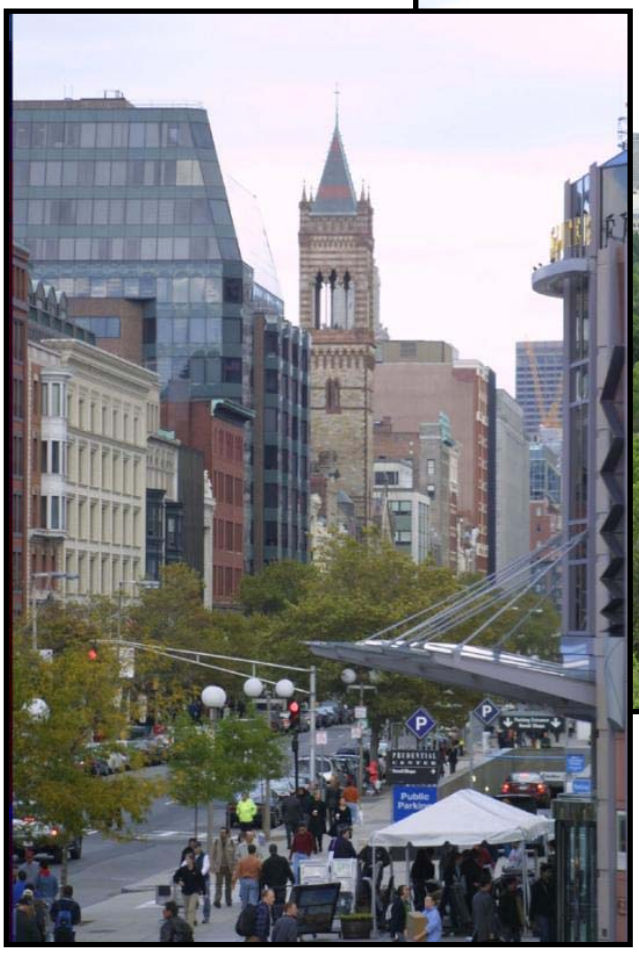
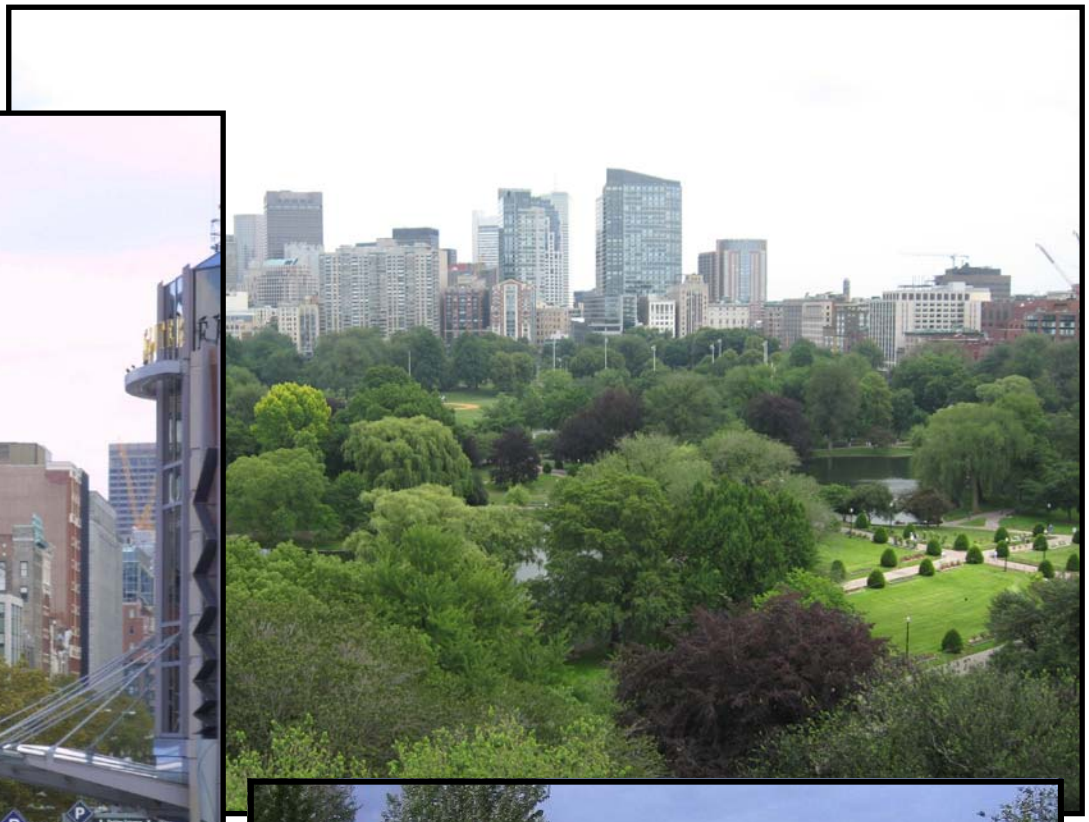
Northeastern University

Feasibility Study for the Boylston Street and Public Garden Cycle Track





April 2009

Submitted by *The Boylston Boneshakers*
James Barnack Sean Carr Tom Leduc Dan Liepins

Table of Contents

List of Tables and Figures

1.0 Introduction to Project

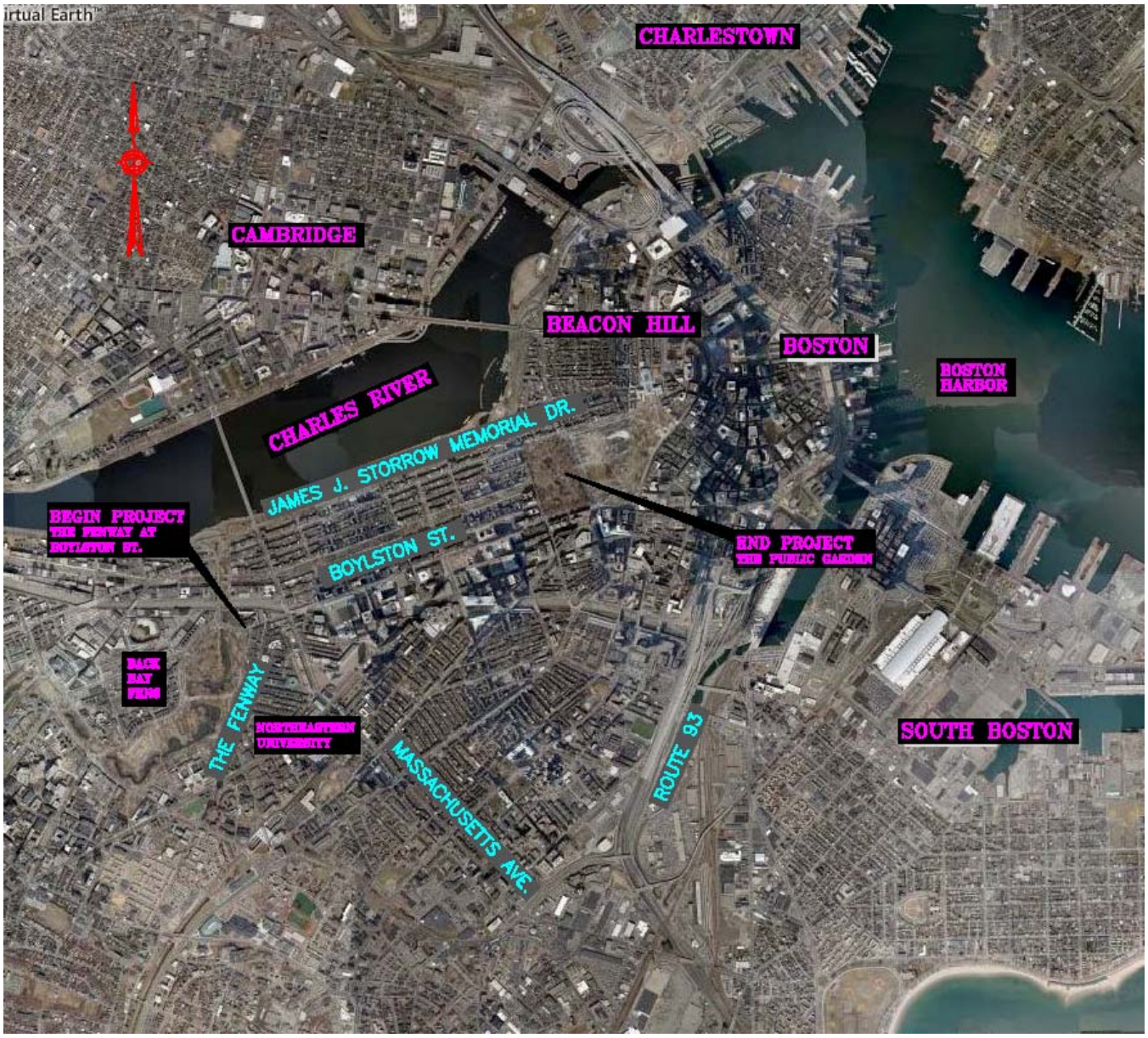


Figure 1.1A – Locus Map

1.1 Introduction

As traffic engineering students, planners and activists, it has been recognized that transportation systems are causing crowding and standstills on many roads. To combat this foremost setback, traffic engineers are trying to incorporate bicycles to help alleviate the problem. Current engineering trends are turning towards bicycles because they produce less pollution, promote active lifestyles and bicycle improvements are relatively inexpensive.

The Boylston Boneshakers are proud to present a feasible design for a continuous two-way cycle track on Boylston Street from Fenway to and around the Public Garden. The cycle track design maintains existing curb widths by removing one travel lane while stile maintaining acceptable vehicular traffic. The cycle track is separated from moving vehicles by a buffer zone and parked vehicles to increase safety and encourage commuters and recreational cyclists to ride through Boston.

Not only would this route serve as a connection between communities in Boston, but it would also attract bicyclists to downtown Boston to enjoy the beautiful Public Garden and historical Boston Common. Promoting bicycling within the city of Boston will reduce vehicular traffic and parking problems, and promote a healthy lifestyle.

1.1.1 Purpose of the Report

At the request of Nicole Freedman, bicycle planner for the City of Boston, and Dr. Peter Furth of Northeastern University, the *Boylston Boneshakers* senior design team designed a two-way cycle track from Boylston at The Fenway down Boylston Street to Charles Street and around the Public Garden.

The project includes the following:

- Conceptual design analysis of alternatives
- Design of a two-way cycle track
- Existing and proposed traffic and corridor conditions
- Cost analysis

1.2 Study Area

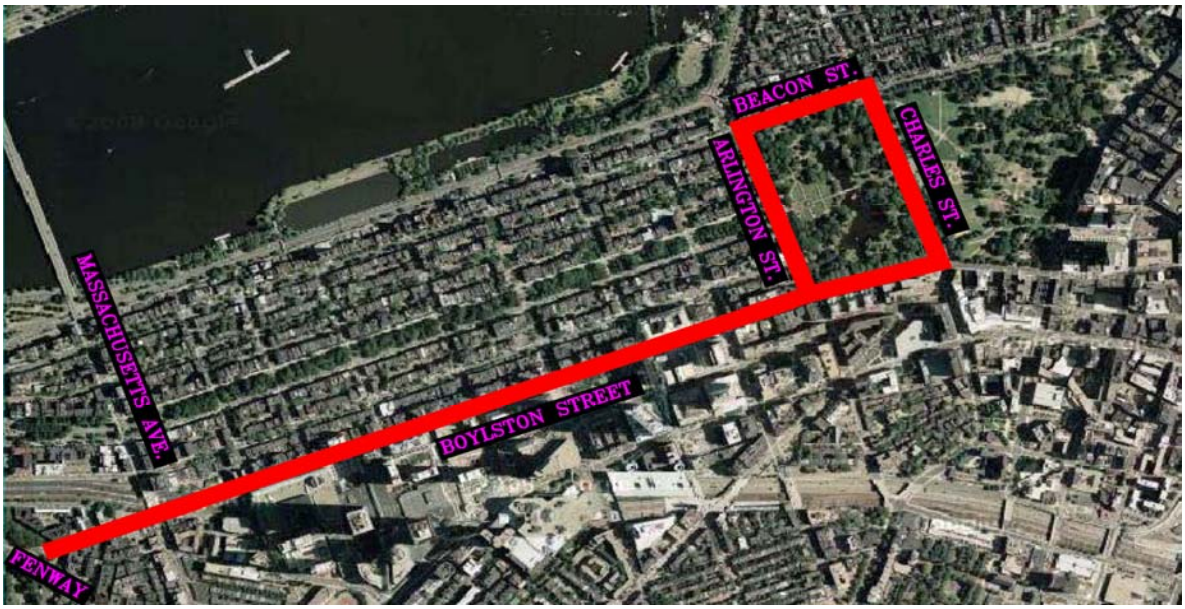


Figure 1.2A - Study Area

Figure 1.2A above shows the study area from Fenway to and around and Public Garden along Boylston Street.

2.0 Context

2.1 What is a Cycle Track?

Cycle tracks are unique bicycle accommodations that are gaining popularity in the transportation planning and engineering fields. They are different than both bicycle lanes and bicycle paths, but also combine the best aspects of both.

A bicycle lane located next to vehicular lanes in a roadway creates several negative side effects. The additional open space in the roadway that bicycle lanes create is commonly considered by drivers as a de-facto double parking lane. When vehicles are double parked in the bicycle lane the bicycle lane is blocked and bicyclists are forced to swerve into vehicular lanes to go around the double parked vehicle, rendering the bicycle lane completely useless. A bicycle lane next to vehicular lanes also creates vehicle-bicycle interaction, especially at intersections where turning movements occur, which is extremely stressful for a bicyclist. This stressful ride can keep people from using the bicycle lane at all.

Despite these two major faults of bicycle lanes, they offer direct routes to destinations because they are on main roads. Accommodating bicyclists within the main roadways is therefore important for bicyclists to get between destinations in a quick, direct route.

A bicycle path offers physical separation between cars and bicyclists because they are not located within roadways. Bicycle paths are typically situated in parks and trails, and therefore cars are not present. The lack of cars means that bicyclists are safer and stress-free when riding in bicycle paths. The location of bicycle paths within parks, however, means that they do not typically offer a best or direct route to many destinations.

A cycle track combines the stress free and safe ride of a bicycle path with the direct route advantage of bicycle lanes. Cycle tracks are located in or directly next to a roadway and bicyclists within the cycle track are physically separated from traffic by some sort of buffer zone. This buffer zone is meant to keep vehicular traffic out of the cycle track which can be accomplished by a range of options from raised medians, to vertical bollards and even parking lanes. The lack of vehicles within the cycle track results in a great increase in safety, as opposed to a bicycle lane, and results in a stress-free ride.

2.1.1 Cycle Tracks Outside of The United States

Figure 2.1A – Urban Cycle Tracks in the Netherlands

Cycle tracks have been adopted in other countries as a safe and practical bicycle accommodation and have become the most popular form of bicycle accommodation in the Netherlands, where more trips are made per year via bicycles than in the United States despite there being approximately 290 million less residents. Please refer to Figure 2.1A for photographs of urban cycle tracks in the Netherlands. Cycle tracks are adapted in all areas of the Netherlands, including both urban cycle tracks and rural cycle tracks.

Figure 2.1B – Cycle Tracks in Montreal, Canada

Montreal, Canada, has also adopted cycle tracks on many of its roads. Cycle tracks in Montreal often travel from the suburban outskirts of the city and through the dense, urban areas. On several of Montreal's cycle tracks, two-way bicycle traffic is supported on one-way vehicular roads, which offers similar treatments to those needed on Boylston Street in Boston. Figure 2.1B shows two-way cycle tracks in Montreal along urban one-way roads. Note that the physical separation between bicycles and vehicles is achieved by a raised median in the photograph on the left, and with a parking lane and vertical metal poles in the photograph on the right.

