds. This shows that the passenger volumes (or other conditions such as high cash boardings) at this stop are causing long dwell times, but not so long as the stop at Pearl St.



4.2.5 Massachusetts Ave and Sidney St (Inbound)

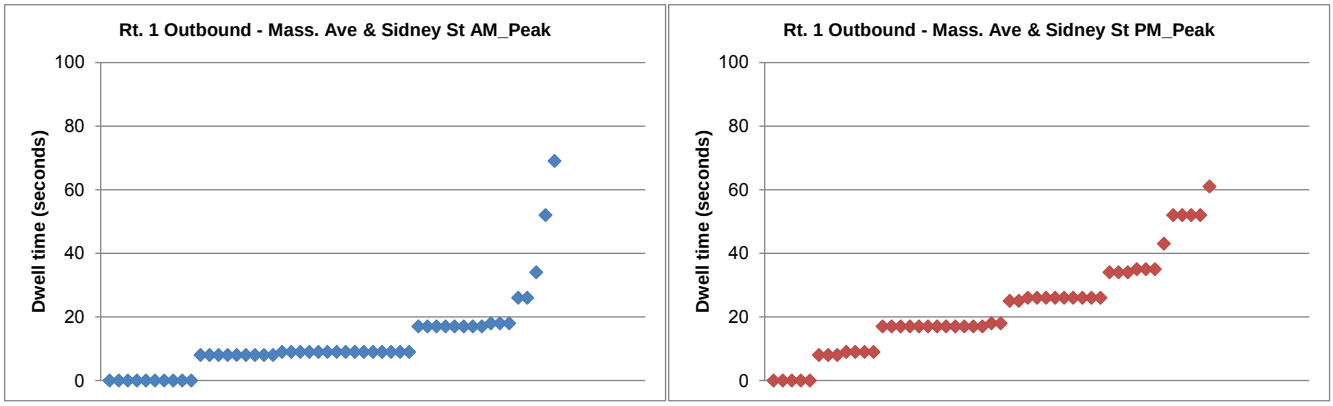
The stop at Massachusetts Ave and Sidney St (Route 1 in the Inbound direction from Harvard to Dudley and Route CT1 in the Inbound Direction from Central to B.U. Medical Center) has a typical distribution of a bus stop with some crowding or other dwell time issues. Approximately 71% of the dwell times in the peaks for Route 1

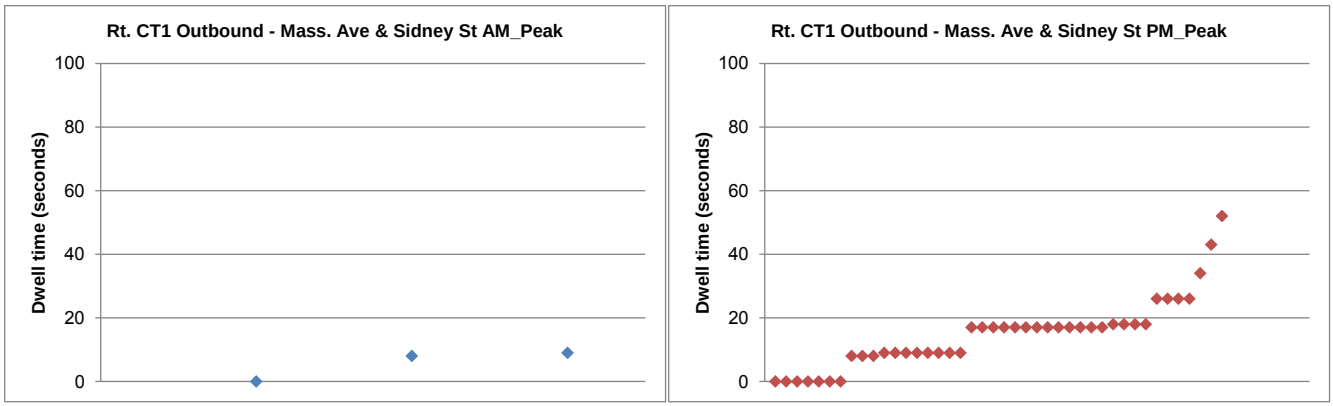
and 75% for Route CT1 are below 20 seconds. This suggests that the passenger volumes (or other conditions such as high cash boardings) at this stop are causing dwell times for both routes that are sometimes higher than typical.



4.2.6 Massachusetts Ave and Sidney St (Outbound)

The stop at Massachusetts Ave and Sidney St (Route 1 in the Outbound direction to Harvard from Dudley and Route CT1 in the Outbound Direction to Central from B.U. Medical Center) has a typical distribution of a bus stop with some crowding or other dwell time issues. Approximately 80% of the dwell times in the peaks for Route 1 and 84% for Route CT1 are below 20 seconds. This shows that the passenger volumes or other conditions at this stop are causing dwell times for both routes that are sometimes higher than normal.





4.3 Time between Scheduled Arrivals and Departures at Central Square

Routes 47, 64, 70, 70A, 83, 91, and CT1 all have layover locations within the Study Area. The General Transit Feed Specification (GTFS) schedule was analyzed to determine the duration between scheduled arrivals and departures for each route at Central Square. These scheduled durations were compared to the distribution of cumulative travel times at the stop just outside the study area in the direction towards Central Square for each route to estimate if there was a reasonable amount of scheduled layover time in Central Square.

The difference between the 95th percentile and the median of cumulative travel time at the stop just outside the study area representss the variability of travel time for each route by the time it gets to Central Square. If the variability of the cumulative travel time is greater than the scheduled duration between arrival and departure times at Central Square, there could be operational issues that require longer scheduled times. Conversely if the estimated variability of the cumulative travel time is much less than the scheduled duration between arrival and departure times then that time could possibly be reduced.

The observations from this analysis are summarized by route as follows:

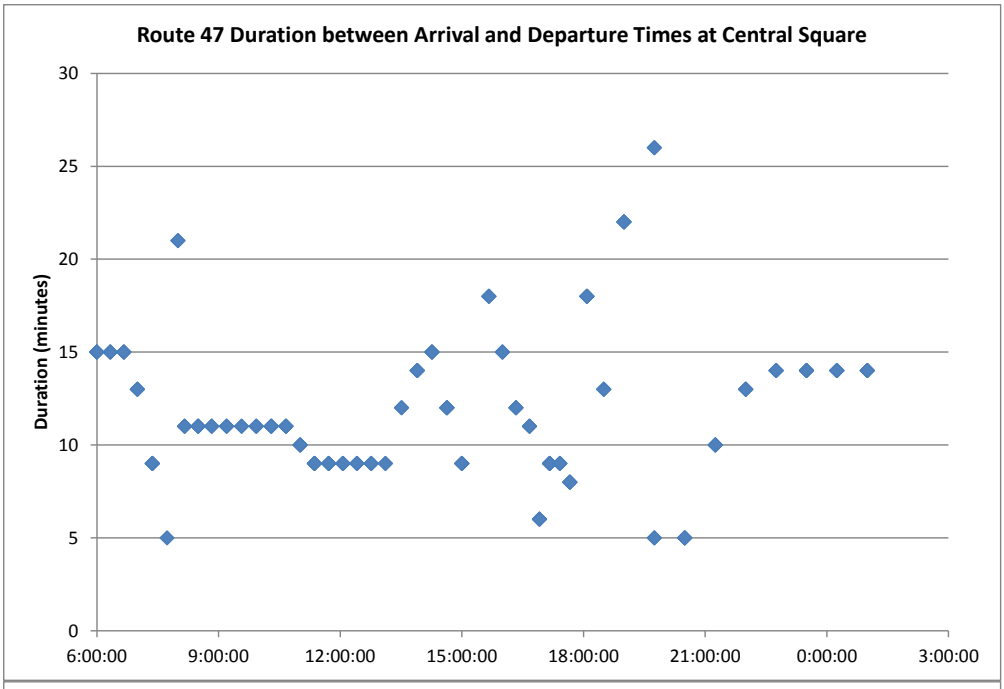
- Route 47 - There may be some unnecessary scheduled duration time between arrivals and departures in the AM peak.
- Route 64 - The scheduled duration times between arrivals and departures in the AM peak seem to be reasonable. It is unclear whether or not the PM peak scheduled duration times between arrivals and departures are reasonable
- Route 70 - Some additional scheduled duration time between arrivals and departures may be needed in the AM peak.
- Route 70A - Some additional scheduled duration time between arrivals and departures may be needed in the AM and PM peaks.
- Route 83 - Some additional scheduled duration time between arrivals and departures may be needed in the AM and PM peaks.
- Route 91 - There may be some unnecessary duration time between arrivals and departures in the AM and PM peaks.

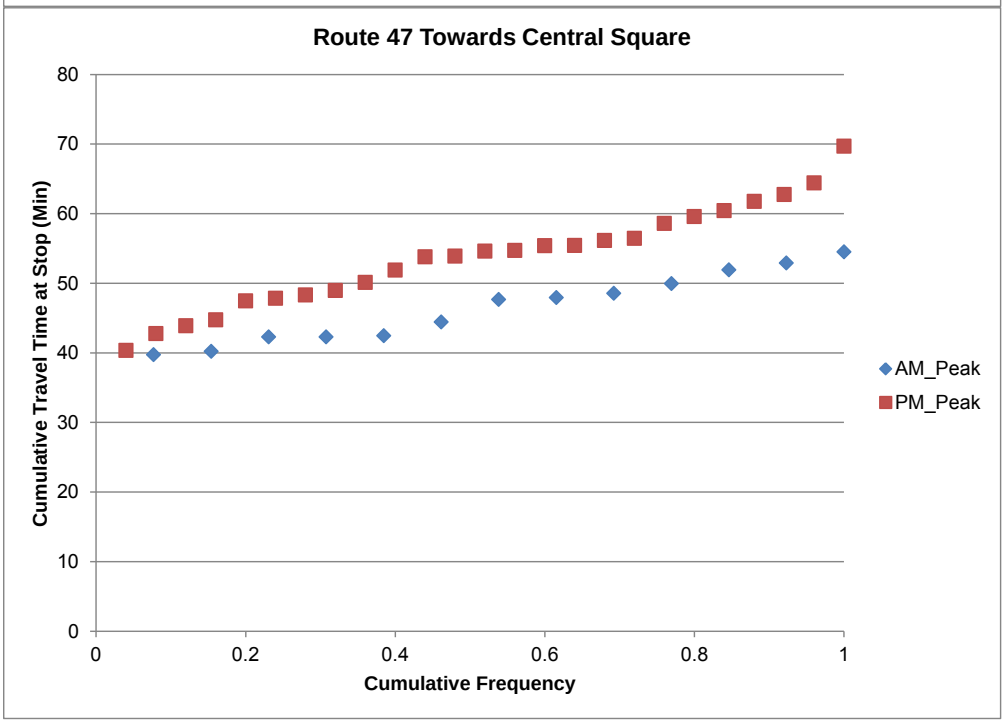
The above statements are conditioned with the word ‘may’ because circumstances outside the Study Area, maintenance of schedules headways, or other MBTA operational requirements may govern the actual amount of layover that is appropriate. Further details of the analysis are presented in Sections 4.3.1-4.3.6.

4.3.1 Route 47

The scheduled durations between arrival and departure times vs. the time of day of the start of the trip for Route 47 according to the GTFS schedule data are shown below. The median scheduled duration is approximately 11 minutes in the AM and PM peaks. The cumulative travel time at Brookline St at Tudor St is also shown below vs. the cumulative frequency of that travel time. The difference between the 95th percentile and the median is 6

minutes in the AM peak, and 9 minutes in the PM peak. There may be some scheduled duration time between arrivals and departures in the AM peak that is not required for schedule recovery alone.