2.2.1 Cycle Tracks In The United States

The United States received its first cycle track in the fall of 2007. Located along 9th Avenue in New York City, NY, and it features several design aspects that are unique and some that are adapted from other cycle tracks. Figure 2.1C shows the 9th Avenue cycle track, note the left turning vehicular lane and bicycle signal heads. The 9th Avenue cycle track is a one-way cycle track along a one-way vehicular street. It promotes safety with a ten foot wide bicycle lane, which is much greater than a standard bicycle lane. Safety is enforced at intersections with turning vehicle lanes and bicycle signal heads that stop bicycles when conflicting car movements have a green signal.

Figure 2.1C – 9th Avenue one way cycle track in New York, NY

2.2 Need for Boylston Street Cycle Track

Figure 2.2A – Boston's Existing Bicycle Network (Green) and Boylston Street and Public Garden Cycle Track (Red)

Bicycle paths exist in Boston within The Emerald Necklace linear parks, notably the Back Bay Fens and Boston Common, as well as in the Charles River Esplanade. Boston also features several bicycle lanes which, in combination with bicycle paths, create the existing bicycle network. These existing bicycle paths and bicycle lanes are shown in Figure 2.2A, which also shows that there is a lack of connectivity between the bicycle lanes and paths within the existing network.

Connections to several major bicycle paths can be achieved by providing bicycle accommodations on Boylston Street and the roads surrounding the Public Garden. The potential exists to create connections to the bicycle paths of the Back Bay Fens at the intersection of Boylston Street and The Fenway. A connection to the bicycle paths on the Charles River Esplanade is at the intersection of Beacon Street and Arlington Street where the David Mugar Overpass is located. A connection to the mixed use paths of Boston Common could be implemented at the intersection of Boylston Street and Charles Street. Lastly, the Southwest Corridor bicycle path could be connected to the network via Dartmouth Street. These potential connections are also shown on Figure 2.2A

It is the potential for connecting the existing bicycle lanes and paths of Boston that makes Boylston Street and the roads surrounding the Public Garden ideal locations for bicycle accommodations. Bicycling between the various bicycle lanes and paths in Boston, which currently occurs on nearby roadways without bicycle accommodations, would tend to funnel to Boylston Street which would aid in promoting bicycle safety. Users of all kinds, from commuters to recreational cyclists, would benefit from bicycle accommodations on Boylston Street.

2.2.1 Why a Cycle Track?

As discussed in Section 2.1, cycle tracks offer the major benefit of increased bicycle safety, which was an important consideration for Boylston Street. A cycle track offers another additional benefit which suits itself ideally for Boylston Street.

The majority of Boylston Street is one-way eastbound, which means that bicycle traffic could only be carried one-way eastbound if a traditional bicycle lane were designed for Boylston Street. West-bound traffic would need to seek an alternative route, or a west-bound bicycle lane would need to be designed for a nearby road (i.e. Newbury Street or Commonwealth Avenue).

A cycle track, on the other hand, can support two-way bicycle traffic even if the adjacent roadway only supports one-way vehicular traffic. This is made possible by the physical separation between bicycle travel areas and vehicular travel lanes and is ideal for Boylston Street, where there are major bicycling destinations at both the western and eastern ends of the street.

3.0 Standard Cycle Track Design Criteria

The following section will outline and discuss the standard design for the cycle track.

3.1 Lane Width

Lane width of a cycle track is a balance between width and function. A cyclist occupies approximately 40 inches of lane space which would result in a cycle track that is 6-feet 8-inches, the bare minimum for two cyclists to pass each other. The design for the Boylston Street cycle track incorporates three main functions: two abreast riding, room for passing, and snow removal. To accommodate these three functions the cycle track has been design at 10-feet wide. The additional width will allow cyclists to ride two abreast in the same direction and still leave enough room for a cyclists travelling in the opposite direction to comfortably pass. Also, the additional width will allow for snow storage during the winter months while still allowing enough room for two cyclists to pass each other comfortably.

3.2 Buffer Zone Width

Buffer zones are important for cyclists comfort and safety from vehicles. The Buffer zone width is important because it will allow drivers to exist their vehicles without going into the cycle track. Through many field observations it was apparent that 3-feet was necessary to allow drivers to open their door and exit the vehicle. Therefore, the design includes a 3-foot minimum buffer zone width.

3.3 Physical Barrier Treatment

A physical barrier for the cycle track will prevent vehicles from parking and driving in the cycle track and warn pedestrians of bicycles. Figure 2.1B and 2.1C in section 2 show flexible markers being used as physical barrier treatments in Montreal and New York City respectively. Flexible channelized tubular markers are included in the design for Boylston Street and will be center in the buffer zone and placed every 10 feet. The markers, essentially, line up parked vehicles and keep them from parking in the cycle track. Once a wall of parked cars has been established against the curb they will be a very effective physical barrier against moving vehicles for the cycle track.

The markers allow the buffer zone to remain at street level so bicyclists will be able to leave the cycle track whenever necessary and not have to worry about dismounting to jump over curbs. The markers can also be removed for special events, snowplowing, etc.

3.4 Crossings

Crossings are the most vulnerable part of the cycle track so designing safe crossings was crucial for the design. Separated cycle crossings were included in the entire design to allow bicyclists to cross independently from pedestrians. Figure 3.4A shows a standard bike crossing in the Netherlands. The design on Boylston Street models these crossings as they have proved to be effective in separating cyclists from pedestrians and warning drivers of crossings.

Figure 3.4A - Voorburg Separated Cycle Crossing

3.5 Bicycle Signals

Bicycle signals along the corridor will be very important for safety especially for contra-flow bicycles. Bicycles will have protected phasing to cross intersections as will left turning vehicles of Boylston Street. Therefore, a bicycle signal is important so bicycles will not cross when left turning vehicles have a protected left turn. Contra-flow bicycles do not have existing signals along their approach so a bicycle signal will alert them whether or not it is safe to cross.

3.6 Cycle Track Orientation

The cycle track will remain on the north side of Boylston throughout the corridor. Placing the cycle track along the north side keeps bicycles and vehicles which are next to each other travelling in the same direction increasing safety. Also, it will minimize pedestrian conflict because of the valet and taxi stands on the south side of Boylston Street. Additionally, during the winter months plows push snow towards the south side of the street alleviating the problem of the cycle track being covered with snow from the plows and minimizing damage to the flexible channelized tubular marker.

The cycle track will run along the sidewalk adjacent to the Public Garden to maintain consistency and add an additional buffer between the vehicles and the tranquil Public Garden.

4.0 Boylston Street at Fenway

4.1 Overview of the Section

Boylston Street at Fenway serves as a gateway of the Back Bay Fens to Boylston Street for pedestrians and bicyclists and a portal for drivers driving on and off of Storrow Drive going towards Longwood Medical Area, Massachusetts Avenue, and the Fenway area. The major aspect of this intersection will be safely transitioning the bicycle path from the Back Bay Fens on the south side of Boylston Street in the cycle track on the north side.

Currently, the delay for pedestrians and bicyclists is in excess of 48 seconds, and they are forced to use the same crossings with narrow islands that restrict the flow and cause conflicts. Conversely, the delay for drivers is, at worst, only 26 seconds.

Because this intersection highly favors vehicular traffic, redesigning the intersection with more emphasis on pedestrian delay and safety while causing minimal impacts to vehicular movements was a challenge. In order to improve pedestrian and bicyclist safety a cycle track and cycle crossings will be added. The following will discuss various design alternatives and the selected design.

Figure 4.1A – Boylston Street at Fenway

Figure 4.1B –Boylston Street Looking West Beyond Fenway

4.1.1 Existing Conditions

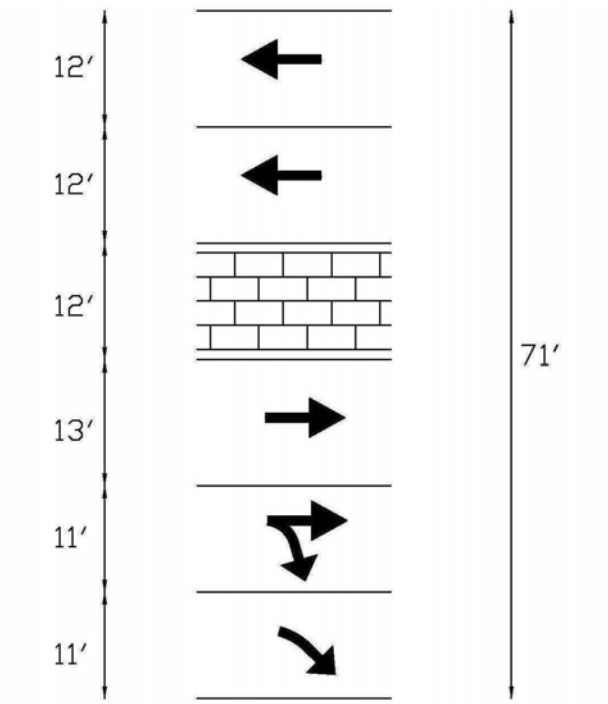


Figure 4.1C – Existing Cross-Section - Boylston Street West of Fenway

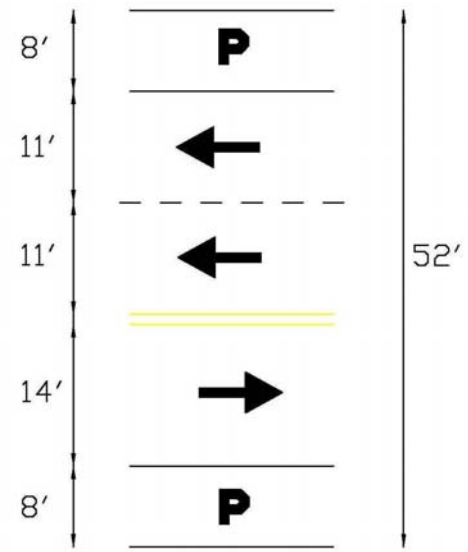


Figure 4.1D – Existing Cross-Section - Boylston Street East of Fenway

The existing intersection is a 3-way 'T' type intersection. Boylston moves east-west and Fenway intersects from the south. For pedestrians there is a two-stage crossing across Fenway and a single crossing across Boylston Street.

The existing cross section west of Fenway can be seen in figure 4.1C. Also, figure 4.1D shows Boylston Street east of Fenway which has a 52-foot wide cross-section. It is important to note that the eastbound lane is 14-feet wide. The lane is wider than necessary and the extra width will be helpful in the design discussed in the following sections.

4.2 Boylston Street East of Fenway Design Alternatives

The intersection design depends on how Boylston Street east of Fenway is designed, therefore only alternatives to the east were considered in the conceptual design process.

4.2.1 Introduction to the Design

The cycle track was designed to fit within the existing cross section of the road as widening the road would take away space from the sidewalks. The required changes to the cross-section involve removing a westbound travel lane east of Fenway, reducing the eastbound travel lane width east of Fenway, and removing one of the eastbound thru lanes west of Fenway. Also, island modifications will be included in the design to channel traffic and enlarge the pedestrian refuge. Two design alternatives were considered for the section of Boylston Street from Fenway to Hemenway Street, one with one-way cycle tracks on each side of the street, and one with a two-way cycle track on the north side of the street.

4.2.2 Alternative Considered

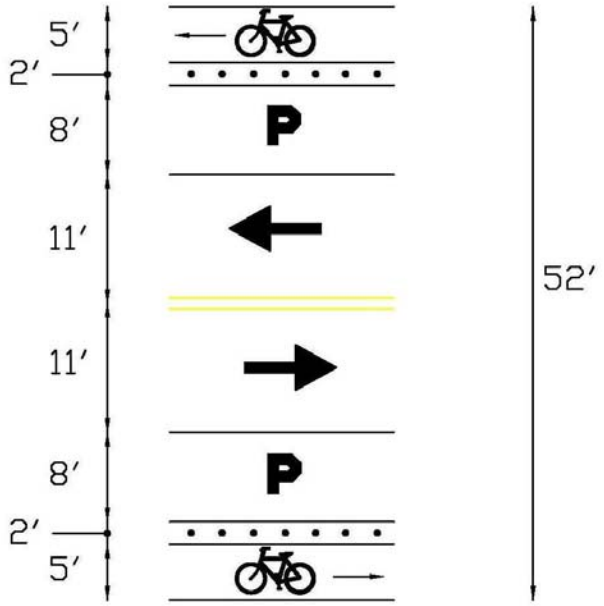


Figure 4.2A – Non-Recommended Alternative – Boylston Street East of Fenway

This section describes an alternative with one-way cycle tracks on each side of Boylston Street, but this alternative was judged inferior to the recommended alternative. Figure 4.2A above shows the cross-section for this alternative. As with every section of Boylston one travel lane was removed to fit the cycle track.

This alternative was judge inferior because bicyclists would be forced to transition into a two way cycle track at Massachusetts Avenue further east on Boylston Street. The transition would result in either a high delay for bicyclists travelling east or they would have to cross Boylston Street mid-block. Because this alternative will increase delay and reduce safety it is not a viable option for this project.

4.3 Recommended Design

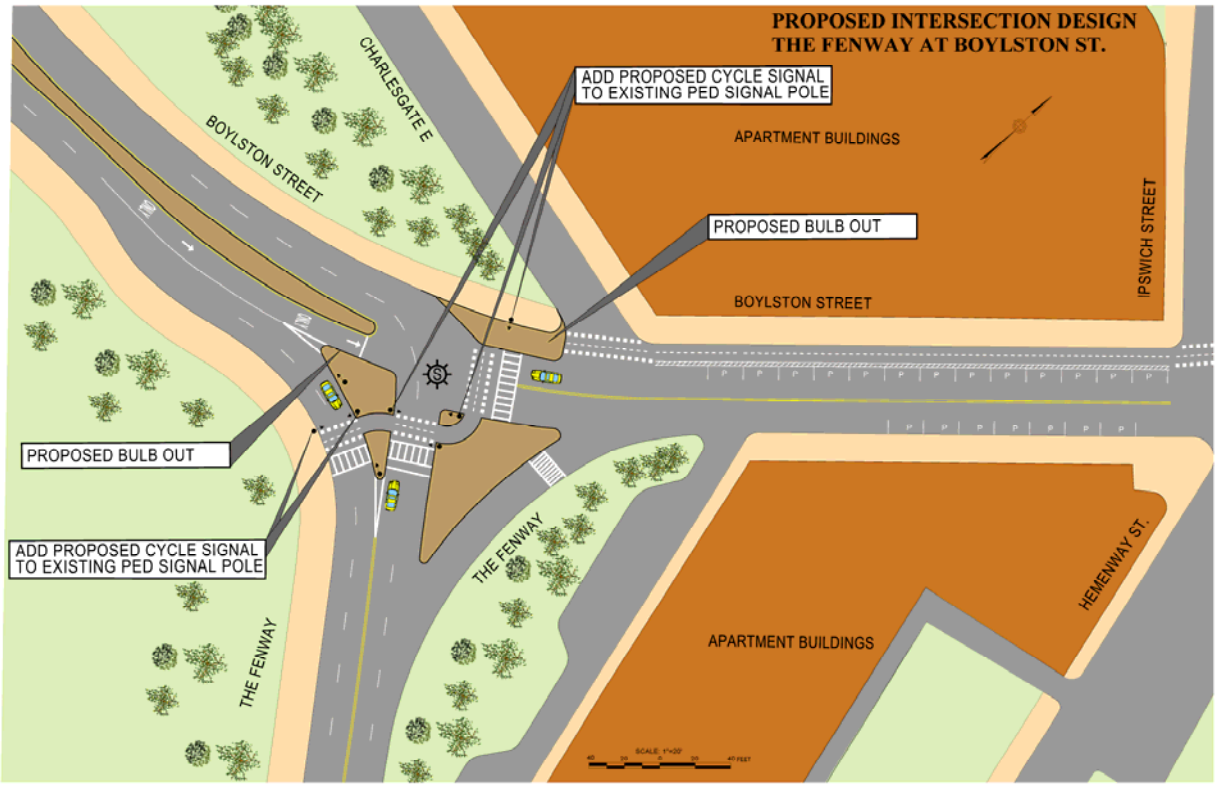


Figure 4.3A – Proposed Plan of Boylston Street at Fenway

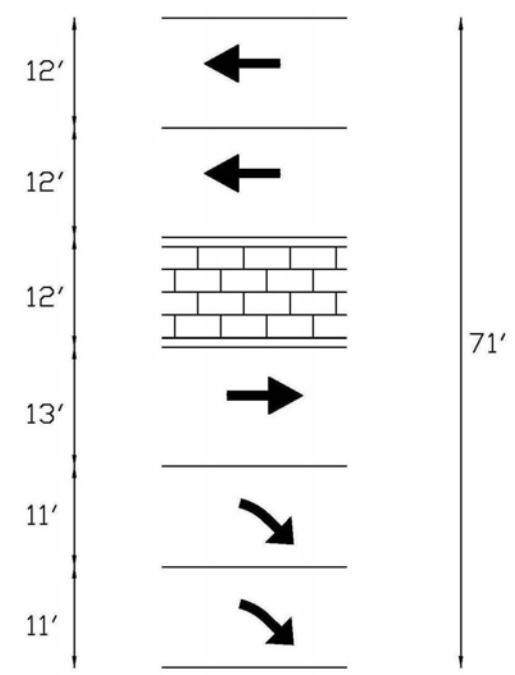


Figure 4.3B – Proposed Cross-Section – Boylston Street West of Fenway

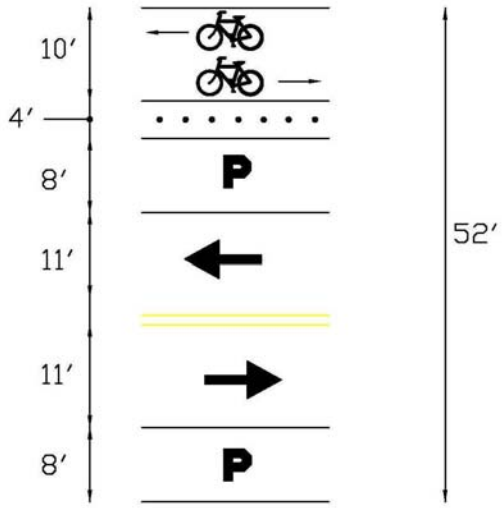


Figure 4.3C – Proposed Cross-Section – Boylston Street East of Fenway

The recommended design successfully solves the following problems at Fenway:

- Create safe path for cyclists to go from south of Boylston to cycle track
- Increase efficiency of eastbound vehicular traffic

Figure 4.3A on the previous page shows the recommended plan at the intersection. Notice the separated cycle track from the bike paths in the Back Bay Fens to the cycle track which allows a safe crossing for bicyclists free of pedestrian conflicts. Also, notice the bulb out on at the intersection of the crossing and the cycle track. The bulb out will act as a refuge for pedestrians and cyclists waiting to cross Boylston Street, and it will decrease the crossing distance. The cycle track is at grade with the street, as well, to increase cyclists' comfort so they are not riding up and down ramps.

Figure 4.3B shows the cross-section west of Fenway. The existing intersection is not very efficient because vehicles waiting to go thru often wait in the middle lane and block the right turning lanes. In the proposed cross-section the middle lane is a right-turn only lane which will eliminate right turn blockage and keep vehicles consistently moving. Figure 4.3A illustrates the proposed bulb out at this right turn which will further help in channeling traffic either right or straight even more increasing efficiency.

Figure 4.3C shows the cross-section east of Fenway. An existing travel lane has been removed and the cycle track is on the north side of Boylston Street which allows for continuous movement throughout the corridor.

4.4 Existing Vehicular and Pedestrian Traffic Analysis

4.4.1 Field Measurements and Observations

To analyze existing traffic conditions turning movement traffic counts were conducted during the peak hour, field measurements and parking counts were collected, and signal phase timings were received from the City of Boston. Vehicular conditions were analyzed using Synchro 6 software for all analyses. Synchro 6 calculates delay, volume to capacity ratio, 95th and 50th queue length, and level of service which enables the group to evaluate the operation of the intersection.

During numerous field visits an overall inefficient flow of the intersection was observed. Vehicles often wait at a light with no vehicles traveling in conflicting movements. Wasted green time drastically increases the intersection delay and results in an unsafe intersection because vehicles travel quite rapidly through the intersection.

Eastbound traffic has a high right turn movement compared to the thru movement. The middle lane is a shared thru and right-turn lane but has a small queue lane for thru traffic. But, that lane often fills up quickly because it is only two car lengths long and blocks right turning traffic, creating an even larger queue. It was obvious

that the thru and right-turn lane would function more efficiently as right-turn only lanes which are shown in the recommended design. Also on the eastbound right turn movement, the signal is constantly green unless a pedestrian pushes the walk button resulting in a very small delay for vehicles. The constant green, however, results in an unsafe condition for pedestrians and bicyclists because the vehicles travel very quickly through that right turning lane.

Westbound traffic is very light and it is apparent that one travel lane is more than adequate to effectively move traffic through the intersection. Bicycles travel out of the Back Bay Fens and use existing crosswalks to travel eastbound onto Boylston and follow the same path when traveling westbound.

4.4.2 Existing Conditions

The current timing plan highly favors vehicular traffic. The eastbound right movement has a constant green unless a pedestrian pushes the walk button to cross Fenway. The northbound and eastbound movements often gap out resulting in a green light with no vehicles travelling through the intersection. It is clear that the intersection is not operating at an efficient level. See Appendix A for the existing timing plan.

4.5 Modification of Vehicular and Pedestrian Traffic

The proposed layout for Boylston Street and Fenway will completely change the way the intersection will operate. Accordingly, the timing plan needed to be modified to accommodate these changes. An analysis into a new timing plan was completed and the results are posted in this section.

4.5.1 Signal Timing Modification Peak Hour

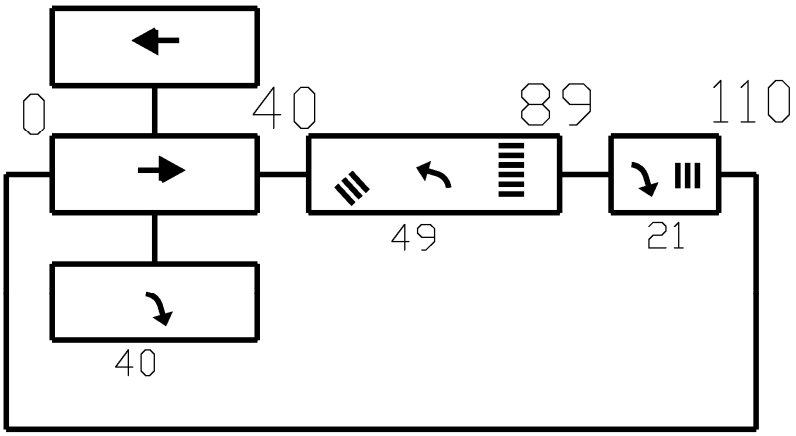


Figure 4.5A - Proposed Phasing Ring Diagram

As shown in figure 4.5A above the new phasing plan retains the same cycle length as existing of 110 seconds to maintain coordination throughout the network. The crossings are all on recall and run concurrently with the vehicular movements which will eliminate the need for cyclists to dismount and press the walk button. The eastbound right turn is no longer continuous but broken up with a pedestrian phase which results in a green wave for pedestrians to make the two-stage crossing in one phase.

Table 4.5A
Boylston Street and The Fenway: PM Peak Hour Vehicular and Pedestrian Level of Service

	Existing				
Approach	Delay (s)	V/C Ratio	95% Queue Length	50% Queue Length	LOS
Boylston EB Thru	33.1	0.42	170	123	C
Boylston EB Right	22.1	0.69	356	273	C
Boylston WB Thru	31.8	0.29	122	84	C
Fenway NB Left	25	0.67	354	282	C
Pedestrians Crossing Boylston	24.2	-	-	-	C
Pedestrians Crossing Fenway EB	47.2	-	-	-	E
Pedestrians Crossing Fenway WB	48.7	-	-	-	E
Entire Intersection	26	0.69	-	-	C
	Proposed				
Approach	Delay (s)	V/C Ratio	95% Queue Length	50% Queue Length	LOS
Boylston EB Thru	27.1	0.55	318	220	C
Boylston EB Right	12	0.66	357	261	B
Boylston WB Thru	25.5	0.42	222	147	C
Fenway NB Left	16.6	0.56	288	228	B
Pedestrians Crossing Boylston	17	-	-	-	B
Pedestrians Crossing Fenway EB	34.8	-	-	-	D
Pedestrians Crossing Fenway WB	39.4	-	-	-	D
WB Cycle Track Crossing	82.5	-	-	-	E
EB Cycle Track Crossing	54.4	-	-	-	E
Entire Intersection	17.6	0.66	-	-	B

Table 4.5A above shows the improvements throughout the intersection. Delays is reduced for every approach and overall the delay of this intersection improved by 10 seconds and the level of service went from C to B. The same can be said for westbound through movements. Even though an eastbound thru lane was removed, the delay still decreased by 6 seconds. The eastbound right improved as well with a level of service of B which is important to note because the constant green is now interrupted by a pedestrian phase.

The existing pedestrian delay was the biggest concern because it was operating at a level of service E for Fenway with delays approaching 50 seconds. Drastic improvements would be difficult but the delay for Fenway was reduced to 35 seconds and 39 seconds for the eastbound and westbound respectively. These

improvements are very good especially considering the high traffic volume for this intersection and the two-stage crossing for Fenway. See Appendix A for Synchro reports and pedestrian delay calculations.

5.0 Boylston Street at Massachusetts Avenue

5.1 Overview of the Section

Figure 5.1A – Boylston Street at Massachusetts Avenue

Boylston Street at Massachusetts Avenue is the busiest intersection along the proposed cycle track. The intersection serves as an access to the Massachusetts Turnpike and a gateway towards downtown Boston. It is also highly congested with pedestrians due to the MBTA-Hynes Convention Center T-stop and because of the proximity of high end shopping on Newbury Street.

The proposed design improves safety by adding a cycle track, cycle crossings, and re-timing of the signal plan.

5.1.1 Existing Conditions

The existing intersection is a four-way signal controlled intersection. Figure 5.1B and 5.1C are pictures of the existing conditions. Figure 5.1C is a very nice photo that shows the conflict between right turning westbound vehicles from Boylston Street onto Massachusetts Avenue with crossing pedestrians. Boylston moves east-west and Massachusetts Avenue moves north south. Pedestrians have four single-stage crossings. The central focus of the re-design of the existing intersection was the non-compliance of pedestrians crossing the intersection and the conflict between right turning westbound vehicles from Boylston Street onto Massachusetts Avenue with crossing pedestrians. The right turning movement is a critical movement

because vehicles use the right turn bay for access onto Interstate-90/Massachusetts Turnpike.

Figure 5.1B – Existing Conditions of Intersection – Boylston Street Looking East

Figure 5.1C – Existing Conditions of Intersection – Boylston Street Looking West

Refer to figure 5.1 D and 5.1 E below for the existing cross-section of the intersection. The existing cross-sections comprise of very wide lanes that induce speeding and double parking. Also, there is no left turn movement for a vehicle heading eastbound onto Massachusetts Avenue.

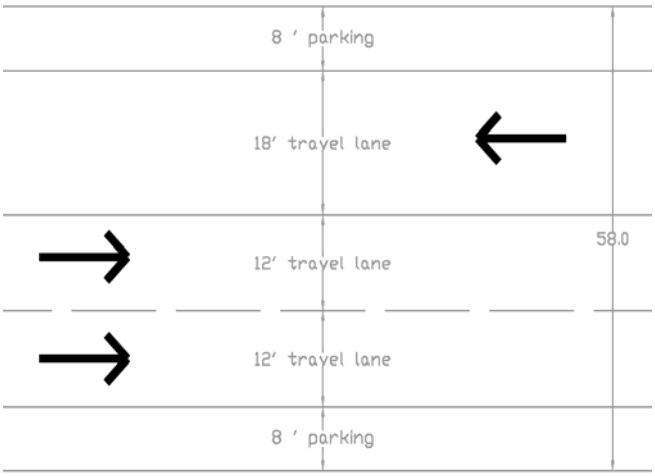


Figure 5.1D – Existing Cross-Section - Boylston Street West of Mass. Ave

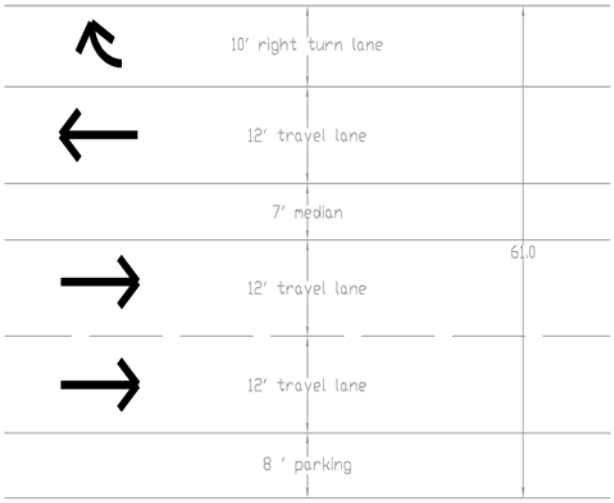


Figure 5.1E – Existing Cross-Section - Boylston Street East of Mass. Ave

5.2 Boylston Street at Massachusetts Avenue Design Alternatives

5.2.1 Introduction to the Design

In order to accommodate a cycle track, vehicular travel lanes were reduced in width without changing existing curb lines. Also, because Massachusetts Avenue spans over the Massachusetts Turnpike, it would not be cost effective to change the existing infrastructure. The required changes to the cross-section involve reducing the lane widths on both the westbound and eastbound travel lanes and resetting the vegetated median on Boylston Street west of Massachusetts Avenue. In section 5.2.2 an alternative will be discussed and in section 5.3 through 5.5 the selected design will be discussed and analyzed.

5.2.2 Alternatives Considered

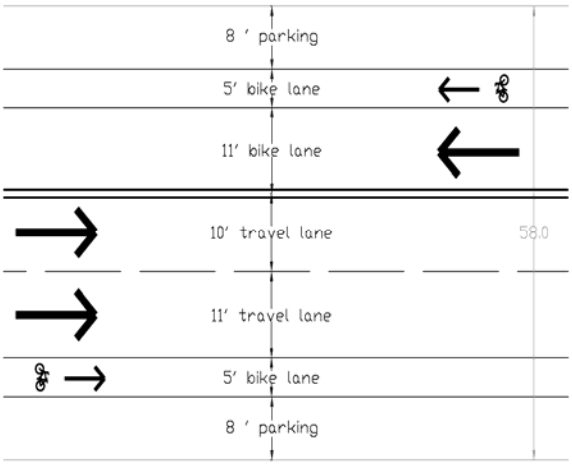


Figure 5.2A – Non-Recommended Alternative – Boylston Street West of Mass. Ave.

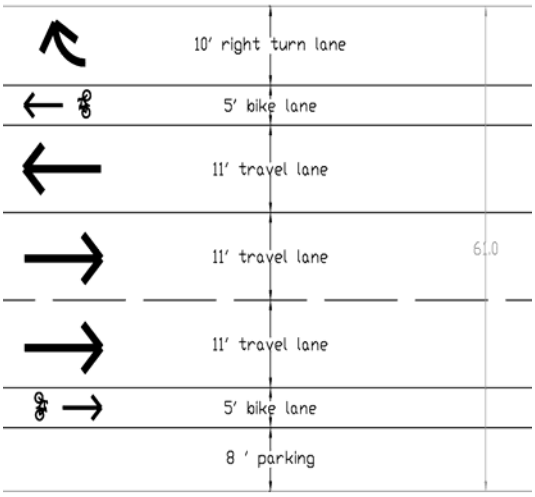


Figure 5.2B – Non-Recommended Alternative – Boylston Street East of Mass. Ave.