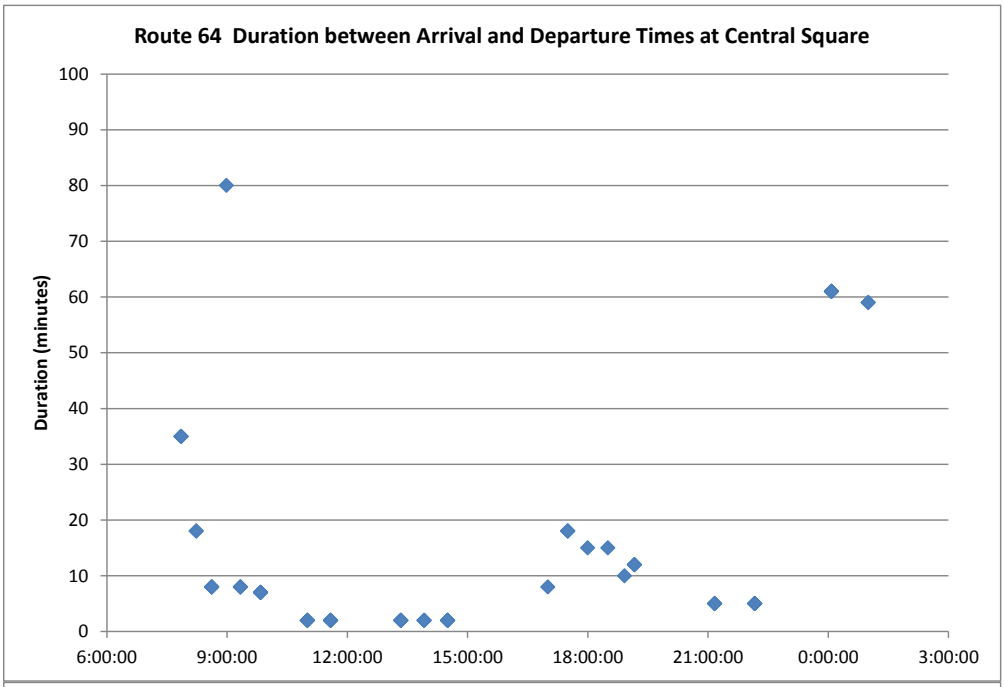


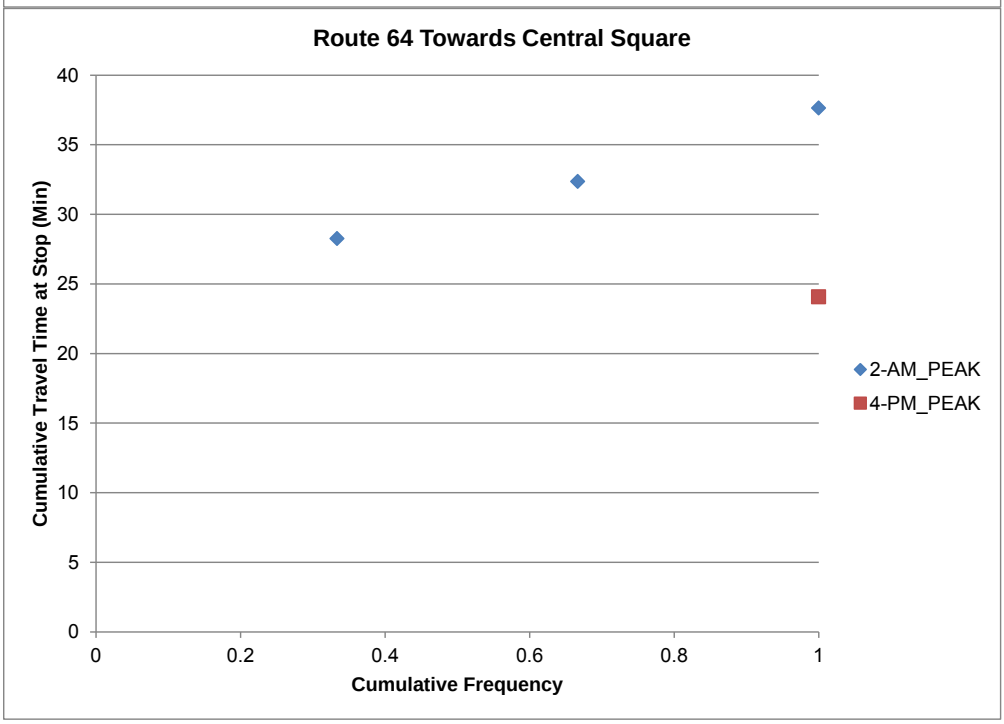


4.3.2 Route 64

The scheduled durations between arrival and departure times vs. the time of day of the start of the trip for Route 64 according to the GTFS schedule data are shown below. The typical scheduled duration is approximately 8 minutes in the AM peak and 15 minutes in the PM peak. The cumulative travel time at Magazine St at Auburn St vs. the cumulative frequency of that travel time is also shown below. There were very few APC data records for Route 64 due to lower sampling and more data errors. It is therefore not possible to estimate the variability of the cumulative travel time with any confidence. However, the difference between the 95th percentile and the median

(with the few data points that are there) is only 5 minutes in the AM peak. It appears that the scheduled duration times between arrivals and departures in the AM peak are reasonable. The data are insufficient to support a statement about the PM peak scheduled duration times between arrivals and departures.

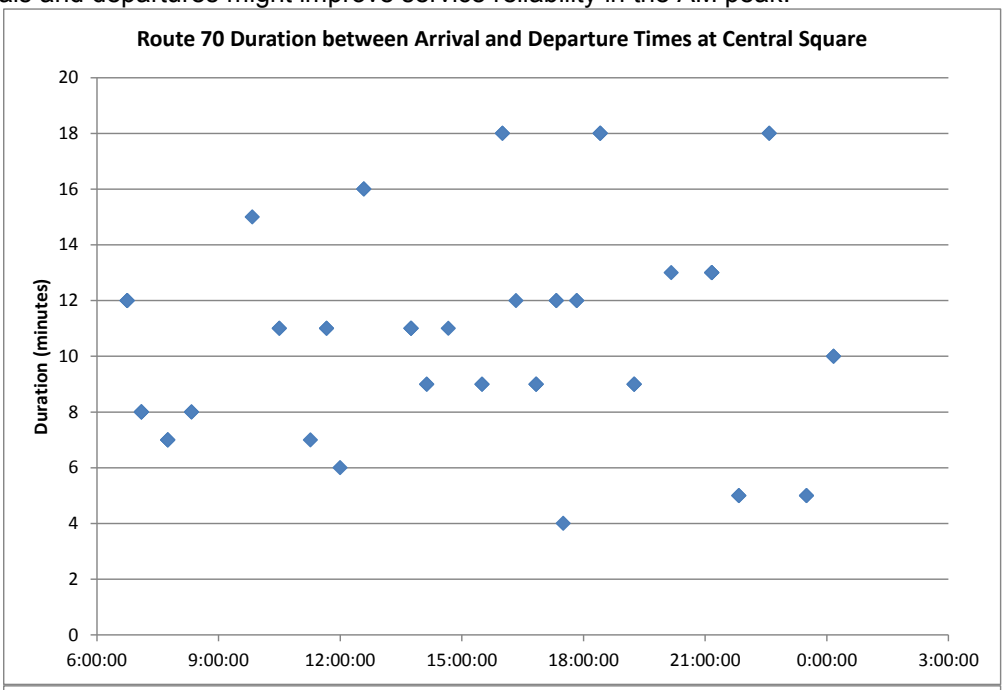


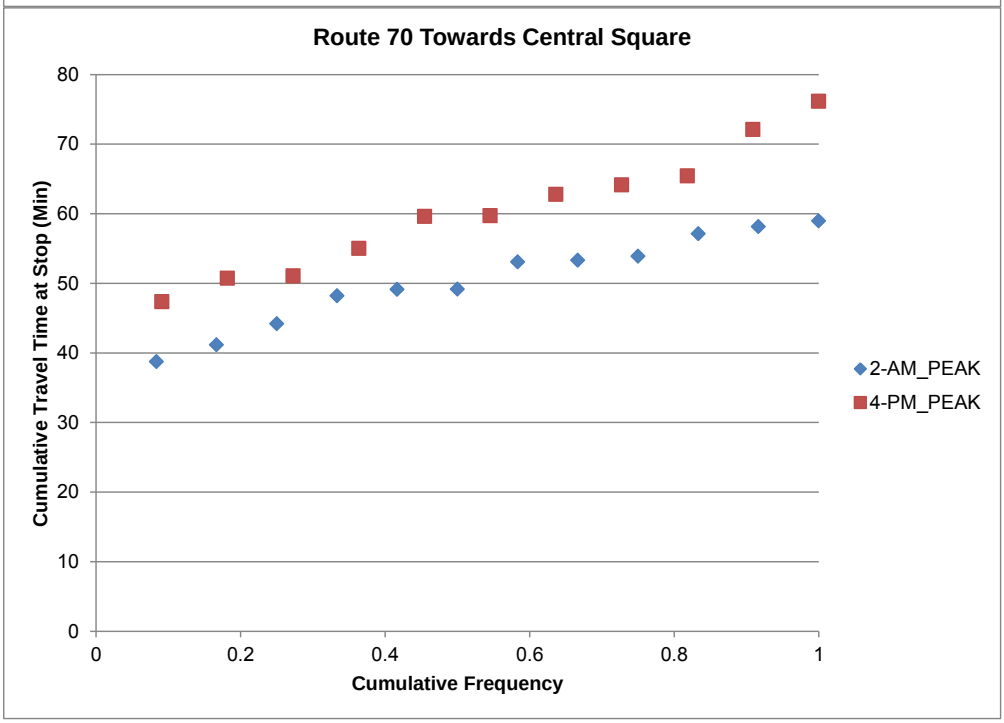


4.3.3 Route 70

The scheduled durations between arrival and departure times vs. the time of day of the start of the trip for Route 70 according to the GTFS schedule data are shown below. The median scheduled duration is approximately 8 minutes in the AM peak 12 minutes in the PM peak. The cumulative travel time at River St at Pleasant St vs. the cumulative frequency of that travel time is also shown below. The difference between the 95th percentile and the

median is 7 minutes in the AM peak, and 14 minutes in the PM peak. Some additional scheduled duration time between arrivals and departures might improve service reliability in the AM peak.

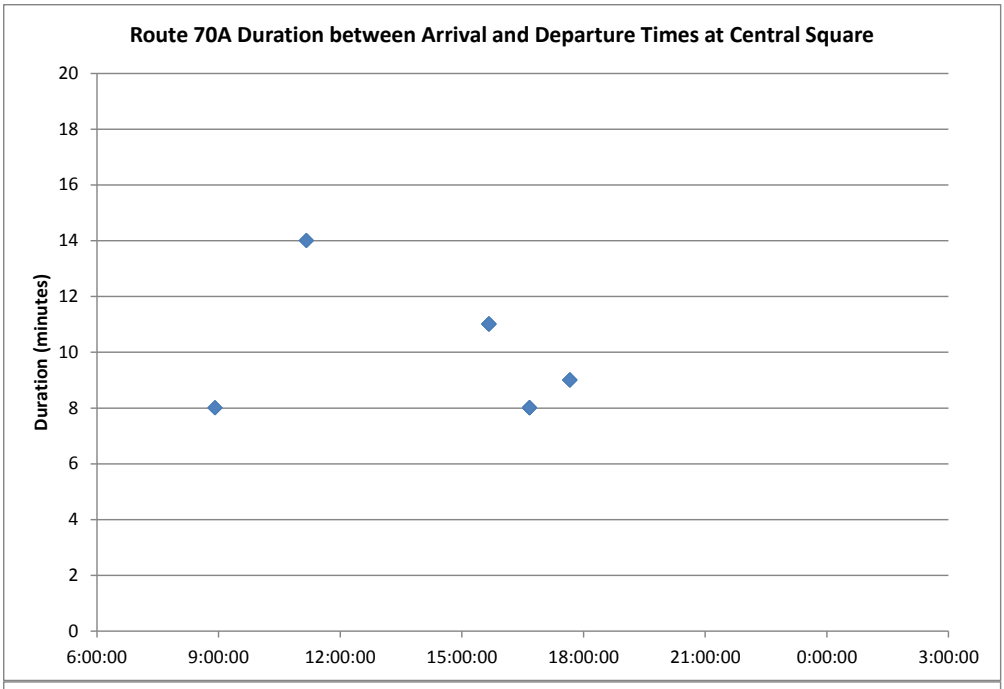


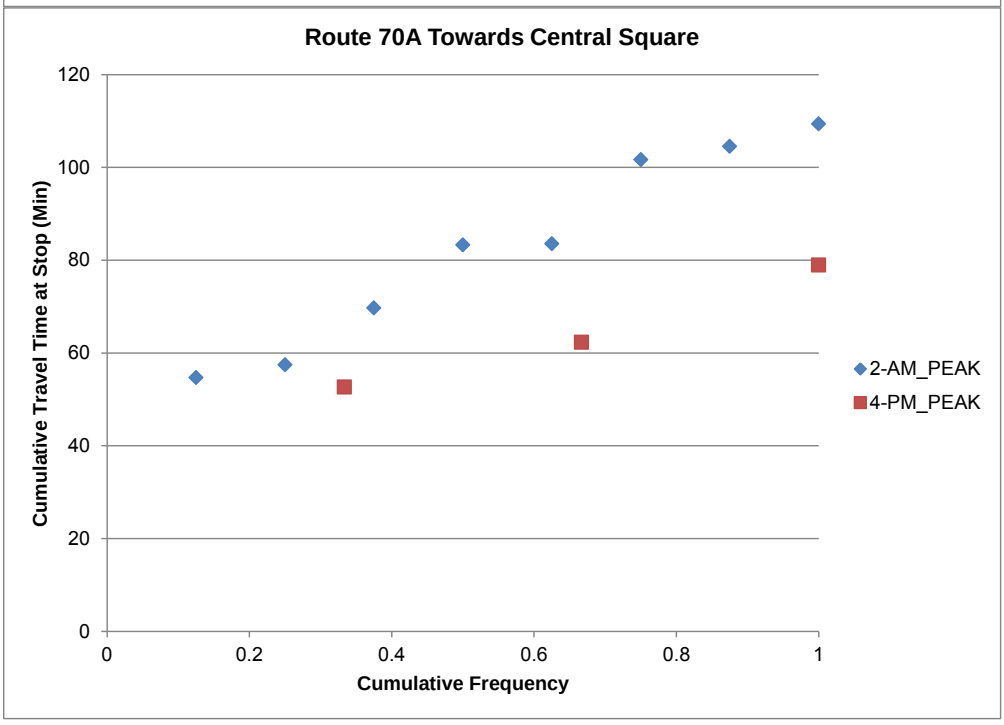


4.3.4 Route 70A

The scheduled durations between arrival and departure times vs. the time of day of the start of the trip for Route 70A according to the GTFS schedule data are shown below. The median scheduled duration is approximately 8 minutes in the AM and PM peaks. The cumulative travel time at River St at Pleasant St vs. the cumulative frequency of that travel time is also shown below. There were very few APC data records for Route 70A due to lower sampling and more data errors. It is therefore not possible to estimate the variability of the cumulative travel time with any confidence. However, the difference between the 95th percentile and the median (with the

few data points that are there) is 24 minutes in the AM peak and 15 minutes in the PM peak. Some additional scheduled duration time between arrivals and departures might be able to improve service reliability in both the AM and PM peaks.