Two different alternatives were considered for the redesign of this intersection.

The first alternative was to create a 5-foot bike lane on each side of Boylston Street while maintaining the existing lane configuration. In this alternative, there is no buffer zone to separate bicyclists from vehicles. A bike lane with no buffer provides inadequate safety and comfort to a cyclist and creates opportunity for double parking, therefore, the alternative was not chosen. See figure 5.2A and 5.2B for the proposed cross section for Boylston Street east and west of Massachusetts Avenue.

The second alternative considered was to create an exclusive right turn lane on Boylston Street east of Massachusetts Avenue by eliminating a parking lane and eliminate the vegetated median on Boylston Street west of Massachusetts Avenue to create a two way cycle track on the north side of Boylston Street. The travel lanes were also reduced in order to create a buffer zone. See figure 5.2C and 5.2D for the proposed cross section for Boylston Street east and west of Massachusetts Avenue.

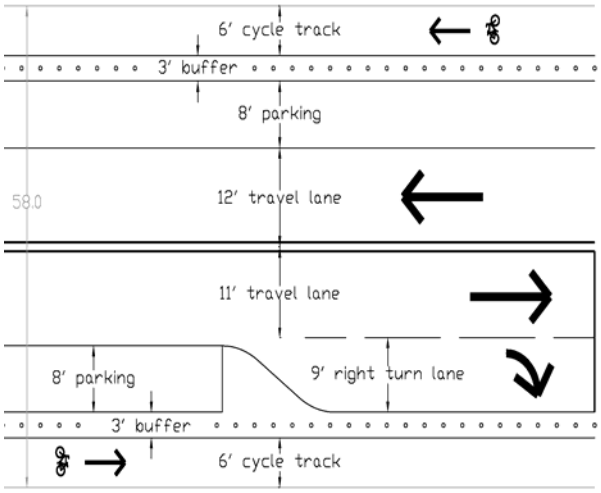


Figure 5.2C – Non-Recommended Alternative – Boylston Street West of Mass. Ave.

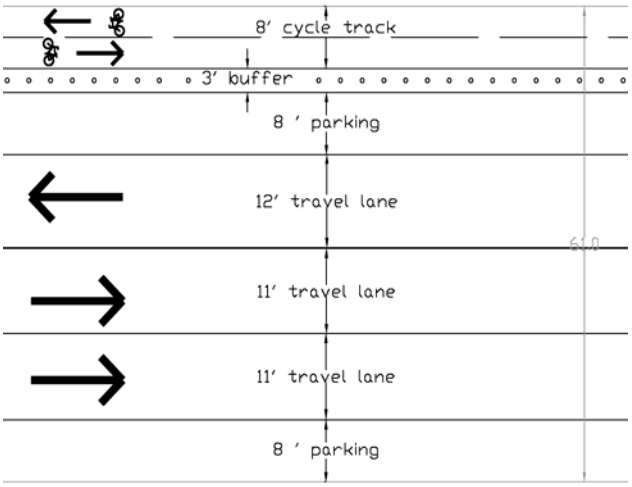


Figure 5.2D – Non-Recommended Alternative – Boylston Street East of Mass. Ave.

Viability

There are some major design challenges to this alternative. A bike box would have to be designed for cyclists to safely allow them to cross Boylston Street. The transition would result in high delay for bicyclists and a dangerous transition. The removal of the center median would eliminate a place for pedestrian refuge and a green area in an urban environment. For these reasons this alternative is not a viable option for this project.

5.3 Recommended Design

The recommended design will reduce the lane widths on Boylston Street to accommodate a two way cycle track, and also remove and reset the median island. Refer to Figure 5.3A, 5.3B and 5.3C below to see the proposed design and cross-sections.

The proposed design reduced the width of the existing lanes to accommodate the cycle track but retained the existing number of lanes to maintain the level of service which is discussed in section 5.5. The cycle track will remain on the north side the entire length of the corridor for reasons discussed in section 3.6. This design will retain all existing parking.

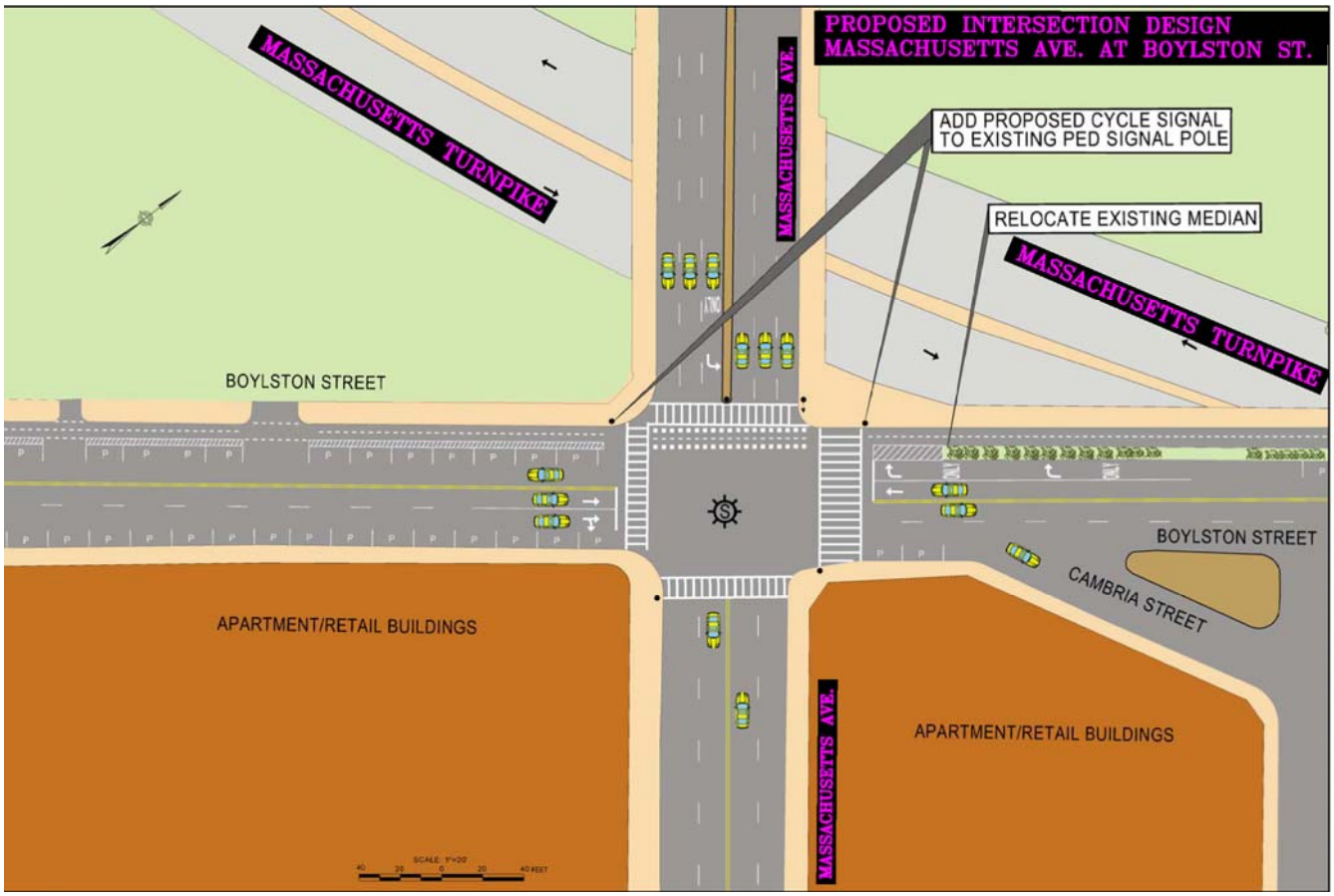


Figure 5.3A – Proposed Plan – Massachusetts Avenue at Boylston Street

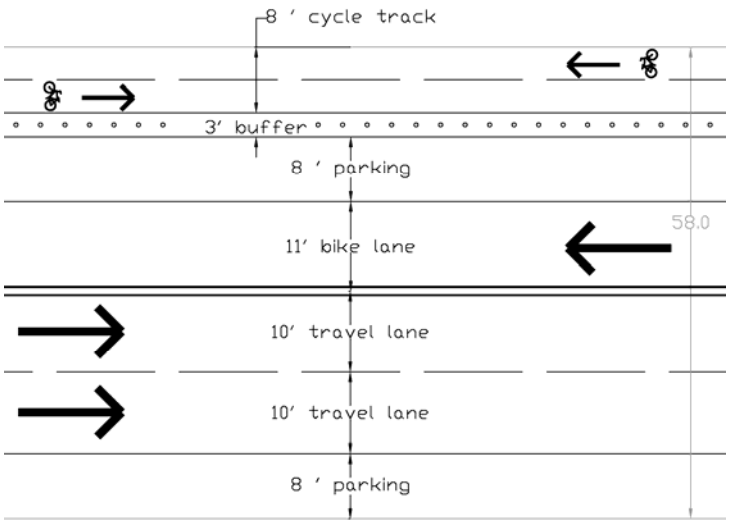


Figure 5.3B – Proposed Cross-Section Boylston Street West of Mass. Ave.

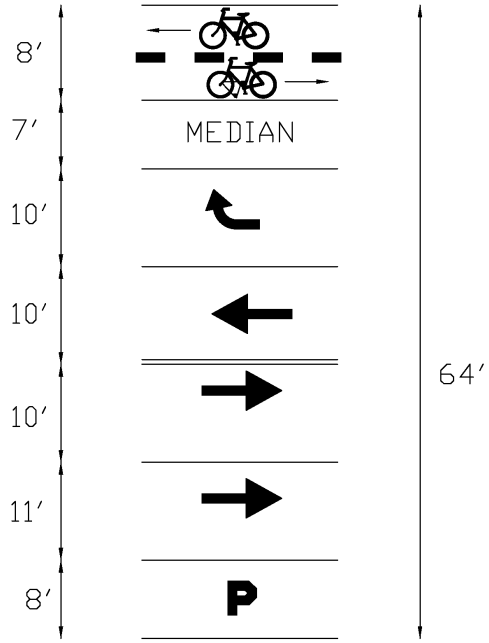


Figure 5.3C – Proposed Cross-Section Boylston Street East of Mass. Ave.

The relocation of the median was an element of the design because it is an aesthetically pleasing safety barrier between cyclist and vehicles. By reducing the lane widths, Boylston Street east of Massachusetts Avenue was able to keep the existing lane configuration. As mentioned in the general section, adding cycle signals should reduce the conflicts between cyclists and right turning vehicles onto Massachusetts Avenue.

5.4 Existing Vehicular and Pedestrian Traffic Analysis

5.4.1 Field Measurements and Observations

During numerous field visits the group observed the disorganized flow of the intersection. The main issue was the non-compliance of pedestrians due to inadequate signal time phasing with the pedestrian walk signals. The existing timing plan gives too much green time to the southbound through movement resulting in wasted green time which drastically increases the intersection delay and results in an unsafe intersection. Due to the short green times on the other approaches vehicles travel quite rapidly through the intersection trying to beat the red light.

Due to the large amount of pedestrian volume mentioned in section 5.1.1, the right turning westbound movement is not allowed enough green time and a large queue occurs. A protected right turn movement is only allowed when there is a green arrow.

The non compliance issue does not allow vehicles to travel through the intersecting causing a large delay. Part of the re-design was to rework the signal timings and concurrent pedestrian walk signals to alleviate the problem.

5.4.2 Existing Conditions

The current timing plan highly favors vehicular traffic. Although the current timing plan does give pedestrians time to walk, the amount of time given is inadequate for the volume of pedestrians. The northbound and southbound movements often run longer than necessary causing pedestrians to cross during a large gap, causing more opportunity for pedestrian-vehicle conflicts.

5.5 Modification of Vehicular and Pedestrian Traffic

The proposed layout for Boylston Street and Massachusetts Avenue signal timing plan has minor changes compared to the existing timing plan. The timing plan needed to be modified to accommodate the proposed cycle track and to reduce the non-compliance of pedestrians. An analysis was done and the new signal timing plan is Figure 5.5A in section 5.5.1.

5.5.1 Signal Timing Modification PM Peak Hour

Signal timing changes are meant to improve the delay and level of service for pedestrians and bicycles and, also, maintain or improve the vehicular delay and level of service.

It is hard to model the effect of right turning vehicles and pedestrian conflicts in Synchro. Since the right turning westbound movement is a dominant turning movement, proposed results are similar to existing conditions. See Table 5.5B for the PM peak hour level of service calculations.

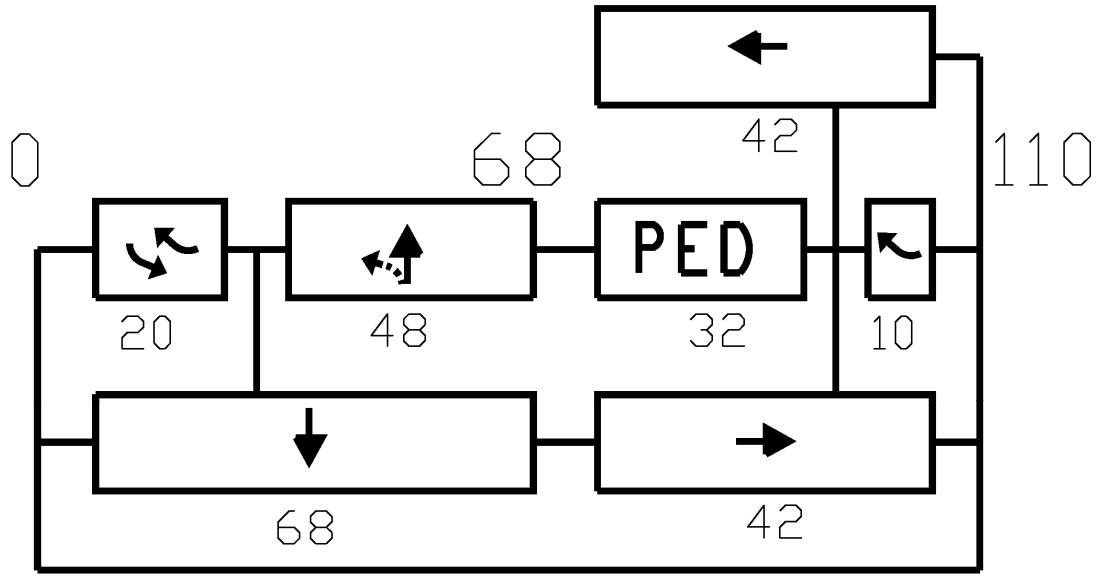


Figure 5.5A – Proposed Signal Timing Plan

Table 5.5B below shows the proposed vehicular and pedestrian level of service of Boylston Street and Massachusetts Avenue. Overall, the improvements are modifications of the exiting intersection because the lane configuration did not change but a cycle track was added. The proposed design retained the same level of service and also added a two-way cycle track. The pedestrian crossing delays all were reduced by at least two seconds. The cycle track crossing delay is thirty three seconds, which is not ideal, however it was necessary to insure a safe crossing and safety is the number one priority of this design. See Appendix A for the existing and proposed Synchro reports.

Table 5.5B
Boylston Street and Mass Ave: PM Peak Hour Vehicular and Pedestrian Level of Service

	Existing				
Approach	Delay (s)	V/C Ratio	95% Queue Length	50% Queue Length	LOS
Boylston EB Thru	28.3	0.54	233	175	C
Boylston WB Thru	26.8	0.19	75	47	C
Boylston WB Right	-	-	-	-	-
Mass Ave NB Thru	12.7	0.62	136	110	B
Mass Ave SB Left	38.7	0.29	101	53	D
Mass Ave SB Thru	20	0.56	275	213	B
Pedestrians Crossing Boylston West Side	24	-	-	-	C
Pedestrians Crossing Boylston East Side	31	-	-	-	D
Pedestrians Crossing Mass Ave North Side	38	-	-	-	D
Pedestrians Crossing Mass Ave South Side	34	-	-	-	D
Cycle Track Crossing	-	-	-	-	-
Entire Intersection	20.4	0.62	-	-	C
	Proposed				
Approach	Delay (s)	V/C Ratio	95% Queue Length	50% Queue Length	LOS
Boylston EB Thru	27.2	0.55	230	172	C
Boylston WB Thru	24.7	0.09	55	27	C
Boylston WB Right	35.8	0.36	128	72	D
Mass Ave NB Thru	25.1	0.58	219	175	C
Mass Ave SB Left	43.2	0.38	107	56	D
Mass Ave SB Thru	13.3	0.46	222	175	B
Pedestrians Crossing Boylston West Side	16	-	-	-	B
Pedestrians Crossing Boylston East Side	29	-	-	-	C
Pedestrians Crossing Mass Ave North Side	45	-	-	-	E
Pedestrians Crossing Mass Ave South Side	33	-	-	-	D
Cycle Track Crossing	33	-	-	-	D
Entire Intersection	22.8	0.58	-	-	C

6.0 Boylston Street at Dalton Street

6.1 Overview of the Section

The main complication for the cycle track at Dalton Street was the informal firefighter parking in the intersection, perpendicular to Boylston Street.

Fire station parking currently exists perpendicular to Boylston Street, on Hereford Street, and behind the building. During field visits, most of this parking was full. As a result, it preferred that a solution be found instead of eliminating the parking.

All lanes and approaches remained the same. The proposed design adds the cycle track and changes the alignment of the parking.

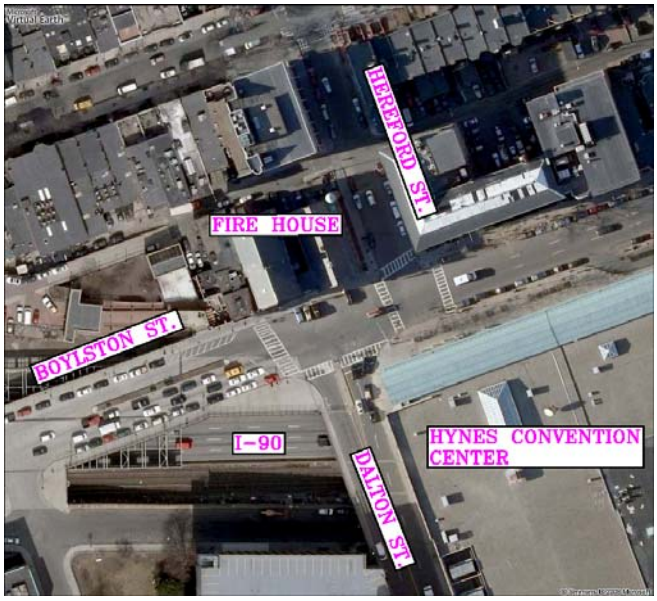


Figure 6.1A – Boylston Street at Dalton Street Site Map

6.1.1 Existing Conditions

The existing intersection has two approaches. Traffic on Boylston Street can turn left onto Hereford Street, which is one-way to the North, continue through on Boylston where it becomes one way heading east, or turn right onto Dalton Street to the South. Dalton Street intersects Boylston at a "T." Traffic can turn left or right onto Boylston or continue straight onto Hereford Street. Cars continuing straight onto Hereford make a slight right, then a slight left. Figure 6.1A illustrates this turning movement.

Figure 6.1B – Boylston Street Looking East

The existing intersection has three pedestrian crossings on Boylston Street. There is one pedestrian crosswalk for Dalton Street with a pedestrian refuge island in the middle, and one pedestrian crosswalk for Hereford Street.

East of Dalton Street, metered parking ends prior to the intersection and firefighters park perpendicular to Boylston next to the fire house. This can also be seen in Figure 6.1A and 6.1B. There is space for seven informal parking spots. There are no pavement markings for these parking spots.

Figure 6.1C – Boylston Street Looking West

There is also a no parking zone to the east of the fire house that existed for an old police station. This zone prevents cars from parking in the turning radius of a police vehicle exiting the station. This building has since been converted into a bar and restaurant and the no-parking buffer is no longer needed. The driveway for this building also remains.

On Boylston Street traveling west, there are temporary jersey barriers. They act as a refuge for pedestrians crossing the street and stop trucks from turning right onto Dalton Street.

6.2 Recommended Design

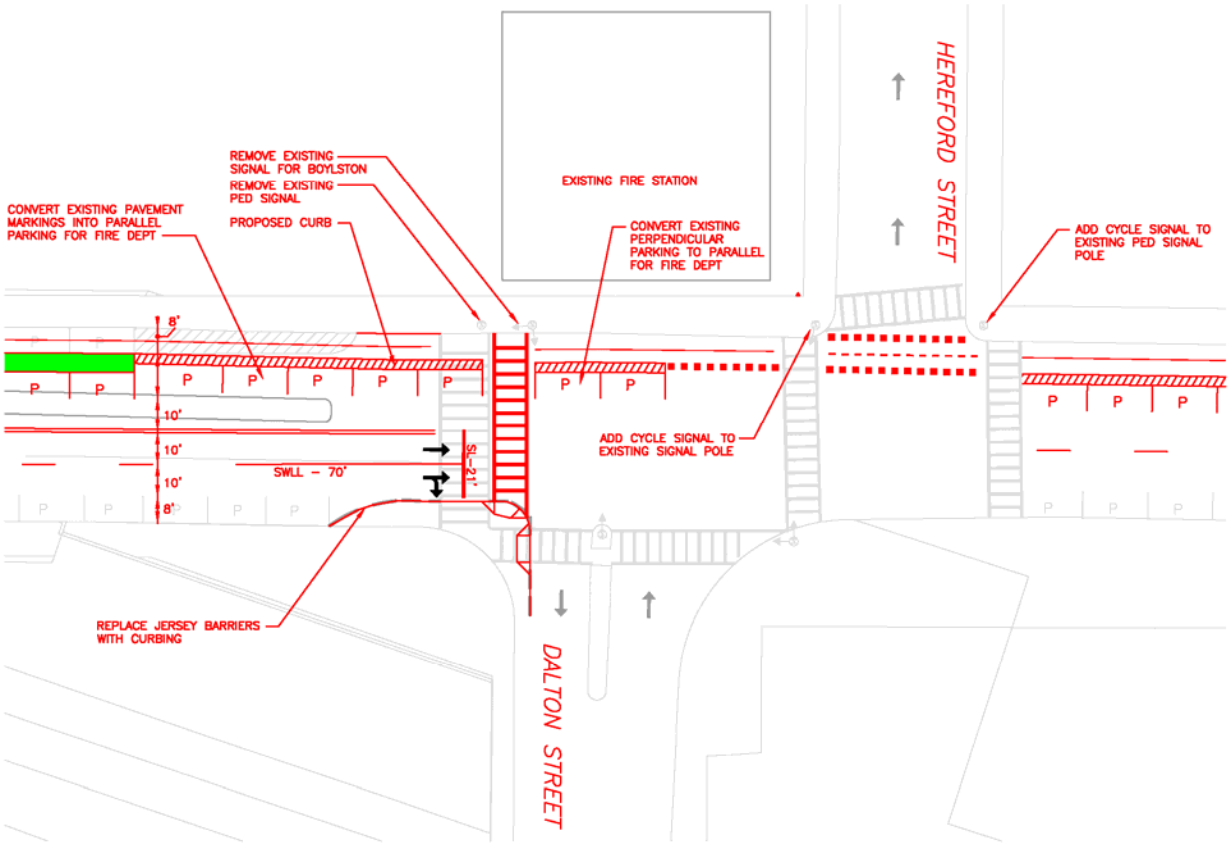


Figure 6.2A – Boylston Street Cycle Track Recommended Design

Various improvements were made to this intersection so the cycle track could continue unobstructed. Figure 6.2A illustrates the improvements and the new parking layout. The informal perpendicular parking spots for the fire station were relocated and converted to parallel. The no parking zone in front of the bar and restaurant was no longer needed. It was removed and converted to five parking spots. The existing pedestrian crosswalk was moved to the east to fit these spots. Two more parking spots were added to the east of the proposed crosswalk to retain the seven total spots.

The concrete jersey barriers are also to be removed and replaced with granite curbing and additional cement sidewalk.

Cycle signals were added near Hereford Street as discussed in section 3.5. The cycle signal will have a leading green so cyclists are established in the intersection and so contra flow bikes get across Hereford Street before left turning traffic from Boylston Street. When a fire truck is exiting the station, all traffic, cycle, and pedestrian signals receive a red signal.

7.0 Boylston Street from Dalton Street to Arlington Street

7.1 Overview of the Section

The section of the proposed cycle track along Boylston Street between Dalton Street and Arlington Street is the major section of the project. Boylston Street has one-way vehicular traffic along this section, and all cross streets are one way roads which alternate in direction. Bus stops, subway stations, valet parking and commercial delivery areas exist throughout this section, creating the need for unique design treatments. Pedestrian crossing delays along this section are generally below 20 seconds and vehicular delays are generally less than 30 seconds.

Figure 7.1A – Boylston Street from Dalton Street to Arlington Street Site Map

Improving bicycle accommodations by adding a cycle track, without hurting existing pedestrian and vehicular conditions, was a major design challenge. Left turning vehicular traffic, which would conflict with a cycle track, exists at multiple intersections and presented a major design challenge that is discussed in section 7.3.3. Additionally, this chapter will discuss various design alternatives and the chosen design for this section.

Figure 7.1B – Existing Conditions of Section – Boylston Street Looking East

7.1.1 Existing Conditions

Boylston Street is a one-way eastbound local road along this section. The cross sectional width of Boylston Street varies along this section, but the constraining cross sectional width is 50 feet.

There are three east-bound travel lanes along Boylston Street in this section. The two left lanes are each 11-feet wide. The right lane is 12-feet wide to accommodate MBTA bus traffic. There is an 8-foot parking lane on the north side of the street. On the southern side of the street is an 8-foot parking lane used for parking, bus stops, valet and commercial

drop off zones. At intersections, the left and right lanes become combined through and turning lanes as needed. Please refer to figure 7.1.C for the existing cross section.

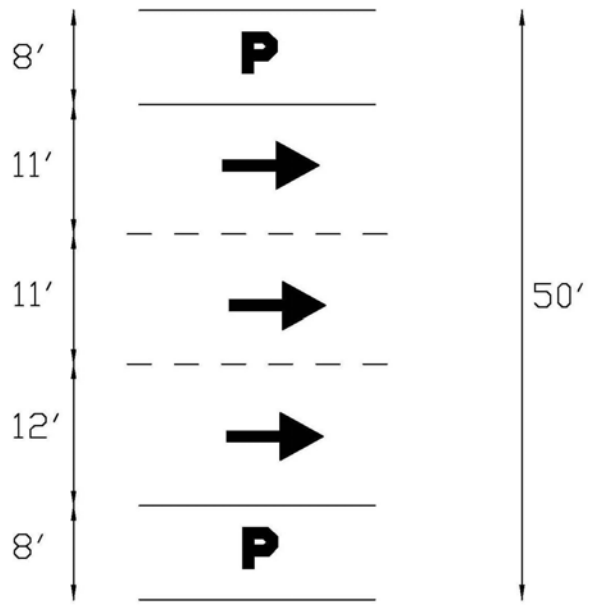


Figure 7.1C – Existing Cross-Section – Boylston Street from Dalton Street to Arlington Street

7.2 Boylston Street from Dalton Street to Arlington Street Design Alternatives

7.2.1 Introduction to the Design

A cycle track needed to be accommodated in the existing cross section of Boylston Street. In order to do this, without changing curb lines, a vehicular travel lane needed to be removed. In addition, access had to be maintained for several subway entrances, bus stops, commercial drop off zones and valet areas. The cycle track required changes to the cross section of Boylston Street. These include removing an eastbound travel lane and reducing the lane widths of the travel lanes. In section 7.2.2 an alternative will be discussed and in sections 7.3 through 7.5 the selected design will be discussed and analyzed.

7.2.2 Alternative Considered

Eliminate one eastbound travel lane on Boylston Street and add a one-way cycle track on each side of Boylston Street. Refer to figure 7.2A (next page) for the cross section view of this alternative on Boylston Street.

This alternative is similar to the chosen design in that one lane is removed from Boylston Street.

Viability

This alternative introduces connectivity challenges to other sections of the cycle track. In order to connect to other areas where the cycle track would exist as a two-way cycle track along the north curb of Boylston Street, awkward and potentially dangerous transitions would need to be included in the design of the cycle track. Additionally, a cycle track along the southern curb of Boylston Street will inhibit the access of local buses to bus stops that exist throughout Boylston Street along the southern curb. Furthermore, the 5' bicycle lanes that are incorporated in this alternative are not wide enough to allow for two cyclists to ride abreast, which means fast cyclists would not have the option to pass slower cyclists and the level of service for bicyclists would be poor. For these reasons, this alternative is not a viable option for this project.

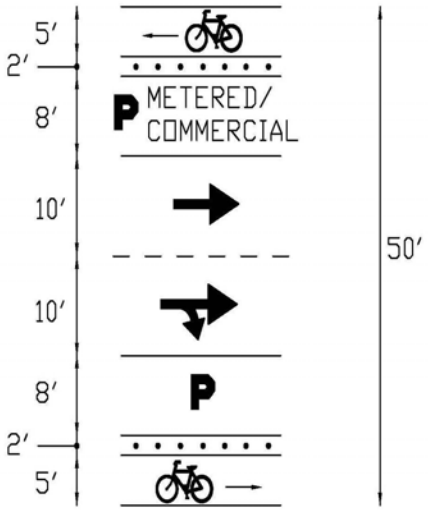


Figure 7.2A – Alternative – Boylston Street from Dalton Street to Arlington Street

7.3 Selected Design

The selected design will involve removing one eastbound through lane along Boylston Street. In some areas, bulb out curb extensions are incorporated into the design in order to reduce the crossing width for pedestrians. At intersections where cross street traffic is one-way northbound, a left turn only lane is recommended to accommodate the large volume of left turning traffic. Conversely, at intersections where cross street traffic is one-way southbound, a right turn only lane is recommended to accommodate the large volume of right turning traffic.

7.3.1 Mid-Block Design

The selected mid-block design will remove one east-bound travel lane and reduce the lane width of the remaining lanes to allow room for a two-way cycle track along the north curb of Boylston Street. This design will maintain existing parking lanes, commercial drop off zones and valet areas at mid-block areas of the section. Please refer to figure 7.3A for the proposed mid-block cross section.

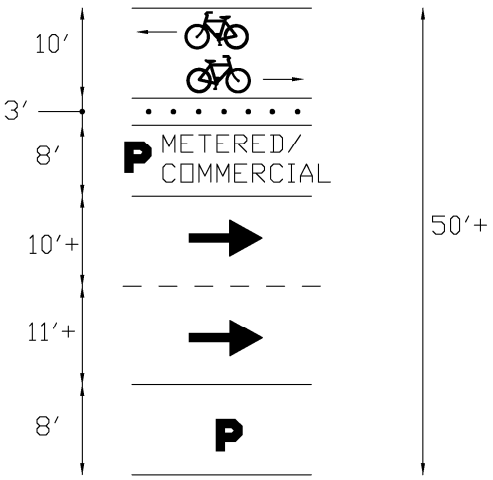


Figure 7.3A – Proposed Mid-Block Cross-Section – Boylston Street from Dalton Street to Arlington Street

7.3.2 Right-Turn Lane Design

The intersections of Exeter Street and Clarendon Street with Boylston Street have large volumes of eastbound right turning traffic and a right turn only lane on Boylston Street is recommended at these intersections to prevent blocking of one of the travel lanes when eastbound right turning cars yield to crossing pedestrians. To incorporate a right turn lane, the parking lane along the southern curb of Boylston Street will need to be removed for a distance of approximately 7 vehicle lengths approaching the intersection. Changes to the mid-block design, in addition to removing the southern curb parking lane, include narrowing the cycle track median, and narrowing all travel lanes. Please refer to figure 7.3B for the proposed right-turn lane cross section and figure 7.3C for the proposed plan view.