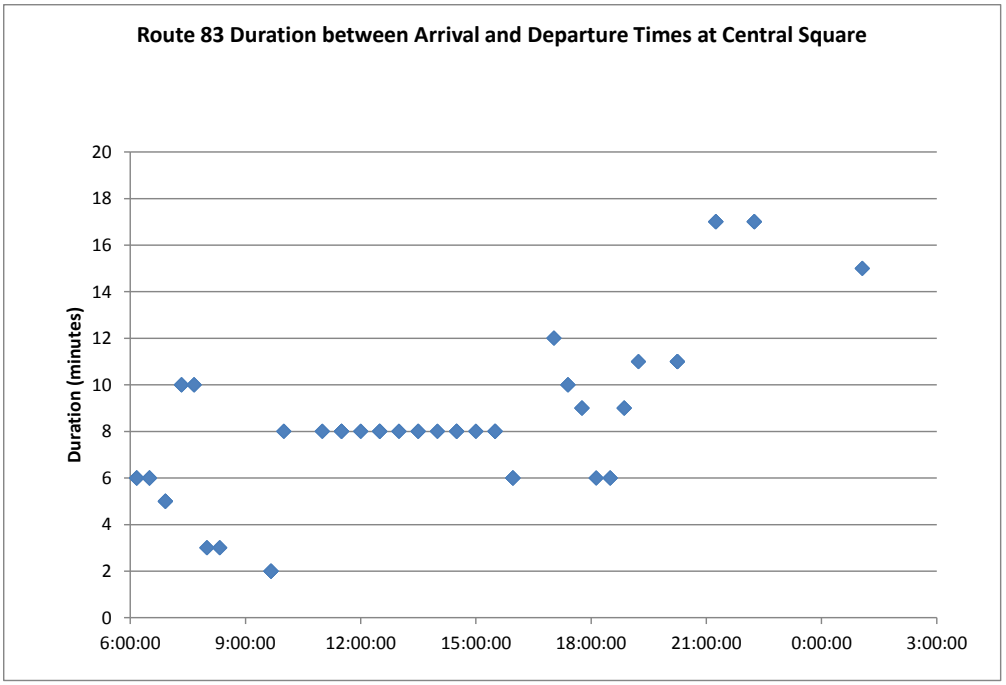


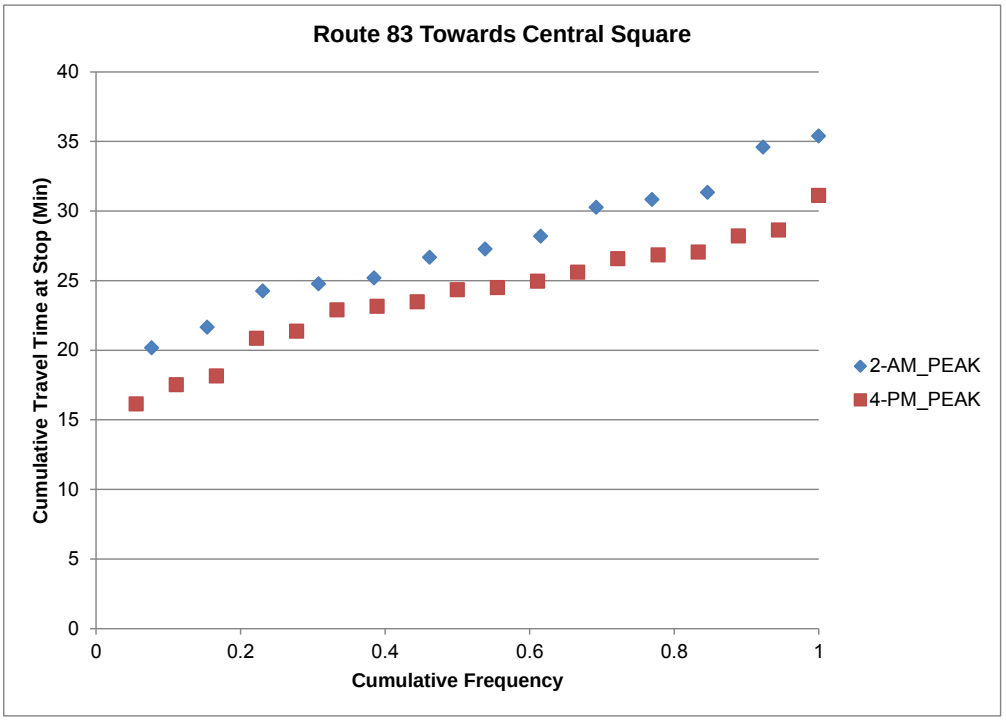


4.3.5 Route 83

The scheduled durations between arrival and departure times vs. the time of day of the start of the trip for Route 83 according to the GTFS schedule data are shown below. The median scheduled duration is approximately 10 minutes in the AM peak and 9 minutes in the PM peak. The cumulative travel time at Prospect St at Harvard St vs. the cumulative frequency of that travel time is also shown below. The difference between the 95th percentile

and the median is 8 minutes in the AM peak, and 5 minutes in the PM peak. Some additional scheduled duration time between arrivals and departures might be able to improve service reliability in both the AM and PM peaks.

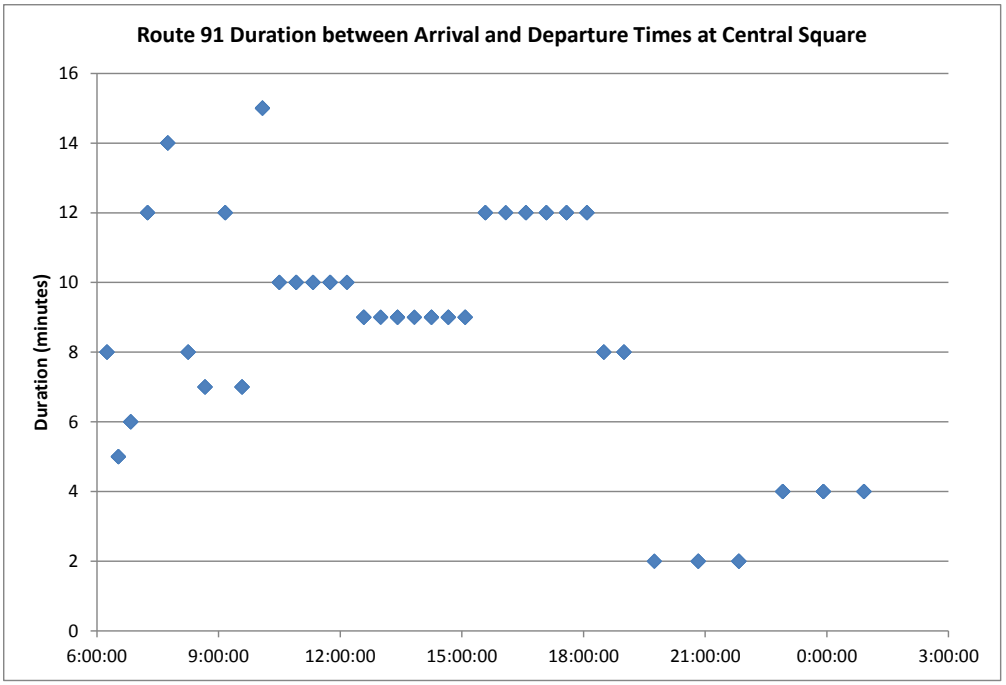


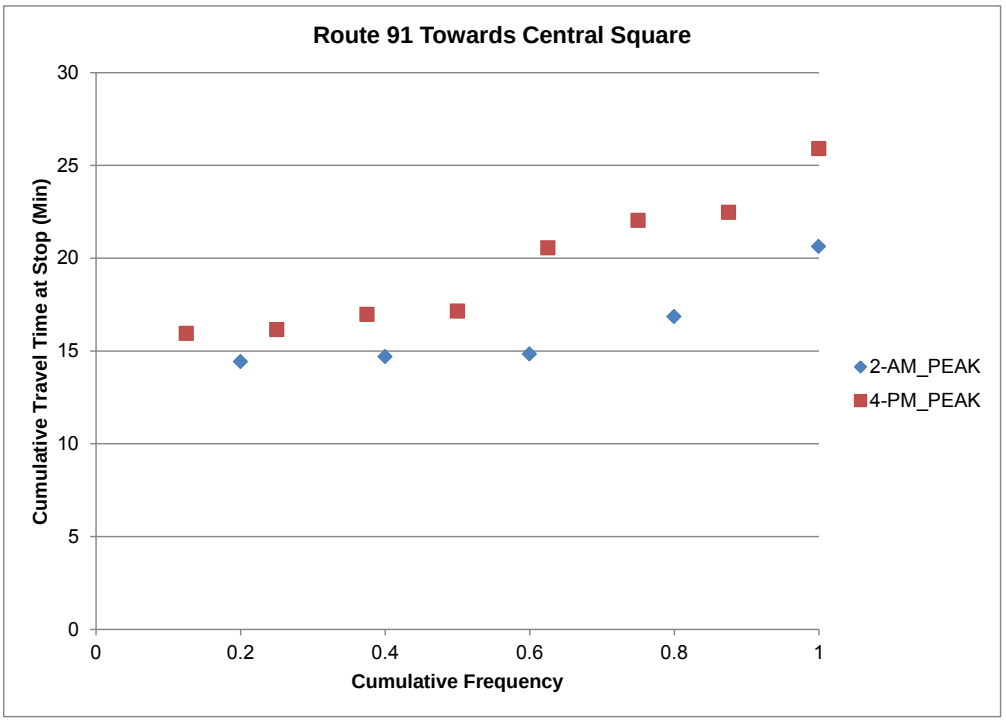


4.3.6 Route 91

The scheduled durations between arrival and departure times vs. the time of day of the start of the trip for Route 91 according to the GTFS schedule data are shown below. The median scheduled duration is approximately 10 minutes in the AM peak and 12 minutes in the PM peak. The cumulative travel time at Prospect St at Harvard St vs. the cumulative frequency of that travel time is also shown below. The difference between the 95th percentile

and the median is 5 minutes in the AM peak, and 6 minutes in the PM peak. There may be some duration time between arrivals and departures in the AM and PM peaks that is not necessary for schedule recoivery alone. .





4.4 Passenger Loads Analysis for Route 64, 70, 70A

The boarding and alighting information in the APC data also support estimation of the passenger load (*i.e.* the number of passengers in the bus) after each stop. This provides information about where most passengers are boarding and alighting and therefore what part of the route carries the most passengers. The passenger load profiles for Routes 64, 70, and 70A were calculated and are shown below.

For Routes 64, 70, and 70A in the inbound direction, the passenger load analysis indicated that during the AM peak the majority of passengers alight at the closest stop to Central Square. For Route 64, this is Magazine St at Green St, and for Route 70/70A, this stop is Mass Ave at Pearl St. A similar pattern was seen during the PM peak for Route 70 and 70A. In the outbound direction for Route 70/70A, the majority of passengers board at Green St at Magazine St, despite there also being a stop at Green St at Pearl St which is nearly as close to Central Square.

As noted in Section 3, a significant number of the passengers transfer between these routes and the Red Line, or have Central Square as their origin/destination, and this has implications for the pedestrian access to and from the buses.

Further details of the analysis are presented in Sections 4.4.1-4.4.3.

4.4.1 Route 64

In the peak periods Route 64 runs from Oak Square to Kendall Square via the stop at Magazine and Green Streets as shown in the figures below.

Figure 13: Route 64 Inbound (Towards Kendall) in Peak Periods

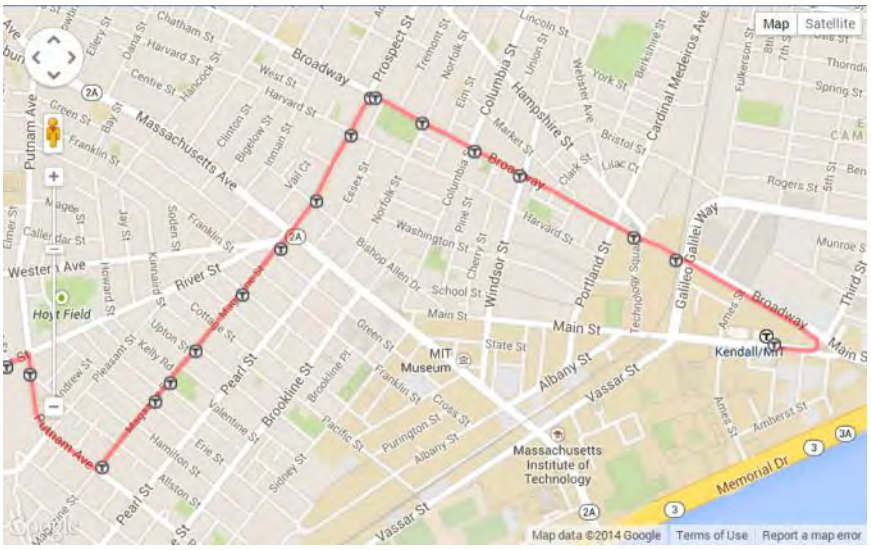
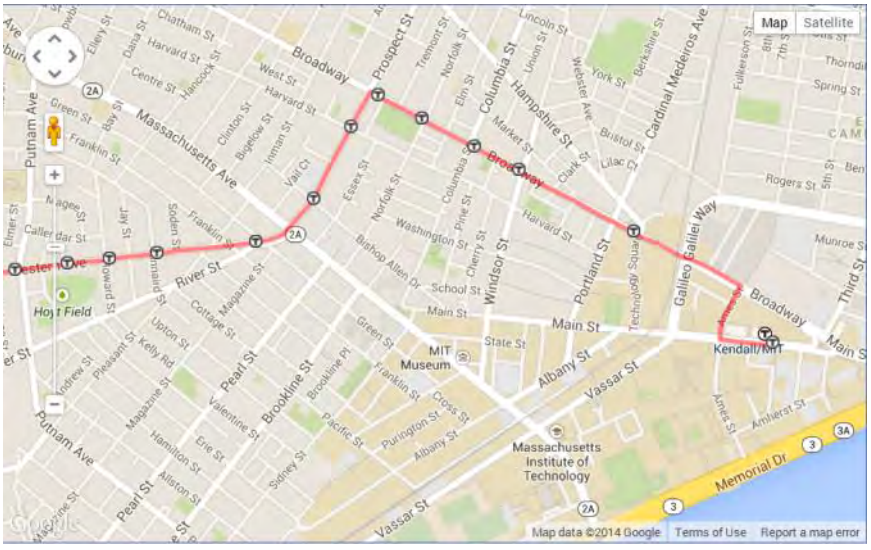
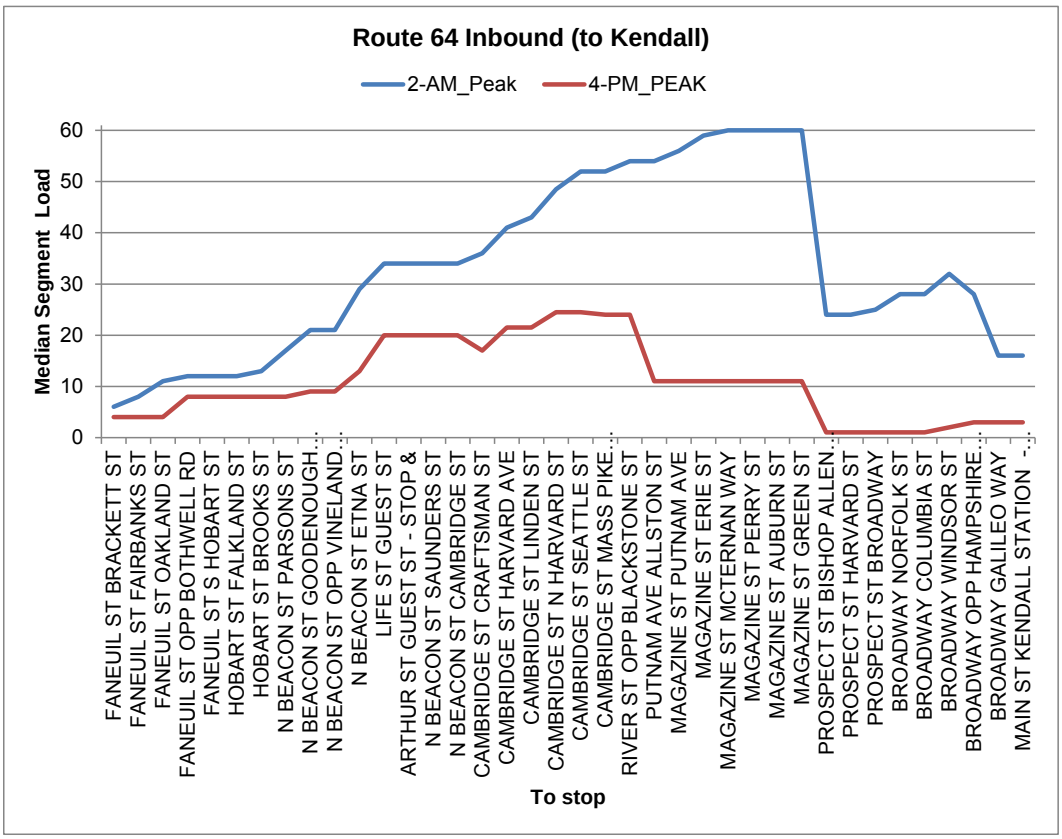
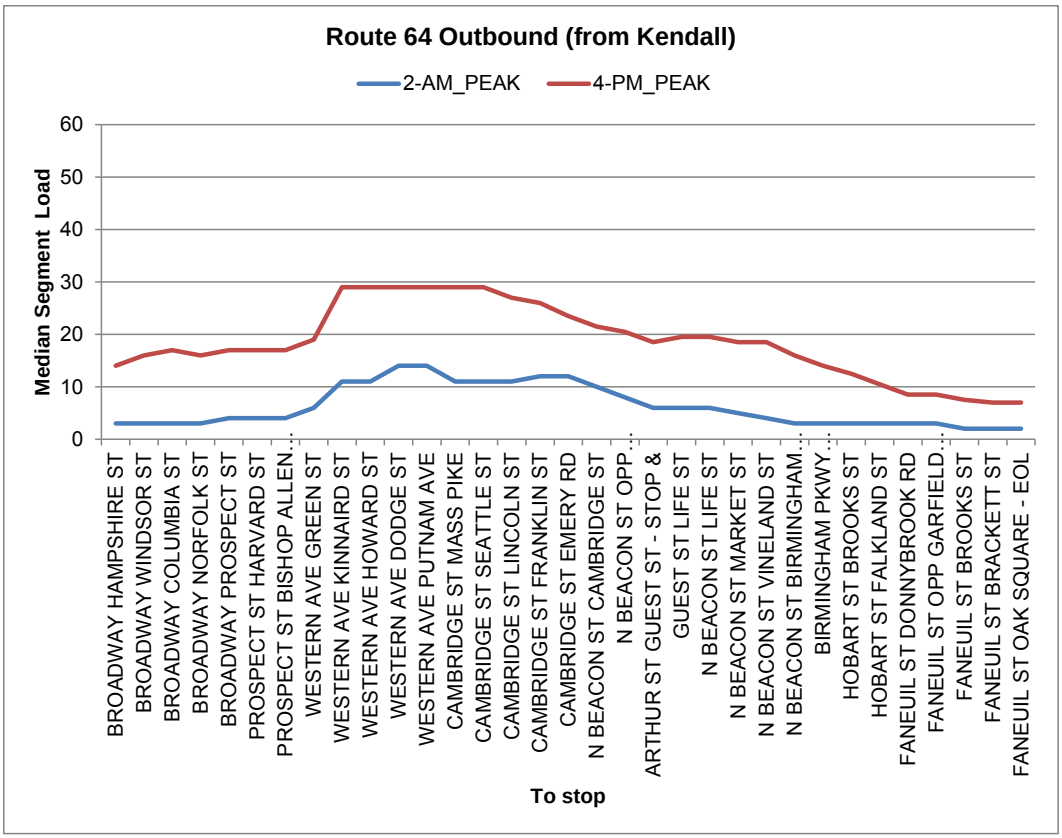


Figure 14: Route 64 Outbound (From Kendall) in Peak Periods



The load profiles show that there are far more passengers in the Inbound direction in the morning and that most passengers are alighting at the stop closest to Central Square (Magazine St at Green St). The average net alightings of about 35 passengers at this stop suggests that there could be crowding issues at the stop in the morning peak period.





During the off-peak periods, Route 64 operates between Oak Square and Central Square using the stop at Green St at Magazine St in the Outbound direction as shown in the figures below.

Figure 15: Route 64 Inbound (Towards Central) in Off-Peak Periods

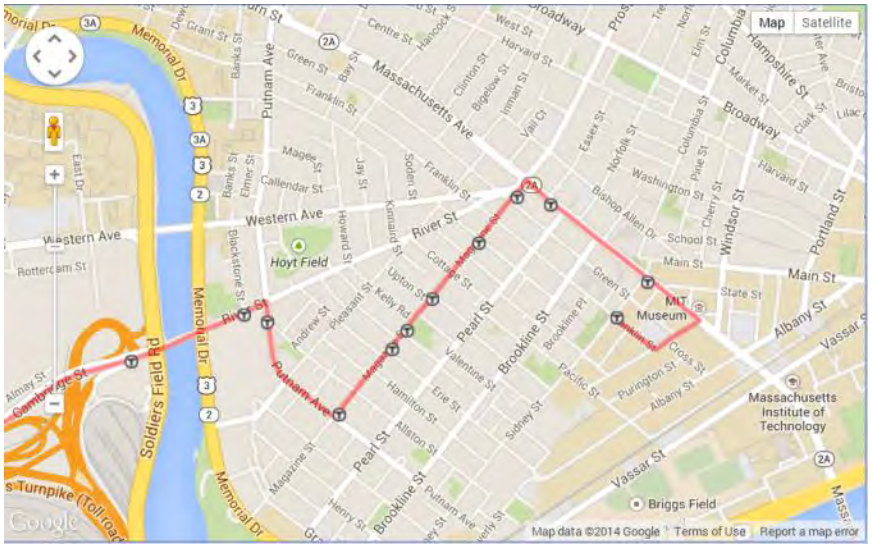
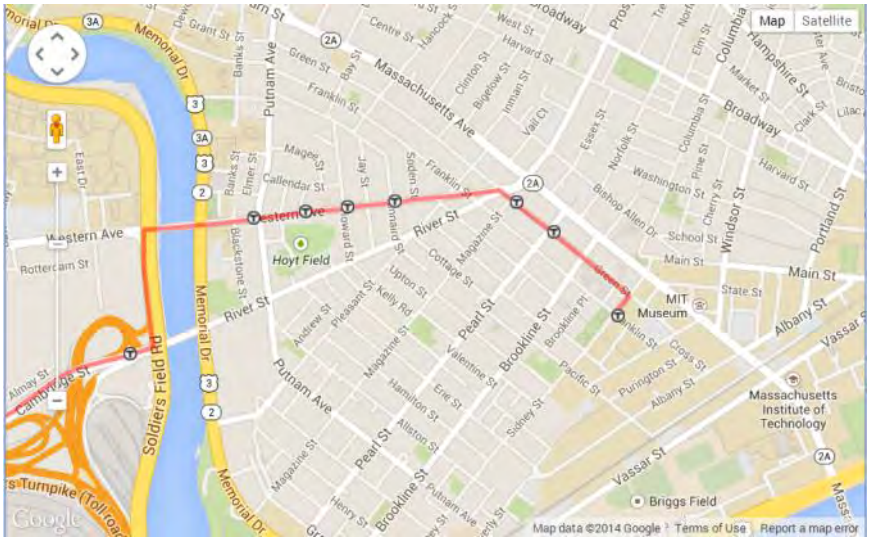
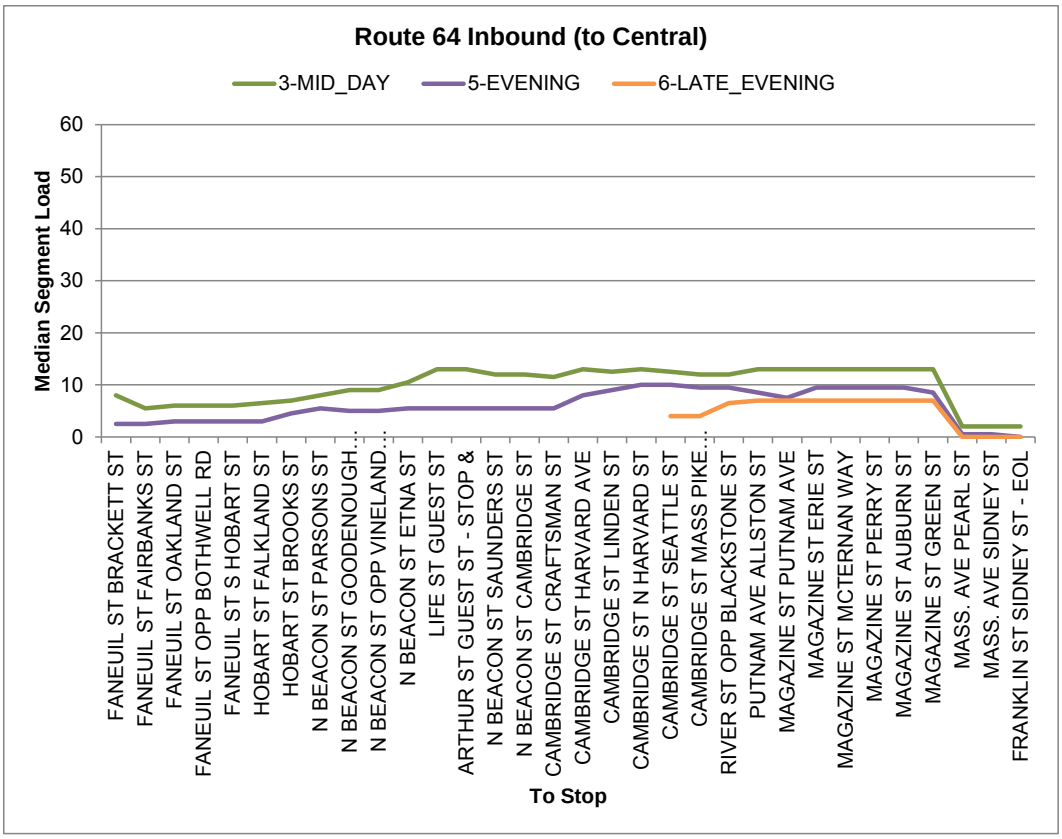
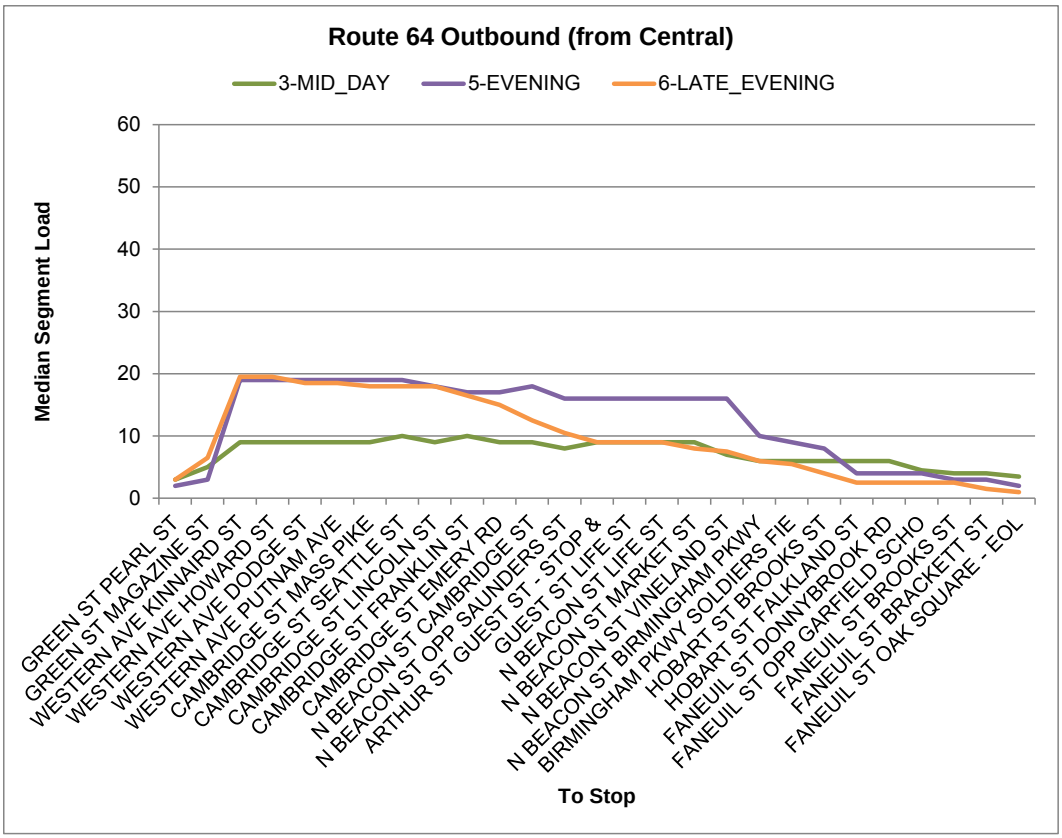