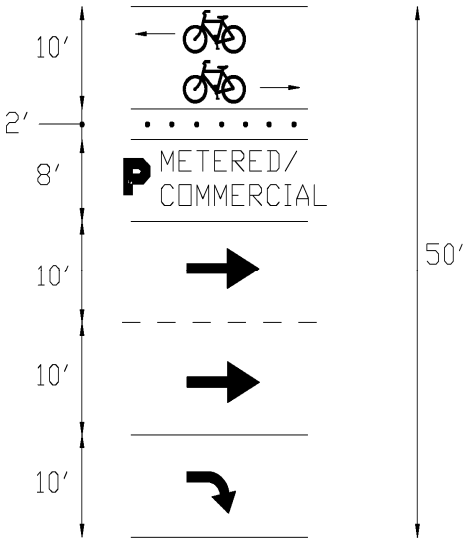


Figure 7.3B – Proposed Right-Turn Lane Cross-Section – Boylston Street from Dalton Street to Arlington Street

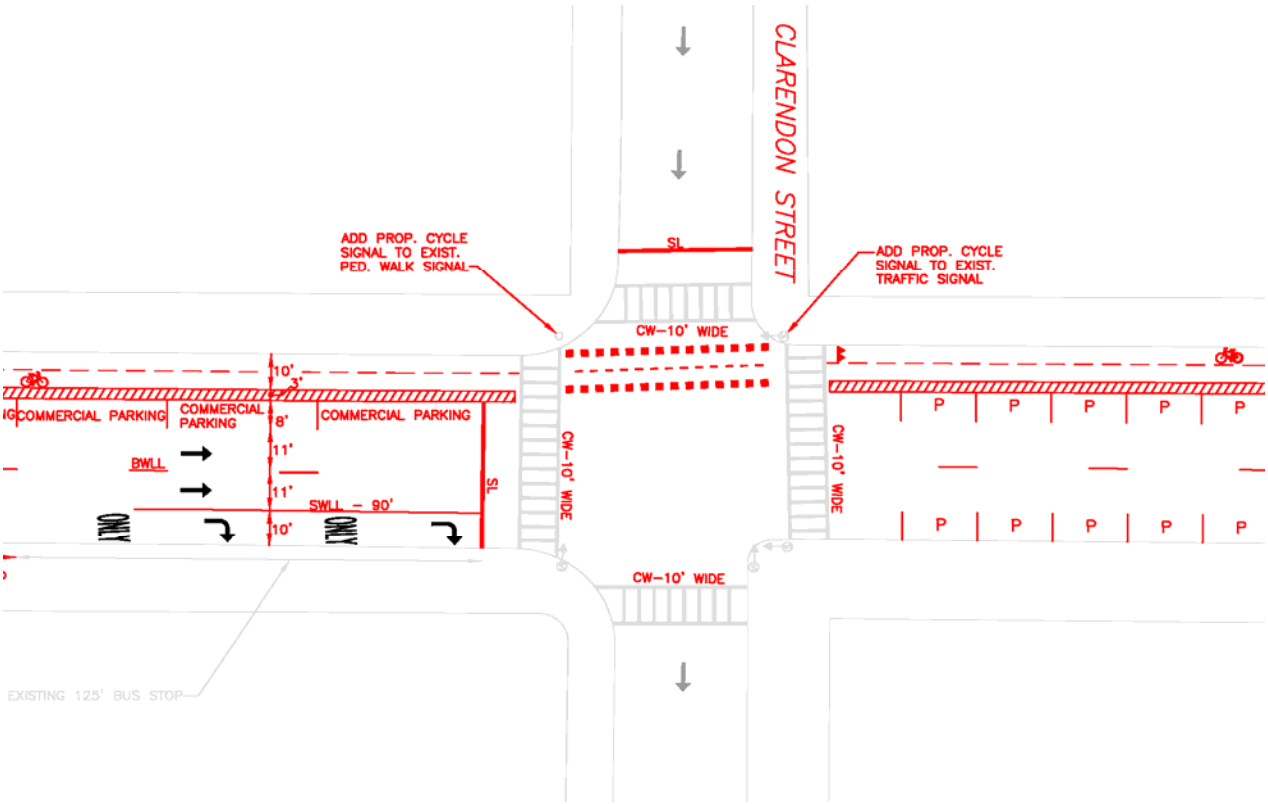


Figure 7.3C – Proposed Plan of Right-Turn Lane – Boylston Street from Dalton Street to Arlington Street

7.3.3 Left-Turn Lane Design

The intersections of Dartmouth Street and Berkeley Street with Boylston Street have large volumes of eastbound left turning traffic and a left turn only lane on Boylston Street is recommended here. This is to ensure that left turning traffic yielding to pedestrians does not block the through lanes. To incorporate a left turn lane, the parking lane along the northern side of Boylston Street will need to be removed for a distance of approximately 7 vehicle lengths approaching the intersection, which is long enough to accommodate the largest volume of left turning traffic during the PM peak hour. Changes to the mid-block design, in addition to removing the northern curb parking lane, include narrowing all through lanes. The signal timing plan needed to be re-designed in order to allow for a protected left turn movement, which is discussed in section 7.5 Please refer to figure 7.3D for the proposed right-turn lane cross section and figure 7.3E for the proposed plan view.

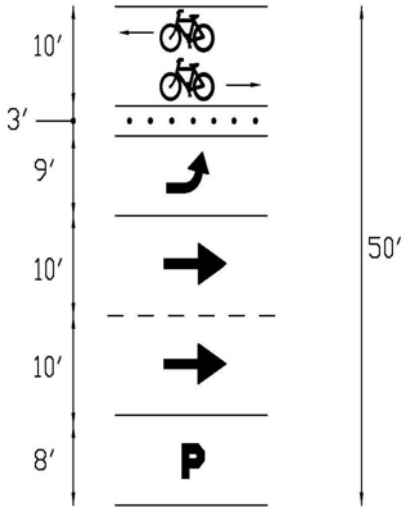


Figure 7.3D – Proposed Left-Turn Lane Cross-Section – Boylston Street from Dalton Street to Arlington Street

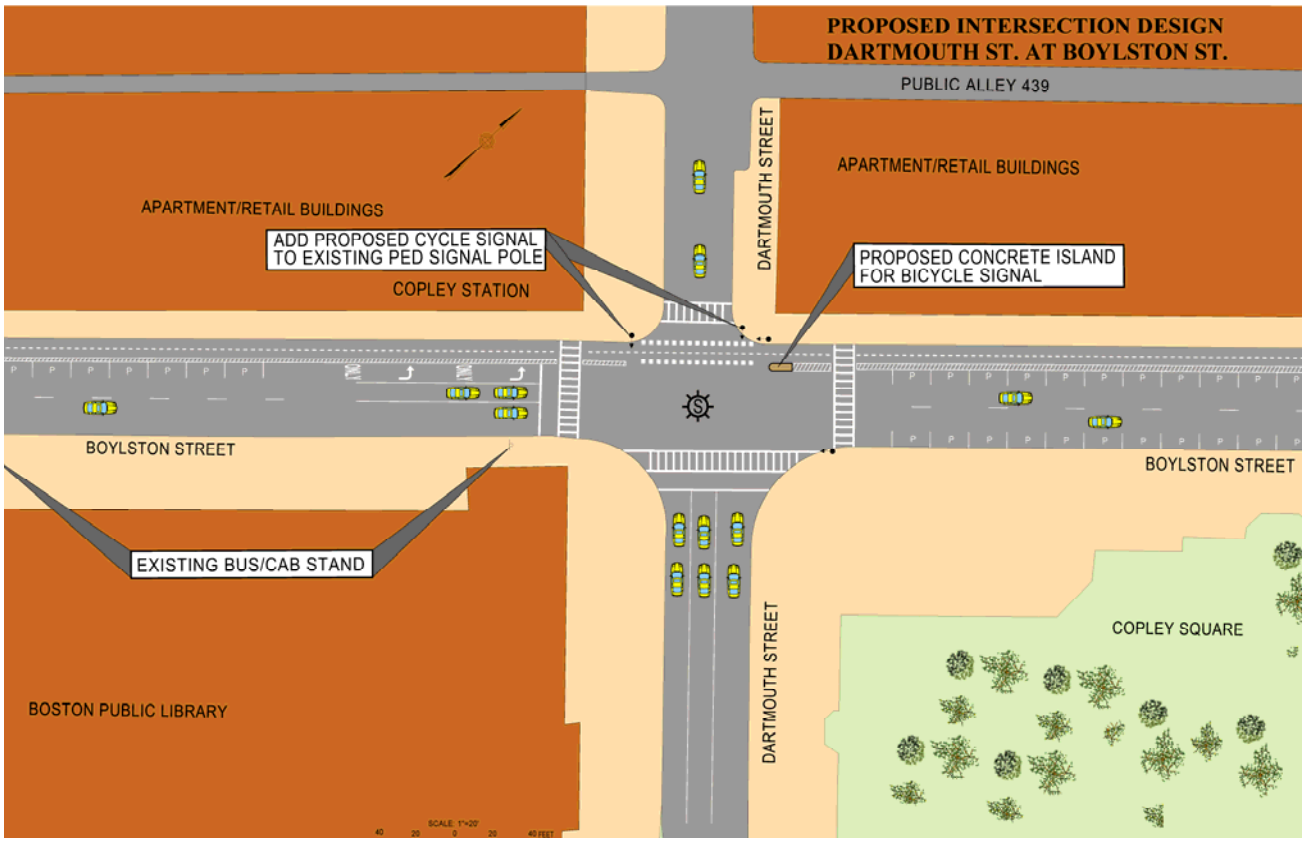


Figure 7.3E – Proposed Plan of Left-Turn Lane – Boylston Street from Dalton Street to Arlington Street

7.4 Existing Vehicular and Pedestrian Traffic Analysis

7.4.1 Field Measurements and Observations

In order to analyze the existing traffic conditions along this section of Boylston Street, several field visits were conducted. Activities during field visits to every intersection along this section included surveying intersection geometry, taking photographs, and observing traffic and pedestrian conditions. Additionally, traffic counts were collected at three critical intersections during the PM peak hour of 4:30-5:30: Boylston Street at Dartmouth Street, Clarendon Street, and Berkeley Street.

Each of these intersections is within close proximity to MBTA bus and subway stations, which resulted in large pedestrian volumes. Pedestrian phases in the cycle are set on recall because of these pedestrians. Boylston Street carries a considerable traffic volume, but the roadway is underutilized. Blocking and short queue buildups occur only when turning vehicles yield to pedestrians in a crosswalk.

7.4.2 Existing Conditions

7.4.2.1 Boylston Street at Dartmouth Street

The Boylston Street approach never experiences large queues. Occasionally, pedestrians will cross the north crosswalk of Dartmouth Street, causing eastbound left traffic to yield and block that through approaches. This leads to minor queues that tend to dissipate within that same cycle. Dartmouth Street queues tend to be larger than Boylston Street, but are never so large as to back up into the preceding intersection. The existing conditions intersection operates at a level of service C. Please refer to Appendix A for the Existing Timing Plan and Synchro 6 Analysis.

7.4.2.2 Boylston Street at Clarendon Street

Queues are never significant on either street due to a coordination network in both the eastbound and southbound approaches and green waves through this intersection. This coordination results in delay that is very low at the intersection for both pedestrians and vehicles. The intersection operates at a level of service of B. Please refer to Appendix A for the Existing Timing Plan and Synchro 6 Analysis.

7.4.2.3 Boylston Street at Berkeley Street

The intersection at Berkeley Street operates much like the one at Dartmouth Street, described in Section 7.4.2.1, but with a higher volume

of left turning traffic from the eastbound Boylston Street approach. This high left turn volume, combined with the usual pedestrian blockage, results in excessive queues and delays on Boylston Street. The Boylston Street approach operates at a level of service D. The intersection of Boylston Street at Berkeley Street operates at a level of service C. Please refer to Appendix A for the Existing Timing Plan and Synchro 6 Analysis.

7.5 Modifications of Vehicular and Pedestrian Traffic

The proposed layouts for intersections on Boylston Street between Dalton Street and Arlington Street changed the way the intersections operated. The introduction of a short, 7 car lengths long, turning bay on Boylston Street as described in sections 7.3.2 and 7.3.3 required that the timing plan be revised for these intersections. These turning only lanes require their own phase in the cycle.

The timing plans for Boylston Street at Dartmouth Street, Clarendon Street, and Berkeley Street were revised and analyzed. These intersections were improved by allowing for concurrent phasing of pedestrians and bicycles with eastbound through movements, while also protecting the pedestrians and bicycles from the eastbound left conflicting movement at Dartmouth Street and Berkeley Street. The existing total cycle length was maintained during modifications for each of these intersections. The results of the changes at each intersection are presented in this section.

7.5.1 Dartmouth Street Intersection Signal Timing Modification for PM Peak Hour

The new phasing plan retains a cycle length of 100 seconds, which allows coordination throughout the network. The overall intersection level of service was improved and the total intersection delay was also reduced. Please refer to Figure 7.5A for the signal timing plan and Appendix a for the Synchro 6 analysis report.

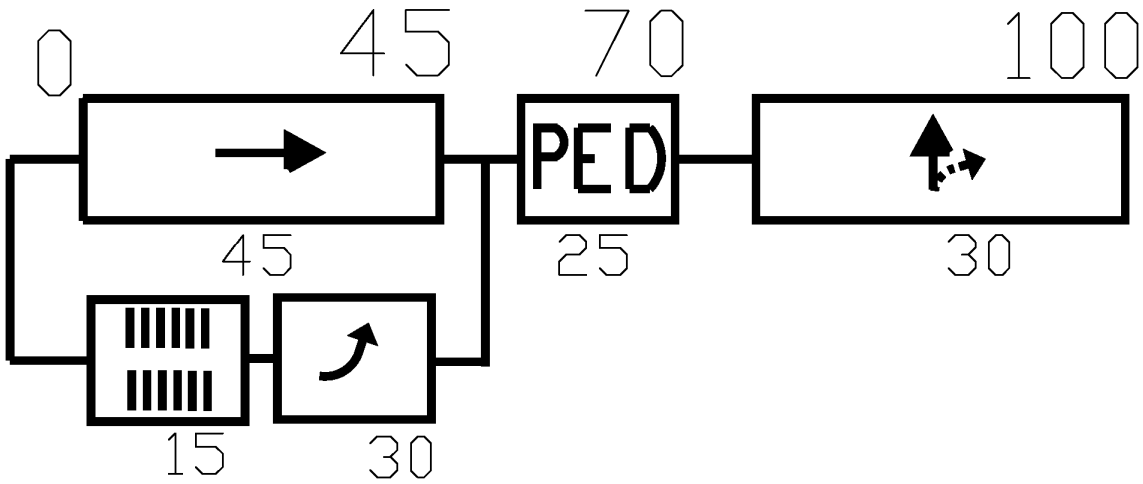


Figure 7.5A – Proposed Signal Timing Plan – Boylston Street at Dartmouth Street

Table 7.5A Boylston Street and Dartmouth Street: PM Peak Hour Vehicular and Pedestrian Level of Service					
	Existing				
Approach	Delay (s)	V/C Ratio	95% Queue Length	50% Queue Length	LOS
Boylston EB Thru	28.1	0.63	234	189	C
Dartmouth NB Thru	25.3	0.45	189	139	C
Dartmouth NB Right	27.6	0.61	305	198	C
Pedestrians Crossing Boylston West Side	13	-	-	-	B
Pedestrians Crossing Boylston East Side	41	-	-	-	E
Pedestrians Crossing Dartmouth North Side	15	-	-	-	B
Pedestrians Crossing Dartmouth South Side	15	-	-	-	B
Cycle Track Crossing	-	-	-	-	-
Entire Intersection	27.3	0.63	-	-	C
	Proposed				
Approach	Delay (s)	V/C Ratio	95% Queue Length	50% Queue Length	LOS
Boylston EB Thru	27	0.68	255	204	C
Dartmouth NB Thru	33.7	0.69	249	185	C
Dartmouth NB Right	33.9	0.67	278	178	C
Pedestrians Crossing Boylston West Side	18	-	-	-	B
Pedestrians Crossing Boylston East Side	41	-	-	-	E
Pedestrians Crossing Dartmouth North Side	29	-	-	-	C
Pedestrians Crossing Dartmouth South Side	10	-	-	-	B
Cycle Track Crossing	23	-	-	-	C
Entire Intersection	30.1	0.69	-	-	C

Table 7.5A shows the existing conditions and proposed conditions of each approach for this intersection. The overall intersection delay was increased by less than three seconds and the level of service remained at C which is typical and acceptable for an urban setting. The signal timing changes revolved around allotting time to the protected cycle track and eastbound left movements, since the two are in direct conflict with each other. The delays for vehicles were increased by such a small amount that this design would result in a very minimal impact on the operational capacity of this intersection.