Figure 16: Route 64 Outbound (From Central) in Off-Peak Periods



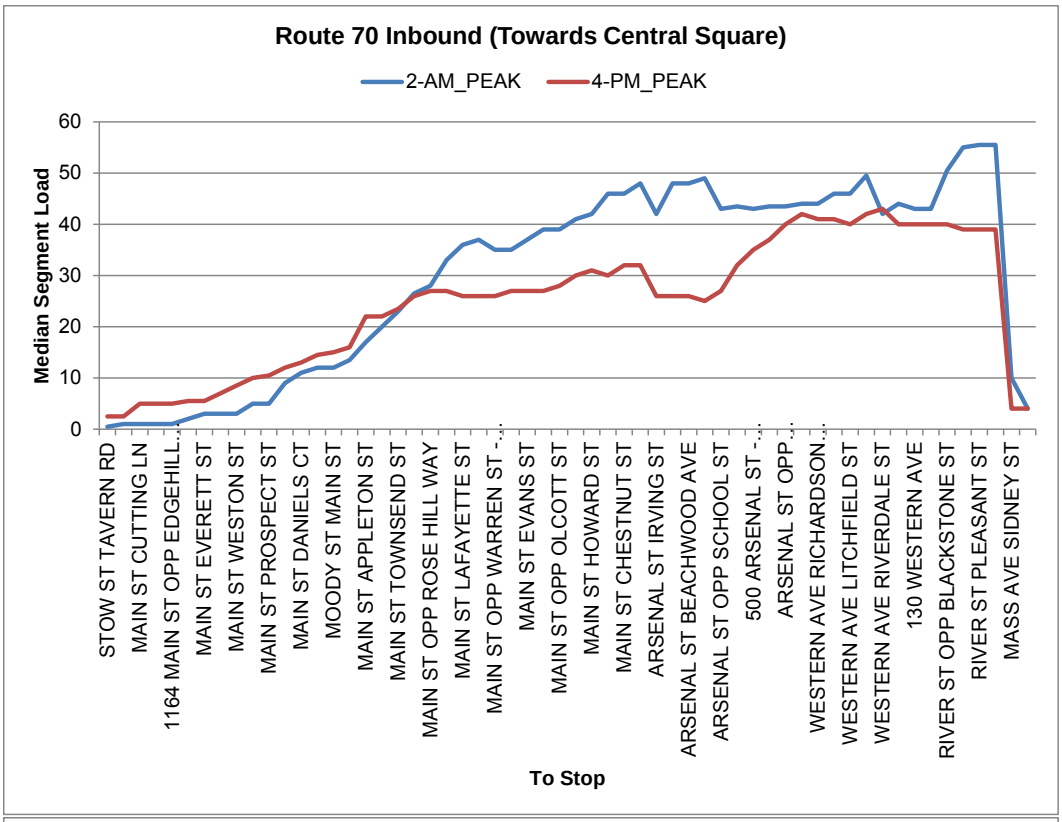
The load profiles show that there are far fewer passengers using this route variant. The highest loads are seen in the outbound direction with most people getting on at Green St at Magazine St at then steadily alighting at stops in Allston/Brighton.

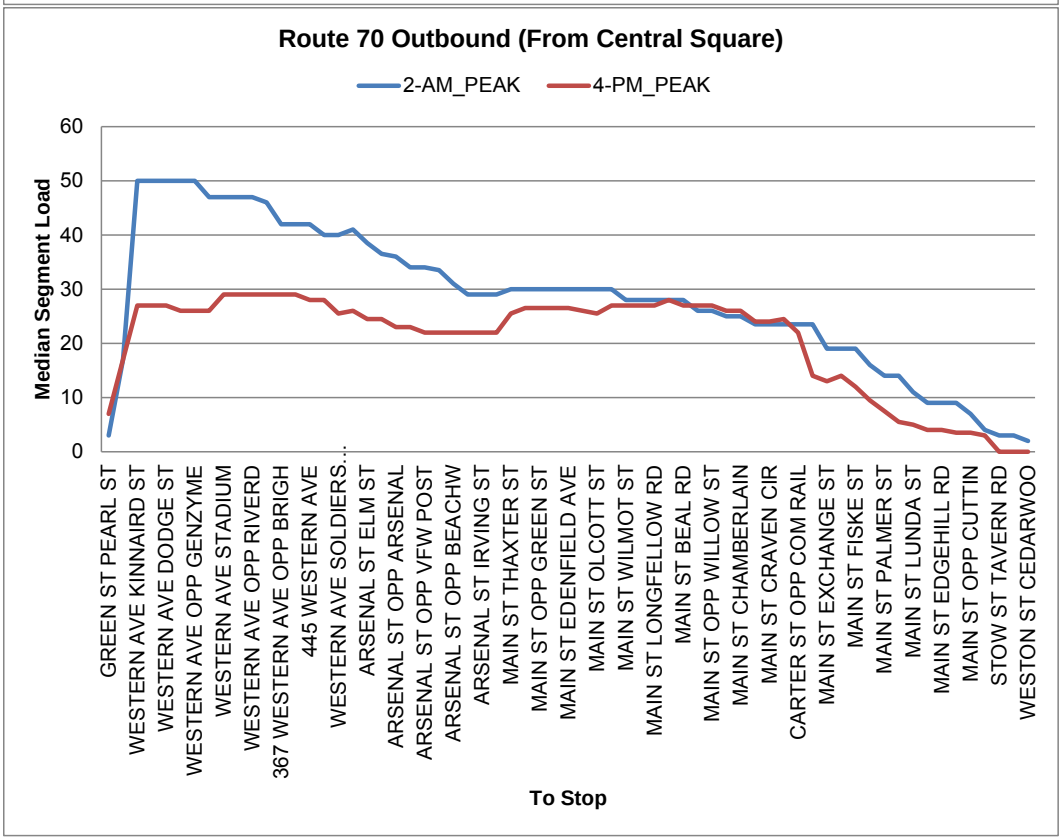




4.4.2 Route 70

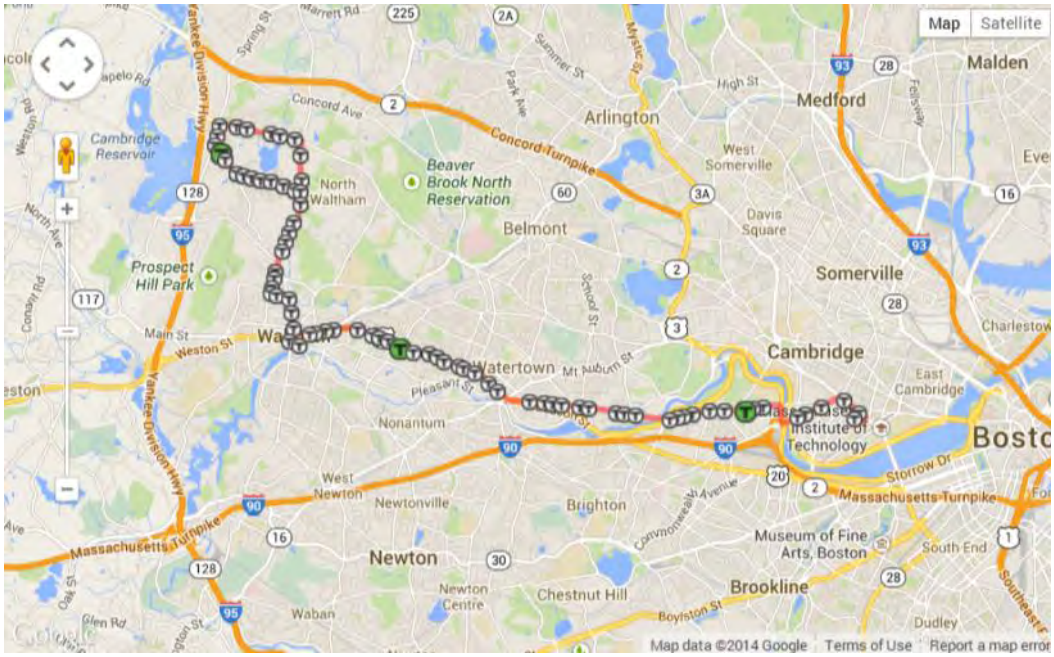
The most frequent variant of Route 70 operates between Weston St at Cedarwood Ave in Waltham to Franklin St at Sidney St in Central Square. In the inbound direction the load profiles below show that most passengers are boarding steadily through Waltham and Watertown with steady loads once the route reaches Western Ave in Boston. There is a large drop in load at Massachusetts Ave and Pearl St. which is the stop closest to Central Square subway station. In the outbound direction, especially in the AM peak most passengers are boarding at the Green St at Magazine St stop, which from site visits also showed large numbers of crowding. There is a steady decline in loads until the Waltham commuter rail station.


Route 70 Inbound (Towards Central Square)
2-AM_PEAK
4-PM_PEAK
Median Segment Load
60
50
40
30
20
10
0
STOW ST TAVERN RD
MAIN ST CUTTING LN
1164 MAIN ST OPP EDGEHILL...
MAIN ST EVERETT ST
MAIN ST WESTON ST
MAIN ST PROSPECT ST
MAIN ST DANIELS CT
MOODY ST MAIN ST
MAIN ST APPLETON ST
MAIN ST TOWNSEND ST
MAIN ST OPP ROSE HILL WAY
MAIN ST LAFAYETTE ST
MAIN ST OPP WARREN ST -...
MAIN ST EVANS ST
MAIN ST OPP OLCOTT ST
MAIN ST HOWARD ST
MAIN ST CHESTNUT ST
ARSENAL ST IRVING ST
ARSENAL ST BEACHWOOD AVE
ARSENAL ST OPP SCHOOL ST
500 ARSENAL ST -...
ARSENAL ST OPP ...
WESTERN AVE RICHARDSON...
WESTERN AVE LITCHFIELD ST
WESTERN AVE RIVERDALE ST
130 WESTERN AVE
RIVER ST OPP BLACKSTONE ST
RIVER ST PLEASANT ST
MASS AVE SIDNEY ST
To Stop

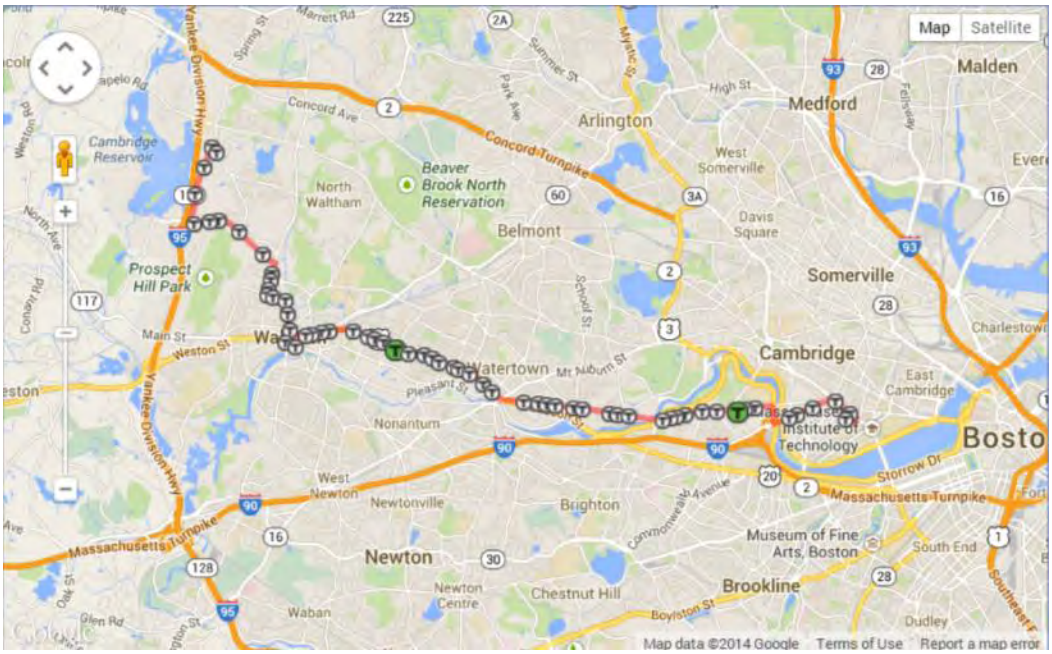

Route 70 Outbound (From Central Square)
2-AM_PEAK
4-PM_PEAK
Median Segment Load
60
50
40
30
20
10
0
GREEN ST PEARL ST
WESTERN AVE KINNAIRD ST
WESTERN AVE DODGE ST
WESTERN AVE OPP GENZYME
WESTERN AVE STADIUM
WESTERN AVE OPP RIVERD
367 WESTERN AVE OPP BRIGH
445 WESTERN AVE
WESTERN AVE SOLDIERS...
ARSENAL ST ELM ST
ARSENAL ST OPP ARSENAL
ARSENAL ST OPP VFW POST
ARSENAL ST OPP BEACHW
ARSENAL ST IRVING ST
MAIN ST THAXTER ST
MAIN ST OPP GREEN ST
MAIN ST EDENFIELD AVE
MAIN ST OLCOTT ST
MAIN ST WILMOT ST
MAIN ST LONGFELLOW RD
MAIN ST BEAL RD
MAIN ST OPP WILLOW ST
MAIN ST CHAMBERLAIN
MAIN ST CRAVEN CIR
CARTER ST OPP COM RAIL
MAIN ST EXCHANGE ST
MAIN ST FISKE ST
MAIN ST PALMER ST
MAIN ST LUNDA ST
MAIN ST EDGEHILL RD
MAIN ST OPP CUTTIN
STOW ST TAVERN RD
WESTON ST CEDARWOO
To Stop

4.4.3 Route 70A

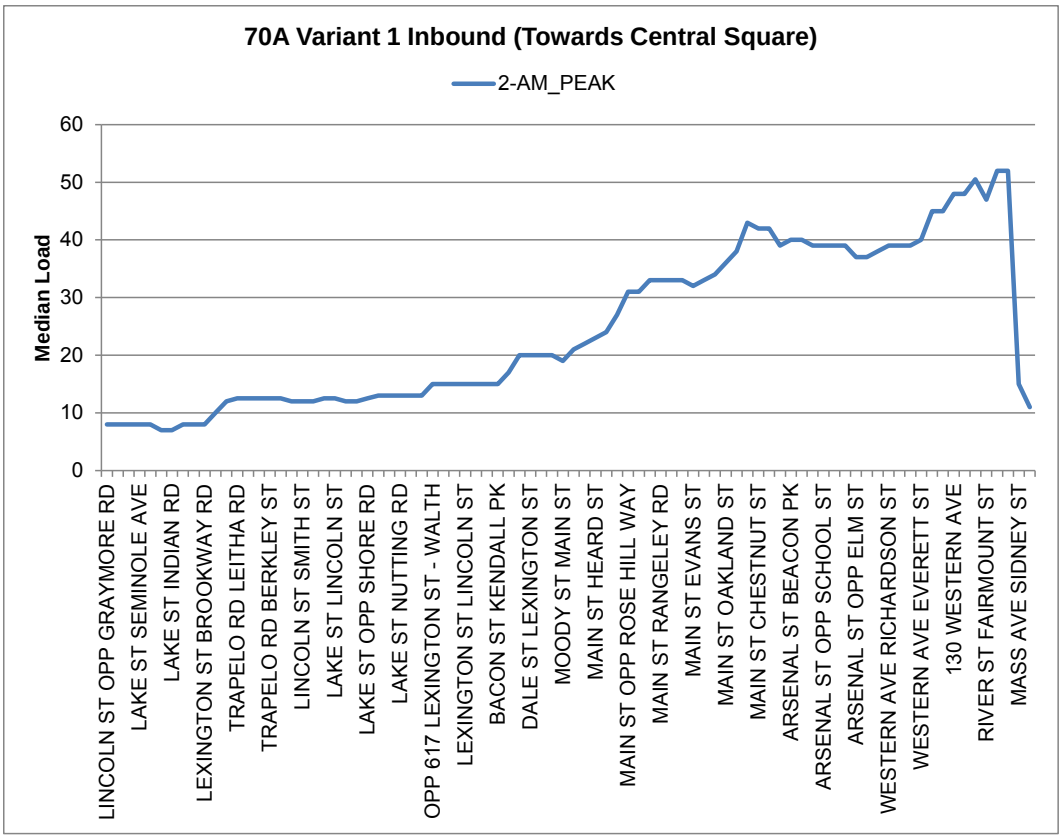
Route 70A operates between Cedarwood and North Waltham or Watertown Square and Central Square with different variants based on the time of day. All 70A variants analyzed operate to and from the stop at Franklin St at Sidney St. Route 70A Variant 1 operates via the route shown below.

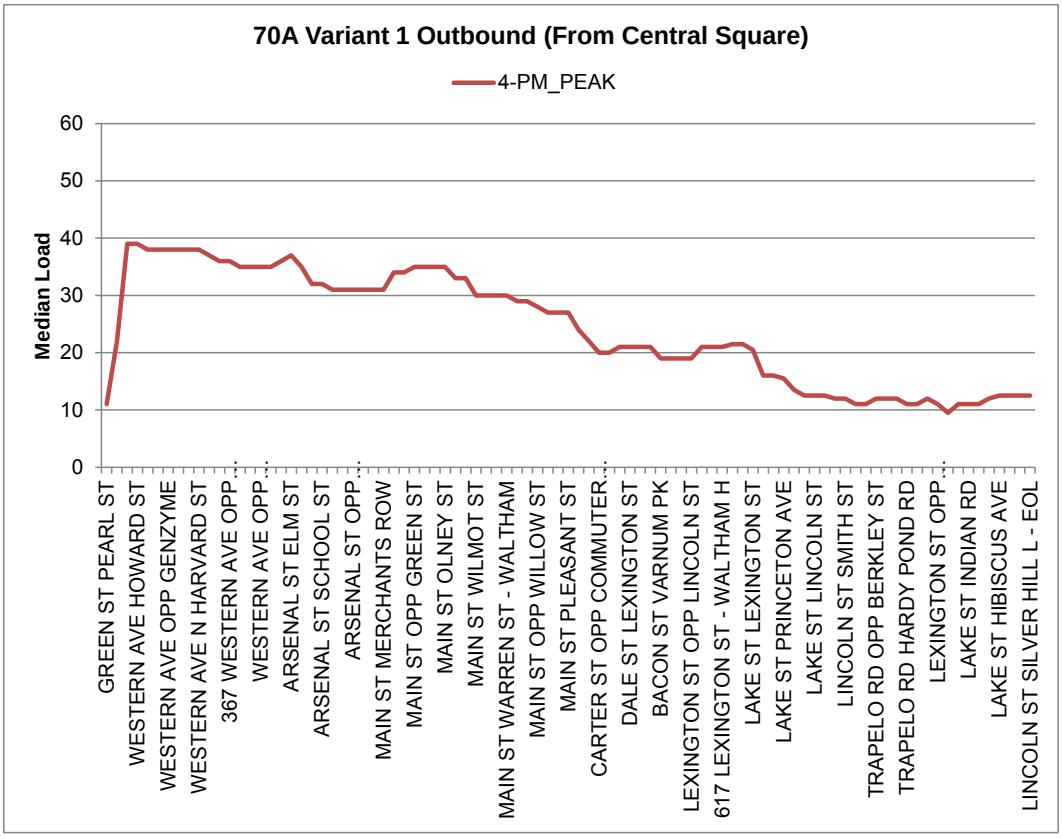


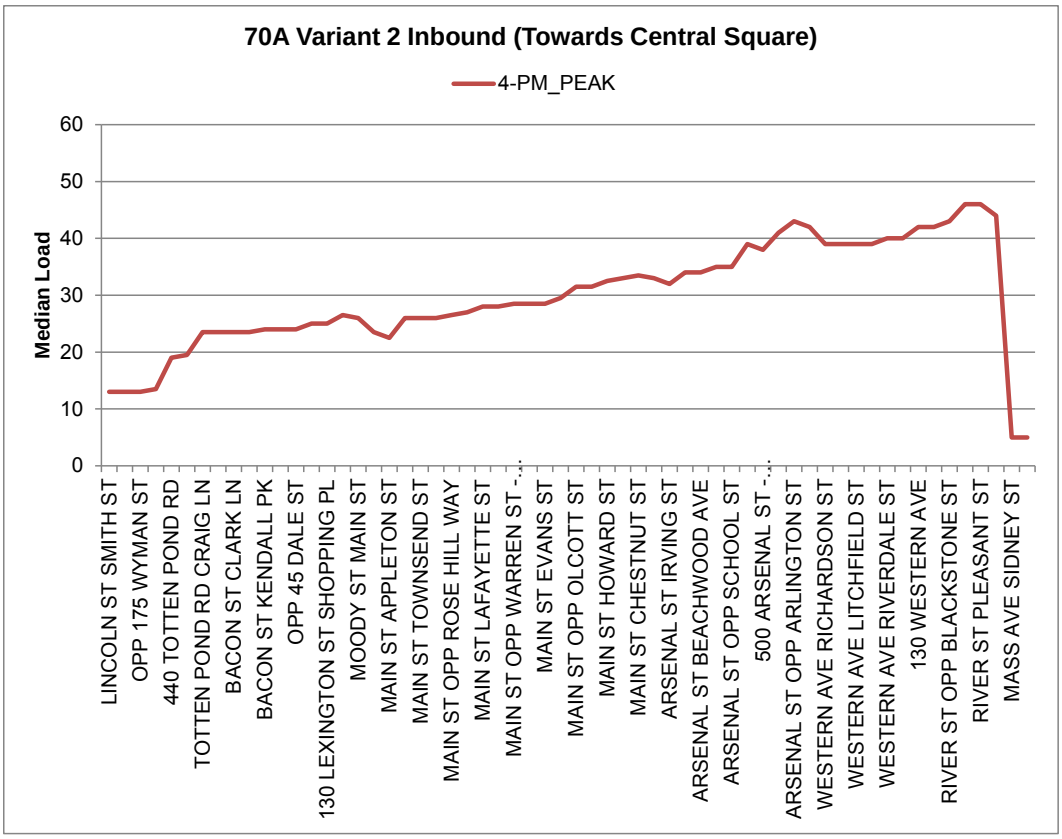
Route 70A Variant 2 operates via the route shown below.

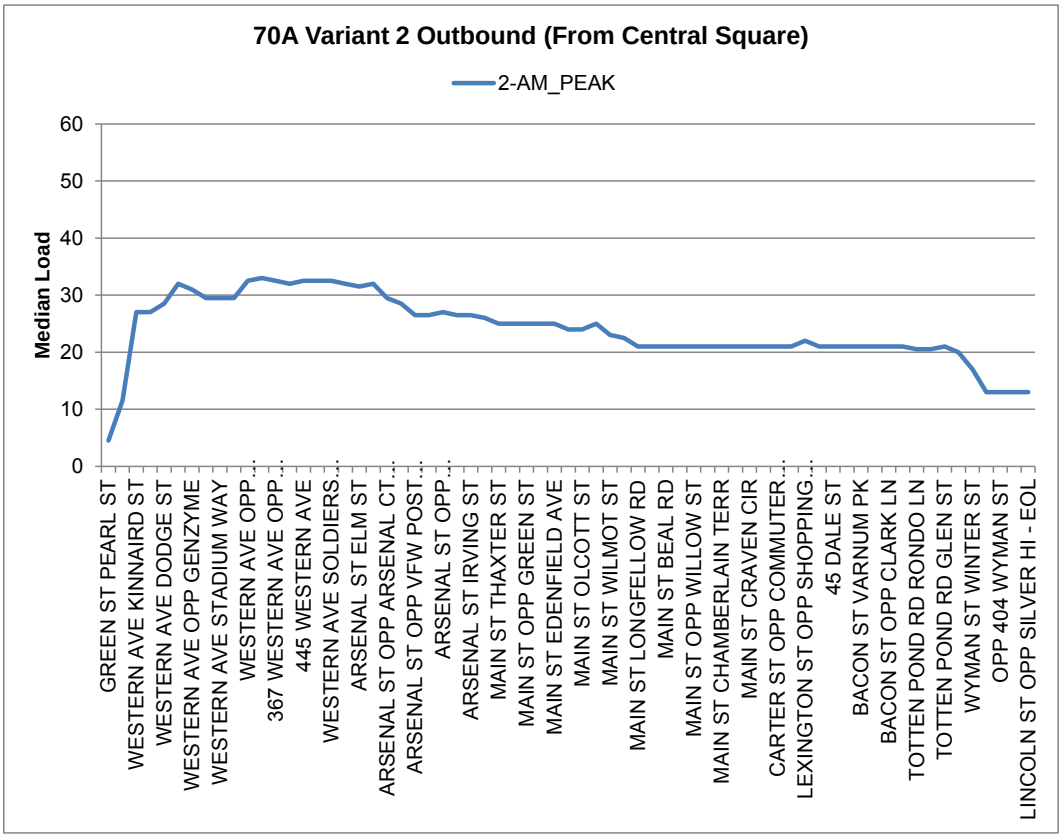


The load profiles for the two variants are shown in the figures below. They have similar load profiles to Route 70.