The introduction of a protected left turning phase from the eastbound Boylston Street approach meant that pedestrians were allotted less time in the revises signal timing plan. Pedestrian delays on the whole were increased by a small amount. One phase in particular, the Dartmouth North Crosswalk, had an increase in delay of 14 seconds and level of service degradation from B to C. This is acceptable considering a level of service C is desirable in urban settings. All other pedestrian crossings had a level of service that remained unchanged.

The cycle track crossing will experience a delay of 27 seconds which results in a level of service C. This is adequate considering that the cycle length is 100 seconds.

7.5.2 Clarendon Street Intersection Signal Timing Modification for PM Peak Hour

The signal phasing plan at Clarendon Street required no changes. The introduction of a right turn only lane on the Boylston Street approach adequately accommodates eastbound right traffic. The remaining two through lanes required no additional time in the cycle to handle eastbound through volumes. The overall intersection level of service was maintained. Overall intersection and individual phase delays were increased a negligible amount. Please refer to Figure 7.5B for the proposed signal timing plan and Appendix A for the Synchro 6 analysis report.

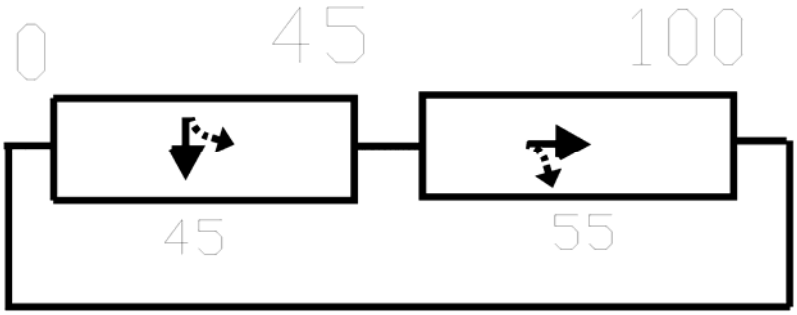


Figure 7.5B – Proposed Signal Timing Plan – Boylston Street at Clarendon Street

Table 7.5B
Boylston Street and Clarendon Street: PM Peak Hour Vehicular and Pedestrian Level of Service

Approach	Existing				
	Delay (s)	V/C Ratio	95% Queue Length	50% Queue Length	LOS
Boylston EB Through	14.9	0.44	186	151	B
Boylston EB Right	-	-	-	-	-
Clarendon SB Through	19.1	0.5	190	139	B
Clarendon SB Left	-	-	-	-	-
Pedestrians Crossing Boylston	25	-	-	-	C
Pedestrians Crossing Clarendon	18	-	-	-	B
Cycle Track Crossing	-	-	-	-	-
Entire Intersection	16.5	0.5	-	-	B
Approach	**Proposed**				
	Delay (s)	V/C Ratio	95% Queue Length	50% Queue Length	LOS
Boylston EB Through	16.7	0.53	266	208	B
Boylston EB Right	2.2	0.2	31	0	A
Clarendon SB Through	22.4	0.52	225	170	C
Clarendon SB Left	-	-	-	-	-
Pedestrians Crossing Boylston	25	-	-	-	C
Pedestrians Crossing Clarendon	18	-	-	-	B
Cycle Track Crossing	12	-	-	-	B
Entire Intersection	17.6	0.53	-	-	B

Table 7.5B, previous page, shows the existing conditions and proposed conditions of each approach for this intersection. The overall delay of this intersection was increased by a negligible 1 second and the level of service was maintained at B. This is because the signal timing plan was not changed, yet the reconfigured intersection layout handled traffic almost identically as the existing conditions. Pedestrian delay and level of service did not change and all pedestrian phases remained a level of service B. Vehicular delays were increased a maximum amount of 3 seconds. This is negligible and retains the same level of service for all vehicular approaches.

The cycle track will experience a delay of 12 seconds. This results in a level of service B which is an excellent level of service considering the cycle is 100 seconds.

7.5.3 Berkeley Street Intersection Signal Timing Modification for PM Peak Hour

The new phasing plan retains a cycle length of 100 seconds but allocates time differently to accommodate a protected left turn from the Boylston eastbound approach. The overall intersection level of service was maintained and the total intersection delay was increased a negligible amount. Please refer to figure 7.5C for the proposed signal timing plan and Appendix A for the Synchro 6 analysis report.

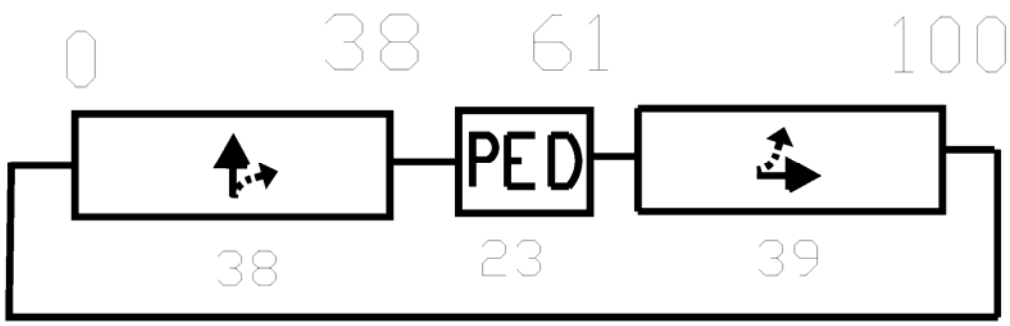


Figure 7.5C – Proposed Signal Timing Plan – Boylston Street at Berkeley Street

Table 7.5C Boylston Street and Berkeley Street: PM Peak Hour Vehicular and Pedestrian Level of Service					
	Existing				
Approach	Delay (s)	V/C Ratio	95% Queue Length	50% Queue Length	LOS
Boylston EB Through	40	0.6	308	267	D
Berkeley NB Through	22.6	0.6	236	192	C
Berkeley NB Right	-	-	-	-	-
Pedestrians Crossing Boylston	16	-	-	-	B
Pedestrians Crossing Berkeley	17	-	-	-	B
Cycle Track Crossing	-	-	-	-	-
Entire Intersection	31.3	0.6	-	-	C
	Proposed 100 second cycle				
Cycle Track Crossing	Delay (s)	V/C Ratio	95% Queue Length	50% Queue Length	LOS
Boylston EB Through	44.2	0.78	334	274	D
Berkeley NB Through	29.9	0.77	350	273	C
Berkeley NB Right	3.1	0.37	51	0	A
Pedestrians Crossing Boylston East	42	-	-	-	E
Pedestrians Crossing Boylston West	16	-	-	-	B
Pedestrians Crossing Berkeley	14	-	-	-	B
Cycle Track Crossing	9	-	-	-	A
Entire Intersection	34	0.78	-	-	C

Table 7.5C shows the existing conditions and proposed conditions of each approach for this intersection. The overall vehicular delay of this intersection was increased by a negligible 3 seconds and the level of service was maintained at C. The slight increases in delay that were experienced by all vehicular phases are the result of additional time allocated to the all pedestrian phase. The largest vehicular delay increase was on the northbound through approach, where delay increased by 7 seconds, yet the level of service was maintained at C.

Pedestrian delay for most approaches remained similar to the existing conditions in the proposed timing plan, except for the pedestrian phases that crosses Boylston Street on the East. Pedestrians crossing this side of Boylston Street conflict with the Berkeley Street northbound right vehicular movement, and therefore are not allowed to cross when this phase has a green. Pedestrians crossing the eastern side of Boylston Street can only cross during the all pedestrian phase in the proposed design. The delay on this pedestrian approach is increased by 26 seconds and the level of service reduced to E. This is acceptable because it is only for one pedestrian phase and all others have a level of service B.

The cycle track will experience a delay of 9 seconds. This results in a level of service B which is an excellent level of service.

7.5.4 Special Consideration - Berkeley Street Intersection Signal Timing Modification for PM Peak Hour 70 Second Cycle

During field visits, it was observed that a 100 second cycle at every intersection along Boylston Street was excessively long and created unnecessary delays for pedestrians and vehicles. An additional 70 second timing plan was prepared for Boylston Street at Berkeley Street to assess the feasibility of a shorter cycle. Please refer to Figure 7.5D for the 70 second signal plan and Appendix A for a Synchro 6 analyis report of this signal plan.

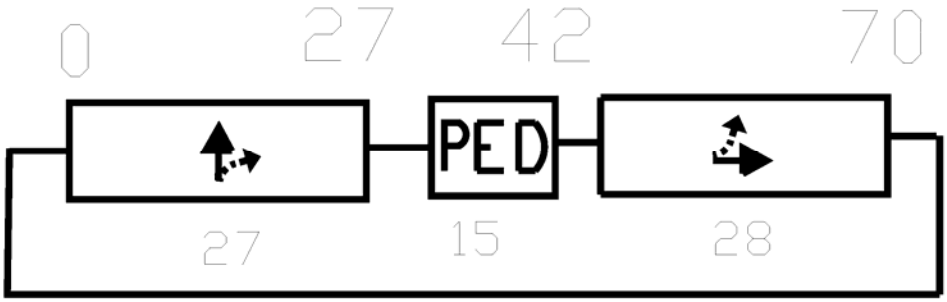


Figure 7.5D – 70 Second Signal Timing Plan – Boylston Street at Berkeley Street

Table 7.5D – 70 Second Signal Plan Boylston Street and Berkeley Street: PM Peak Hour Vehicular and Pedestrian Level of Service					
	Existing				
Approach	Delay (s)	V/C Ratio	95% Queue Length	50% Queue Length	LOS
Boylston EB Through	40	0.6	308	267	D
Berkeley NB Through	22.6	0.6	236	192	C
Berkeley NB Right	-	-	-	-	-
Pedestrians Crossing Boylston	16	-	-	-	B
Pedestrians Crossing Berkeley	17	-	-	-	B
Cycle Track Crossing	-	-	-	-	-
Entire Intersection	31.3	0.6	-	-	C
	Proposed 70 second cycle				
Cycle Track Crossing	Delay (s)	V/C Ratio	95% Queue Length	50% Queue Length	LOS
Boylston EB Through	21.4	0.8	251	191	C
Berkeley NB Through	22.7	0.79	256	186	B
Berkeley NB Right	2.8	0.38	43	0	A
Pedestrians Crossing Boylston	13	-	-	-	B
Pedestrians Crossing Berkeley	13	-	-	-	B
Cycle Track Crossing	7	-	-	-	A
Entire Intersection	19.8	0.8	-	-	B

Table 7.5D shows the existing conditions and proposed 70 second cycle conditions of each approach for this intersection. The overall vehicular delay at this

intersection was decreased by over 11 seconds, and the intersection level of service was improved from C to B. Additionally, all vehicular phases will operate with delays that are either improved or have a negligible difference. The greatest improvement with the potential 70 second cycle was on the eastbound through approach, which experience a delay that was shortened by 19 seconds. This resulted in a level of service C for the eastbound through approach. Volume to capacity ratios for every approach remained under 1 for to potential 70 second cycle.

Pedestrian delays were reduced on all pedestrian crossings in the 70 second signal timing plan. Pedestrian delay was improved by approximately 20% for both approaches. It was expected that pedestrian delays would be shorter with a shorter cycle length, but the improvement of reducing all pedestrian delays to a mere 13 seconds was not anticipated. This is an excellent pedestrian delay, and the corresponding level of service B for both pedestrian crossings is excellent as well.

The cycle track will experience a delay of 7 seconds. This results in a level of service B which is a very good level of service considering the cycle is 100 seconds.

8.0 Boylston Street at Arlington Street

8.1 Overview of the Section

Boylston Street at Arlington Street is a hectic intersection for vehicles, pedestrians and bicycles. Many vehicles travel south along Arlington from Storrow Drive towards downtown and the southeast expressway, and, also, east towards downtown and Beacon Hill. Pedestrian volume is very high in this area due to the Arlington T-stop exit. Currently, the delay for pedestrians and bicyclists is 56 seconds, and they use the same crossings. Conversely, the delay for drivers is only 31 seconds at the worst case.

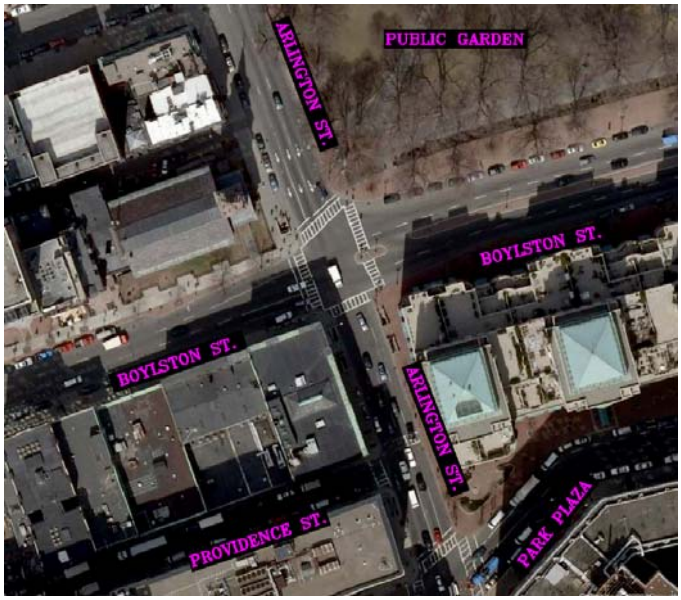


Figure 8.1A - Boylston Street at Arlington Street Site Map

Figure 8.1B - Boylston Street Looking East

Figure 8.1C - Boylston Street Looking West

8.1.1 Existing Conditions

Boylston Street at Arlington Street is a two-way intersection. Boylston Street traffic moves east and Arlington Street traffic moves south. Every approach has a pedestrian crossing and the exit for the Arlington T-stop is on the corner.