70A Variant 1 Inbound (Towards Central Square)
2-AM_PEAK
Median Load
60
50
40
30
20
10
0
LINCOLN ST OPP GRAYMORE RD
LAKE ST SEMINOLE AVE
LAKE ST INDIAN RD
LEXINGTON ST BROOKWAY RD
TRAPELO RD LEITHA RD
TRAPELO RD BERKLEY ST
LINCOLN ST SMITH ST
LAKE ST LINCOLN ST
LAKE ST OPP SHORE RD
LAKE ST NUTTING RD
OPP 617 LEXINGTON ST - WALTH
LEXINGTON ST LINCOLN ST
BACON ST KENDALL PK
DALE ST LEXINGTON ST
MOODY ST MAIN ST
MAIN ST HEARD ST
MAIN ST OPP ROSE HILL WAY
MAIN ST RANGELEY RD
MAIN ST EVANS ST
MAIN ST OAKLAND ST
MAIN ST CHESTNUT ST
ARSENAL ST BEACON PK
ARSENAL ST OPP SCHOOL ST
ARSENAL ST OPP ELM ST
WESTERN AVE RICHARDSON ST
WESTERN AVE EVERETT ST
130 WESTERN AVE
RIVER ST FAIRMOUNT ST
MASS AVE SIDNEY ST


70A Variant 1 Outbound (From Central Square)
4-PM_PEAK
Median Load
60
50
40
30
20
10
0
GREEN ST PEARL ST
WESTERN AVE HOWARD ST
WESTERN AVE OPP GENZYME
WESTERN AVE N HARVARD ST
367 WESTERN AVE OPP...
WESTERN AVE OPP...
ARSENAL ST ELM ST
ARSENAL ST SCHOOL ST
ARSENAL ST OPP...
MAIN ST MERCHANTS ROW
MAIN ST OPP GREEN ST
MAIN ST OLNEY ST
MAIN ST WILMOT ST
MAIN ST WARREN ST - WALTHAM
MAIN ST OPP WILLOW ST
MAIN ST PLEASANT ST
CARTER ST OPP COMMUTER...
DALE ST LEXINGTON ST
BACON ST VARNUM PK
LEXINGTON ST OPP LINCOLN ST
617 LEXINGTON ST - WALTHAM H
LAKE ST LEXINGTON ST
LAKE ST PRINCETON AVE
LAKE ST LINCOLN ST
LINCOLN ST SMITH ST
TRAPELO RD OPP BERKLEY ST
TRAPELO RD HARDY POND RD
LEXINGTON ST OPP...
LAKE ST INDIAN RD
LAKE ST HIBISCUS AVE
LINCOLN ST SILVER HILL L - EOL


70A Variant 2 Inbound (Towards Central Square)
4-PM_PEAK
Median Load
60
50
40
30
20
10
0
LINCOLN ST SMITH ST
OPP 175 WYMAN ST
440 TOTTEN POND RD
TOTTEN POND RD CRAIG LN
BACON ST CLARK LN
BACON ST KENDALL PK
OPP 45 DALE ST
130 LEXINGTON ST SHOPPING PL
MOODY ST MAIN ST
MAIN ST APPLETON ST
MAIN ST TOWNSEND ST
MAIN ST OPP ROSE HILL WAY
MAIN ST LAFAYETTE ST
MAIN ST OPP WARREN ST -...
MAIN ST EVANS ST
MAIN ST OPP OLCOTT ST
MAIN ST HOWARD ST
MAIN ST CHESTNUT ST
ARSENAL ST IRVING ST
ARSENAL ST BEACHWOOD AVE
ARSENAL ST OPP SCHOOL ST
500 ARSENAL ST -...
ARSENAL ST OPP ARLINGTON ST
WESTERN AVE RICHARDSON ST
WESTERN AVE LITCHFIELD ST
WESTERN AVE RIVERDALE ST
130 WESTERN AVE
RIVER ST OPP BLACKSTONE ST
RIVER ST PLEASANT ST
MASS AVE SIDNEY ST


70A Variant 2 Outbound (From Central Square)
2-AM_PEAK
Median Load
60
50
40
30
20
10
0
GREEN ST PEARL ST
WESTERN AVE KINNAIRD ST
WESTERN AVE DODGE ST
WESTERN AVE OPP GENZYME
WESTERN AVE STADIUM WAY
WESTERN AVE OPP...
367 WESTERN AVE OPP...
445 WESTERN AVE
WESTERN AVE SOLDIERS...
ARSENAL ST ELM ST
ARSENAL ST OPP ARSENAL CT...
ARSENAL ST OPP VFW POST...
ARSENAL ST OPP...
ARSENAL ST IRVING ST
MAIN ST THAXTER ST
MAIN ST OPP GREEN ST
MAIN ST EDENFIELD AVE
MAIN ST OLCOTT ST
MAIN ST WILMOT ST
MAIN ST LONGFELLOW RD
MAIN ST BEAL RD
MAIN ST OPP WILLOW ST
MAIN ST CHAMBERLAIN TERR
MAIN ST CRAVEN CIR
CARTER ST OPP COMMUTER...
LEXINGTON ST OPP SHOPPING...
45 DALE ST
BACON ST VARNUM PK
BACON ST OPP CLARK LN
TOTTEN POND RD RONDO LN
TOTTEN POND RD GLEN ST
WYMAN ST WINTER ST
OPP 404 WYMAN ST
LINCOLN ST OPP SILVER HI - EOL

4.5 Potential for Crowding at Stops in the Study Area

APC data were used to estimate the number of passengers boarding and alighting at the two stops at Green and Magazine streets. If the stop is not an origin or destination point of the route, this was done by taking the load at the segment after the stop minus the load of the segment before the stop. For these routes, Route 64, 70, 70A, the boarding and alighting estimates are not exact because passengers are both boarding and alighting at the stop and only the net result is known. For stops where many more passengers board than alight, the load of the following segment will be much higher than the load of the previous segment. Therefore this is a conservative estimate of the number of passengers that boarded the stop. If there is not much difference between the load of the following segment vs. the load of the previous segment, it could be that no one got on or off, or the same number of people got on and off. However, the routes where the stop is not the origin or destination, 64, 70, and 70A, the stop of interest is very close to the start/end of the route and the boarding/alighting estimates at this stop should be good estimates.

If the route terminated at the stop (Route 47 Outbound, 83 Inbound, 91 Inbound, and CT1 Inbound) the load of the last segment was used. This is a good estimate of the number of passengers that alighted at this stop because passengers are not allowed to board at the last stop. If the route originated at the stop (Route 83 Outbound, 91 Outbound, and CT1 Outbound), the load of the first segment was used.

This analysis found that the Green St at Magazine St bus stop is likely crowded throughout the day. Further details are in Sections 4.5.1-4.5.3.

4.5.1 Green St at Magazine St

The stop on Green St. at Magazine St. serves routes, 47, 64, 70, and 70A.

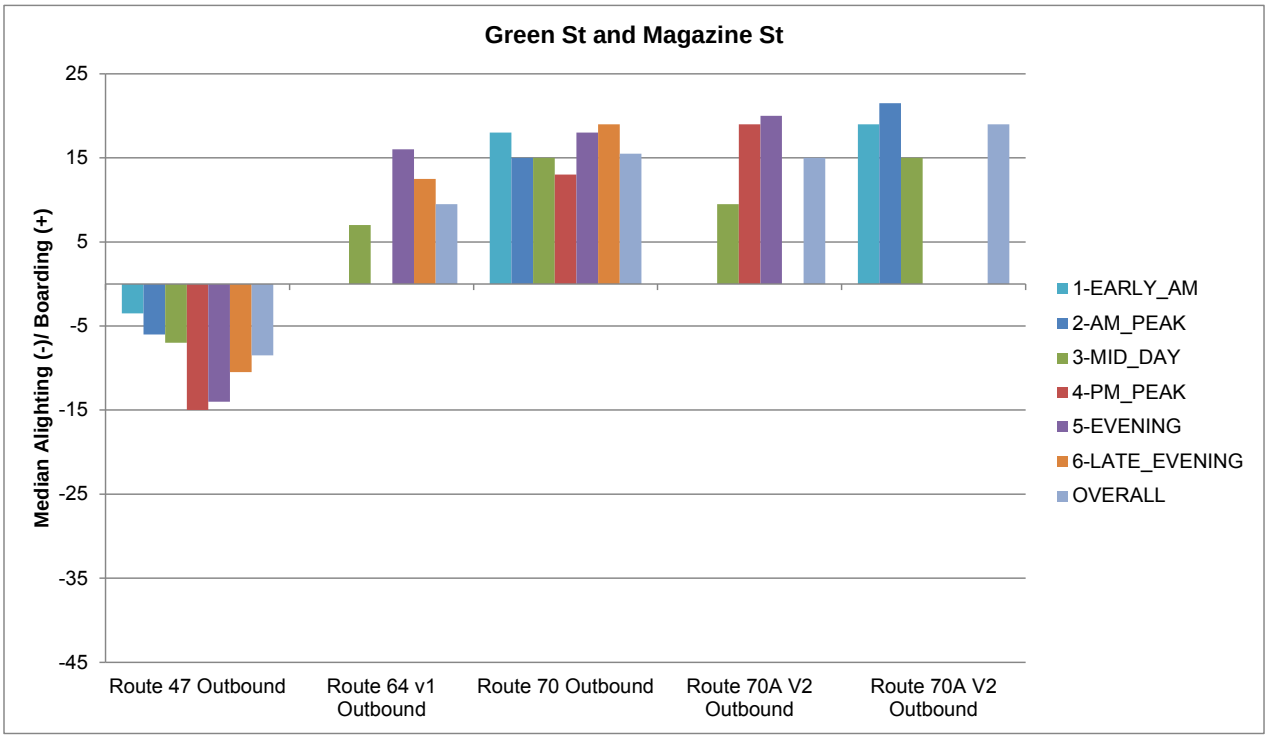
This stop is the last stop for Route 47 in the Outbound direction (towards Central Square).

This stop is also served by the variant of Route 64 that starts in Central Square in the outbound direction in the off-peak. This is the 3rd stop of this route variant. This route originates at Franklin St at Sidney St. then stops at Green St at Pearl St., then stops at Green St at Magazine St before carrying on with the rest of the route.

Routes 70 and 70A use this stop in the Outbound direction. This is the 3rd stop for these routes. These routes originate at Franklin St at Sidney St. then stop at Green St at Pearl St., then stop at Green St at Magazine St before carrying on with the rest of the route.

This figure shows that this stop is an alighting location for Route 47, with the most passengers alighting during the PM peak. This stop is a boarding location for the other routes. Boardings at this stop for Route 70 are relatively similar at all times of the day, and for Route 64 in off-peak times and 70A at peak times, showing that the stop is likely crowded at all times of the day.

Figure 17: Bus Median Alightings/Boardings at Green St at Magazine St



4.5.2 Magazine St at Green St. Berth 1

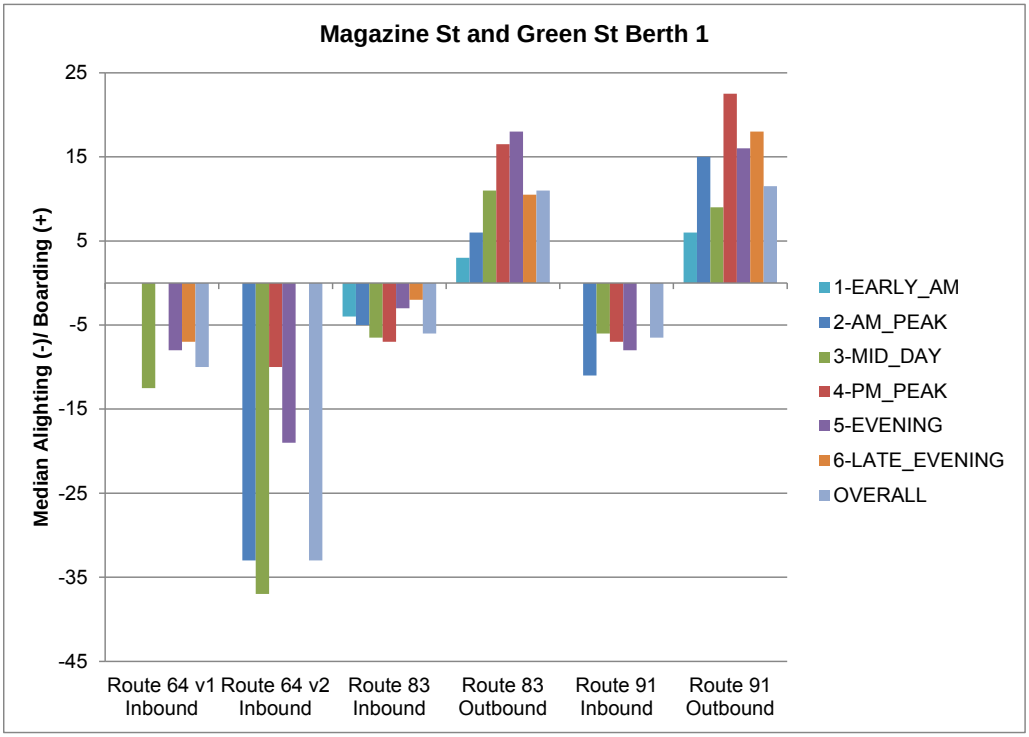
The stop on Magazine St. at Green St. berth 1 serves Route 64, 83, and 91.

There are two variants of Route 64 that serve this stop in the Inbound direction. Variant 1 is in the off-peak inbound to Central and variant 2 is in the peak times inbound to Kendall). This stop is the 3rd to last stop for variant 1 (followed by Massachusetts Ave. and Pearl St., then Massachusetts Ave. and Sidney St., and terminating at Franklin St at Sidney St.) This stop is the 10th to last stop for variant 2 that terminates at Kendall Square. Note: there are very few data points for Route 64 v2 (3 data points for AM peak, 2 data points for Midday, and 1 data point each for PM peak and Evening).

Trips for the Inbound direction for Routes 83 and 91 terminate at this stop and trips in the Outbound direction for these routes originate at this stop.

This stop is a boarding location for Routes 83 and 91 in the Outbound direction. These are highest in the PM peak and evening for Route 83, and the peaks, evening, and late evening for Route 91. This is an alighting stop for Routes 64, 83, and 91 in the Inbound direction. Alightings are highest for Route 64 for the variant to Kendall Square in the AM peak and Midday.

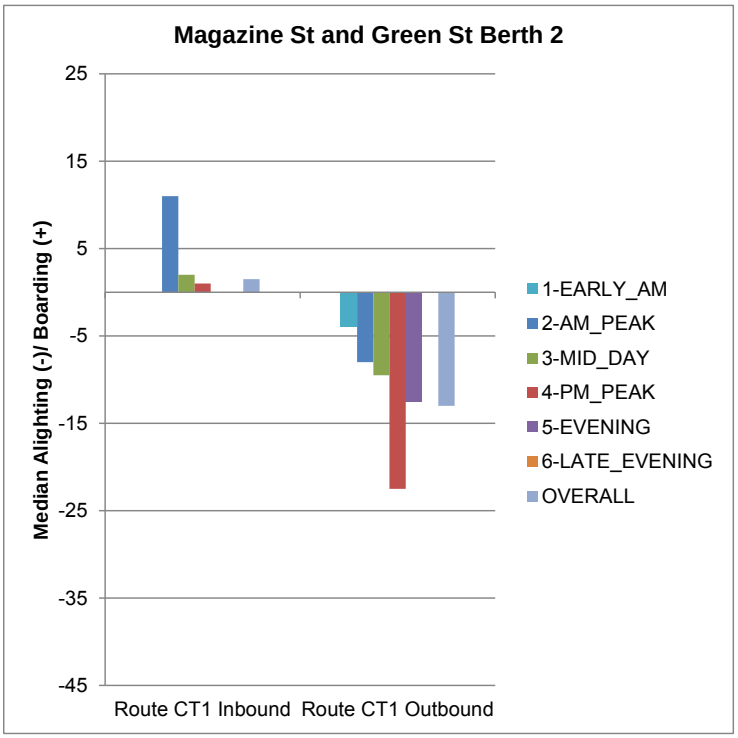
Figure 18: Bus Median Alightings/Boardings at Magazine St at Green St Berth 1



4.5.3 Magazine St at Green St. Berth 2

The stop on Magazine St. at Green St. Berth 2 only serves Route CT1. The Outbound direction terminates at this stop and the Inbound direction originates at this stop. This stop has the largest number of passengers alighting in the PM peak.

Figure 19: Bus Median Alightings/Boardings at Magazine St at Green St Berth 2



5 Field Observation Summary

The IBI Group team, with representatives from the City of Cambridge, and the MBTA, conducted a field survey of Central Square on August 5, 2014. The field survey included a visit to the various bus stops within the Study Area and discussions with MBTA staff regarding their observations and major concerns for their operations within the Study Area. In addition, IBI Group attended a second visit to the Study Area with the Transit Committee on August 13, 2014. This section presents a summary of the important observations from those site visits. Section 5.1 presents the bus routing related observations, Section 5.2 presents bus stop and layover related observations, and Section 5.3 presents signage and wayfinding related observations.

5.1 Bus Routing

During the site visit, it was observed that some buses do not follow the MBTA-established routing from Green St to Magazine St. When the layover bay at Magazine St at Green St Berth 2 island is not occupied by the CT1, rather than turning at the signalized intersection of River St at Green St, some buses turn towards Central Square via the bus layover bay at Magazine St at Green St Berth 2 (Figure 20). Additionally, some buses are routed to drive around the First Baptist Church by taking a left on Western Ave, a left on Franklin St, and a right on Magazine St, but instead turn directly from Green St towards Central Square via the second bus layover bay. This saves them time but is hazardous because it was not designed for this purpose and is an extremely tight turn.

Figure 20: Route 47 bus ad-hoc routing via the Magazine St at Green St Berth 2 bus layover bay

As per MBTA and City of Cambridge staff, because the pedestrian crossing at Mass Ave and Pearl St is unsignalized, during periods of peak pedestrian traffic this can cause delays for the buses (Rt. 47 and Rt. CT1) and other vehicles that turn from Mass Ave onto Pearl St, and other vehicles behind them. The turning is particularly tough for vehicles and bus routes turning left from Massachusetts Ave (Rt. CT1). This turning is the source of multiple pedestrian and motor vehicle conflicts.

The location of the taxi stands on Mass Ave between Pearl St and Essex St can also cause conflicts with buses, bicycles, and cars traveling along Mass Ave, as taxis frequently pull in and out of the curb.

City of Cambridge staff also noted that the right turn by buses from Magazine St onto Mass Ave is a source of conflict with pedestrians and buses can be delayed.

It was also noted that the use of different stops for Route 64 by time of day (Figure 21) may create confusion among passengers.

Figure 21: Route 64 signage for routing change by time of day

5.2 Bus Stops and Layover Locations

The main bus stops along Mass Ave near Central Square are very imbalanced. The stop at Mass Ave and Prospect St only serves buses on one route (Rt. 1), while the stop at Mass Ave and Pearl St serves buses from up to six routes (Rts.1, 47, 64, 70, 70A, CT1).

The length of the bus layover spot at Magazine St at Green St Berth 1 is not sufficient to accommodate one bus each from both designated routes for this stop, 83 and 91. As shown in Figure 22, when two buses layover at the same time, the rear of the second bus in the queue blocks both the pedestrian crossing as well as a part of Green St. This hinders the movement of pedestrians and vehicles coming from Green St.

Figure 22: Bus layover at Magazine St at Green St Berth 1

Bus drivers, however, report that they like the layover location at Magazine St at Green St due to the location of the convenience/grocery store and restrooms.

Bus drivers are also reported to like the location at Franklin St at Sidney St for bus layovers, particularly due to the ease of using restrooms. MBTA staff noted that this location is also preferable for making layovers because it can accommodate multiple buses.

It was also observed that the loading zone on Mass Ave (Eastbound) between River St and Essex St is quite often occupied by illegally parked vehicles (Figure 23). On occasion, some buses (typically Route 47) also lay over at this location.

Figure 23: Loading zone occupied by vehicles on Mass Ave (Eastbound) between River St and Essex St

For Route 70/70A, the bus stop at Green St at Magazine St is not very wide and can easily get overcrowded. When this happens, the pedestrian movement gets restricted. This problem is further compounded by the placement and design of the pedestrian shelter, which can act as a barrier to pedestrian movement. Figure 24 illustrates this problem during a Route 70 weekday peak boarding scenario. The placement of the trash bin in close proximity to the shelter further hinders movement along the sidewalk.

Figure 24: Bus Shelter for Routes 70/70A at Green St at Magazine St

5.3 Signage and Wayfinding

During the site visits, it was noted that the existing signage for buses could not be easily viewed by passengers. This was due to the placement of the signage and the associated sightlines. Particularly in the case of routes 64, 70/70A, 83, and 91, there is no signage directing passengers coming from Central Square toward the location of bus stops. While moving from Massachusetts Ave along Magazine St, passengers are required to negotiate through a series of signs to find their relevant route. The signs are also facing away from Central Square and are attached to different poles at a significant height, and often right next to the bus shelters, increasing the level of difficulty in negotiating through them. Figure 25 shows the signage for Routes 64, 83, and 91 while Figure 26 shows signage for Route CT1.

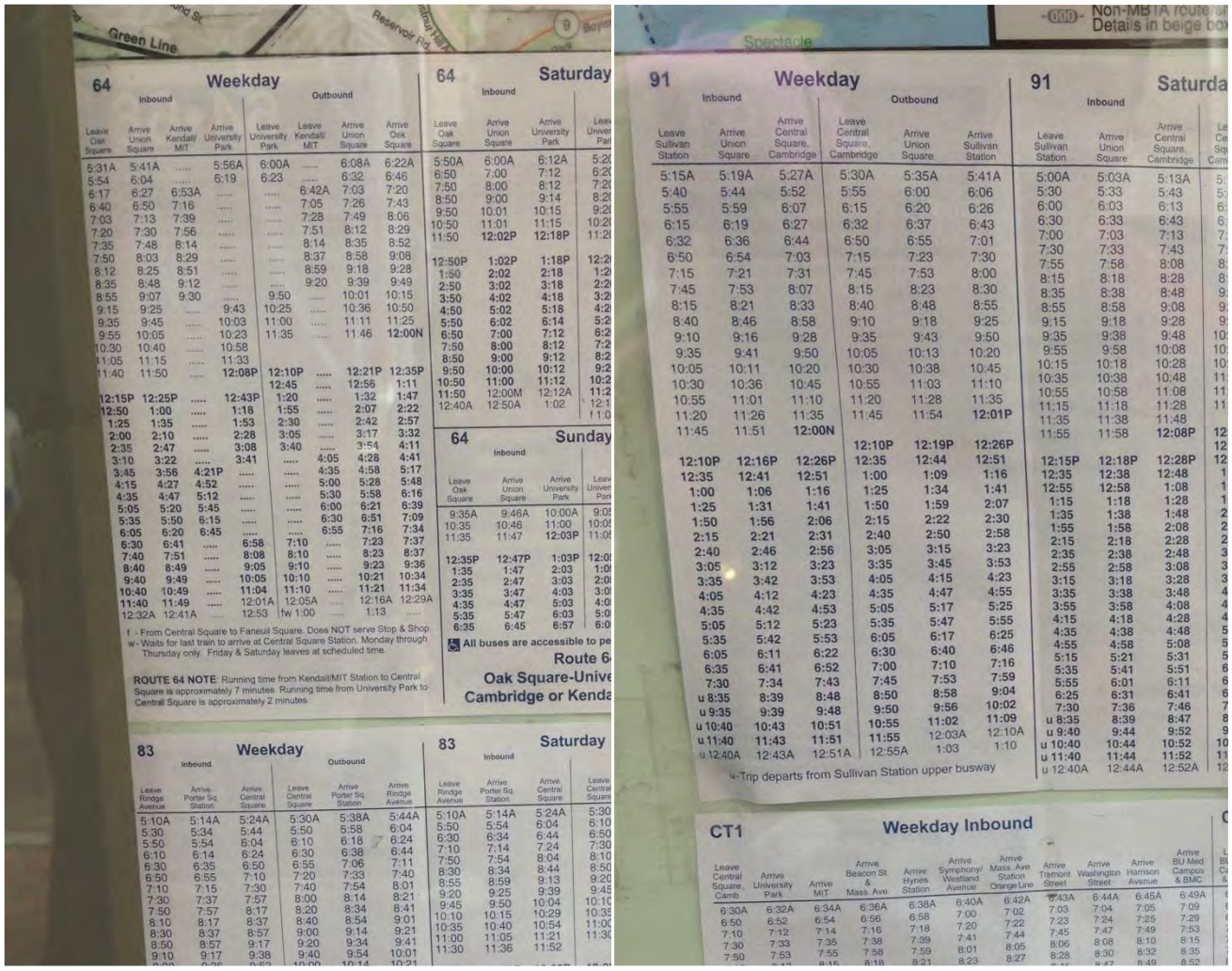
Figure 25: Signage for Routes 64, 83, 91 at Magazine St at Green St Berth 1

Figure 26: Signage for Route CT1 at Magazine St at Green St Berth 2

As can be seen, some of the route signs are not easily viewed by passengers. In addition, there is no wayfinding from Central Square to the bus routes near Central Square. Better wayfinding information could be provided near the bus shelters and within the Red Line station.

The bus information provided at some of the bus shelters and bus stops is not always location-specific. As shown in Figure 27, the schedules for routes 64, 83, 91, and CT1 are provided in the bus shelter at the Green St at Magazine St, despite the fact that this stop specifically caters to routes 70 and 70A.

Figure 27: Schedules at Green St at Magazine St shelter



It was also observed that there is no signage within the Central Square Red Line Station directing passengers to different bus routes. Some of the station maps within the subway are also on wrong platform. For example, the inbound map is on the outbound side, and vice versa.

6 Next Steps

As the next step in this project, IBI Group will review and refine the list of issues identified by Cambridge staff in the RFP. This list of issues will be refined on the basis of the 2013 K2C2 Central Square Final Report and the information developed as part of Task 1. Task 2 will result in the compilation of a final list of issues to consider while developing ideas for improving bus circulation and access in Central Square. In Task 3 IBI Group will develop a list of potential ideas to improve bus access and circulation, culminating in a report including conceptual cost estimates as the result of Task 4.