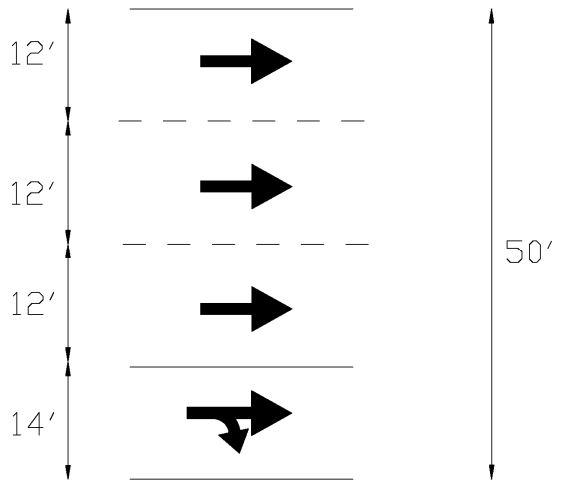


Figure 8.1D - Existing Cross-Section - Boylston Street West of Arlington Street

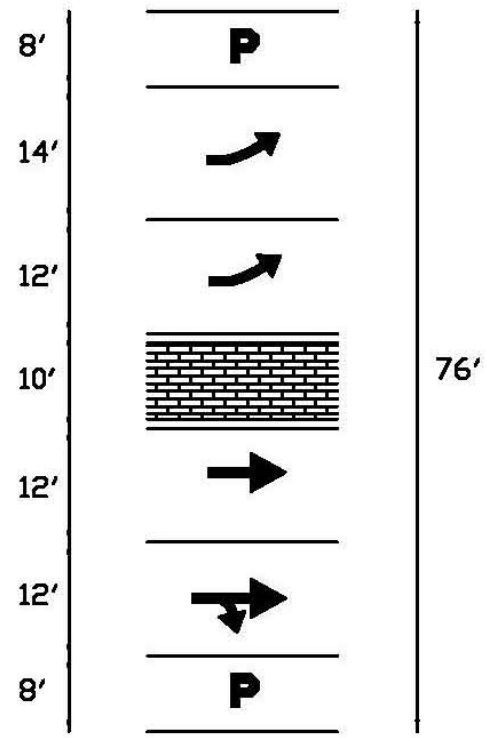


Figure 8.1E - Existing Cross-Section Boylston Street East of Arlington Street

The existing cross-section west of Arlington Street is shown in figure 8.1D. The cross-section is the same as the previous sections of Boylston Street except the parking ends and a right turn lane was added.

The existing cross-section of Boylston Street east of Arlington Street is shown in figure 8.1E.

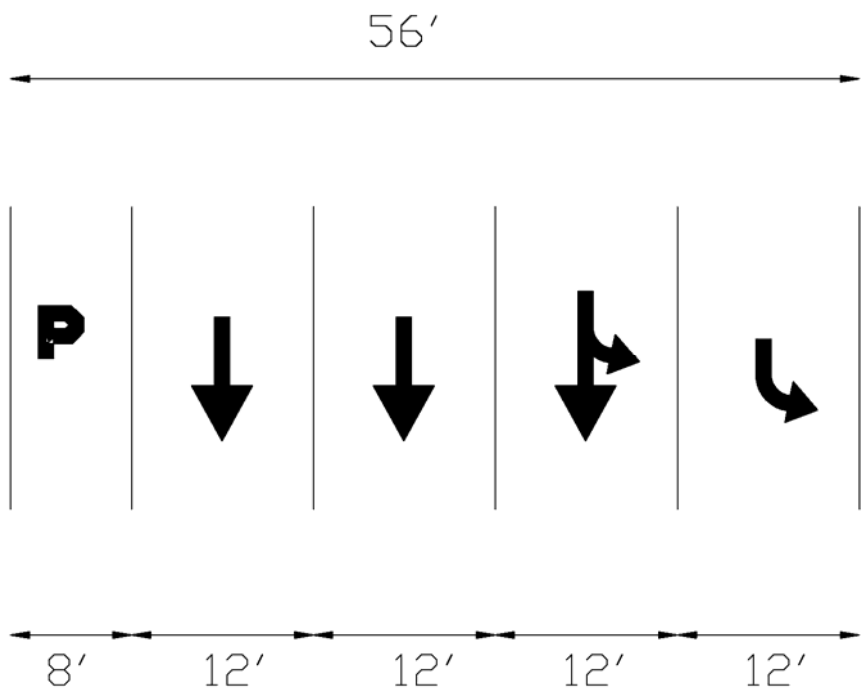


Figure 8.1F - Existing Cross-Section - Arlington Street at Boylston Street

The existing cross-section of Arlington Street is shown in figure 8.1F. It is important to note that the intersection is currently operating with one less lane due to construction which is advantageous because the intersection can be analyzed with similar lane configuration as the recommended design.

8.2 Boylston Street at Arlington Street Design Alternatives

8.2.1 Introduction to the Design

As with the rest of the project the existing curb line did not change with the proposed design. This intersection is especially not amenable to change because altering the new entrance to the Arlington T stop is not realistic, but, fortunately, not necessary. In section 8.2.2 alternatives will be discussed and in section 8.3 thru 8.5 the selected design will be discussed and analyzed.

8.2.2 Alternatives Considered

Boylston Street East of Arlington

Figure 8.2A on the left illustrates the non-recommended alternative considered. Along the Public garden the median will be removed to make room for the cycle track while maintaining the existing number of lanes.

Viability

This alternative has a few flaws:

- Pedestrians will be forced to cross six lanes of traffic resulting in an unsafe situation.
- Signals will need to be relocated for vehicular traffic as the median is used to locate the signals so they are easily seen.
- Removal of concrete medians is very expensive and by maintaining existing curb widths cost will be greatly reduced.

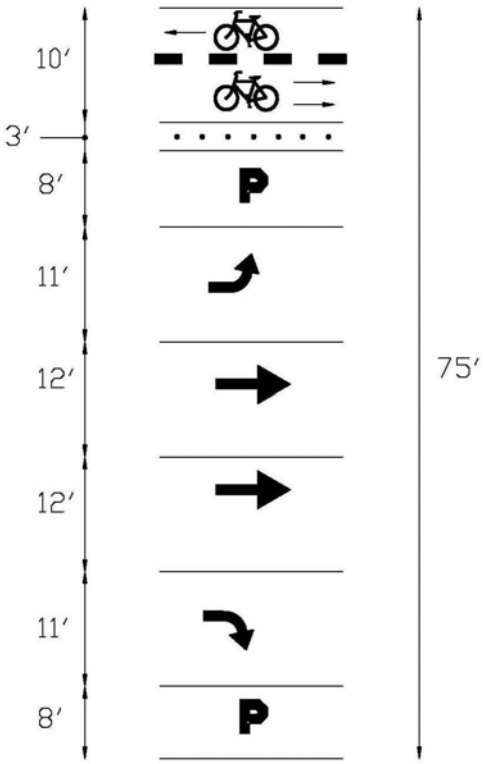


Figure 8.2A – Non-Recommended Alternative Cross-Section - Boylston Street East of Arlington Street

8.3 Recommended Design

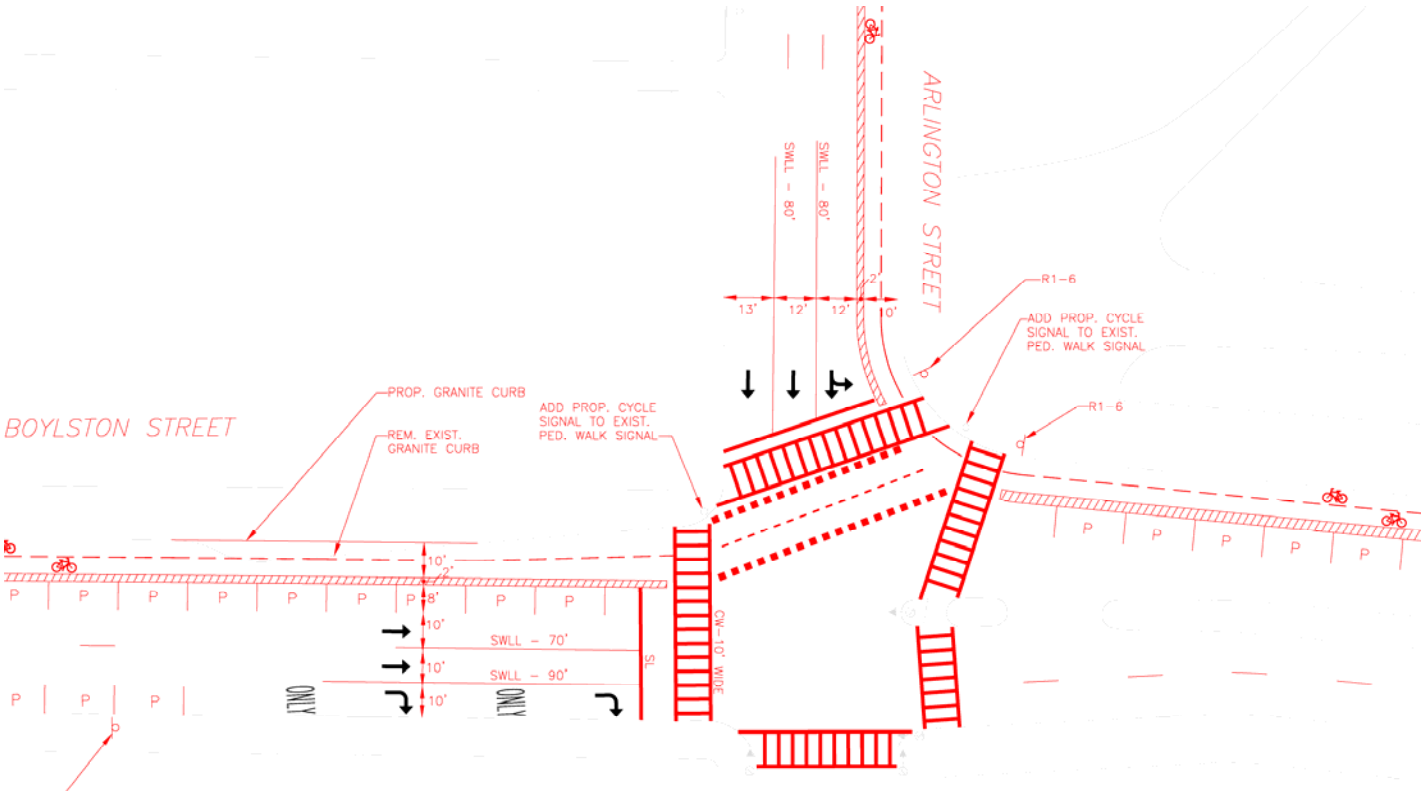


Figure 8.3A - Proposed Plan of Boylston Street at Arlington Street

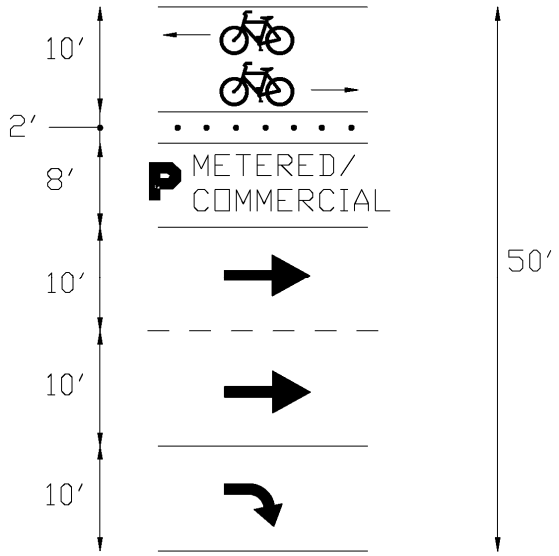


Figure 8.3B - Proposed Cross-Section - Boylston Street West of Arlington Street

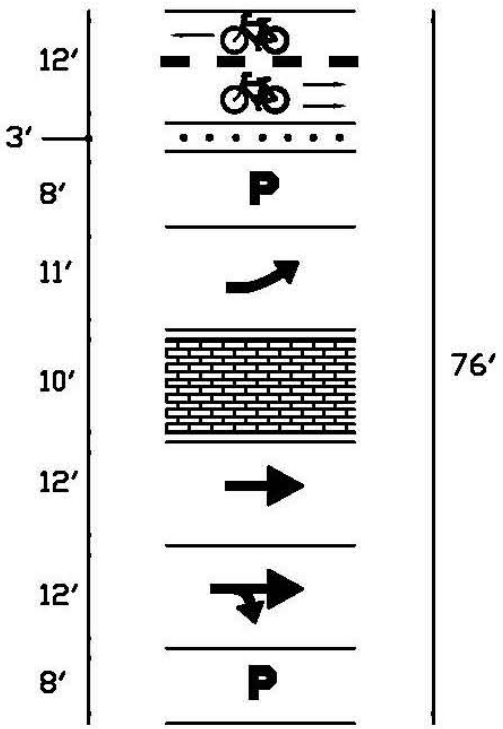


Figure 8.3C - Proposed Cross-Section - Boylston Street East of Arlington Street

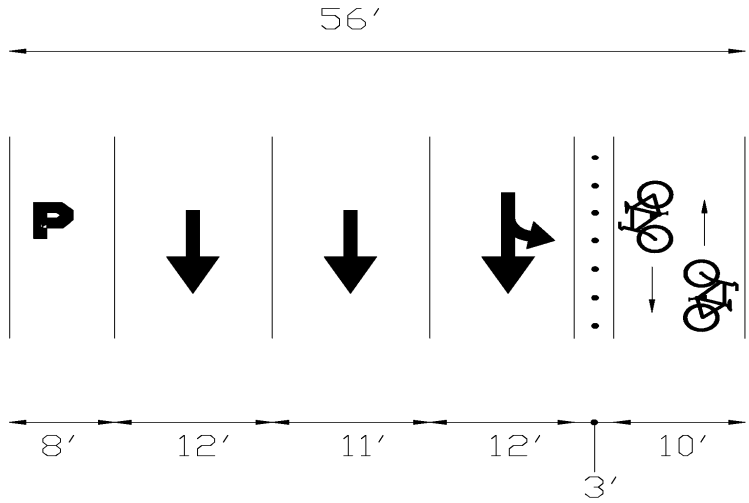


Figure 8.3D - Proposed Cross-Section - Arlington Street at Boylston Street

Figure 8.3A illustrates the proposed plan for the intersection. The intersection geometry is unchanged except for the removal of one lane for the cycle track and the addition of the cycle track crossing. As seen in figure 8.3B Boylston Street west of Arlington Street maintains the same proposed cross section as previously, but parking is removed on the south side of the street to allow for a right-turn lane. Figure 8.3C shows the proposed cross-section east of Arlington Street and again the only change is the removal of one travel lane. Figure 8.3D shows the selected design for Arlington Street which also removes one lane to accommodate the cycle-track.

8.4 Existing Vehicular and Pedestrian Analysis

8.4.1 Field Measurements and Observations

The intersection is currently under construction which was advantageous because the lane configuration was the same as the proposed design. The intersection was able to move with the current lane configuration without and major delays.

The pedestrians crossing on the southern and eastern crossing have a very high delay of 56 seconds. The delay is due to the very short all-ped phase and the lack of concurrent phasing. It appears that concurrent phasing will not work, however, due to the high turning volumes from Arlington Street onto Boylston Street and vice versa. The high turning volumes do warrant the short all ped phase and reducing the ped delay proved to be very challenging.

8.4.2 Existing Conditions

The current timing plan is adequate for the intersection. The pedestrians on the north and west crossing have concurrent phasing with short delays. As described in section 8.4.1 the other two crossings have long delays.

The vehicular approaches are somewhat lopsided in that the Boylston approach has a much higher delay and volume to capacity ratio. But, this movement has a smaller volume so it is expected that they will be given less time in the cycle. Overall the existing timing plan is good and only minor changes need to be made for the proposed plan. Refer to Appendix A to see the existing timing plan.

8.5 Modification of Vehicular and Pedestrian Traffic

8.5.1 Signal Timing Modification Peak Hour

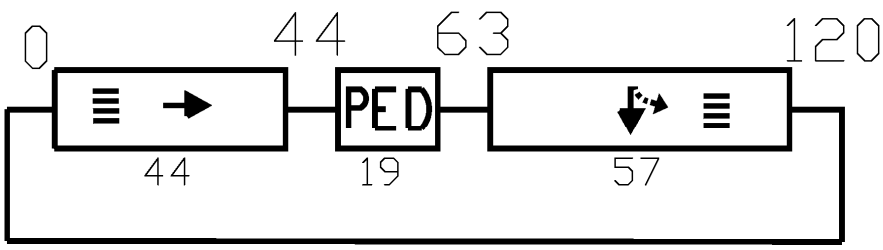


Figure 8.5A - Signal Phasing Ring Diagram

Because the existing timing was adequate the group only made minor changes to the existing plan which means, overall, the intersection does not change much. Figure 8.5A shows the proposed ring diagram which makes only minor changes to the existing. Concurrent phasing was maintained for pedestrians on the north and west crossings and kept the all-ped phase for the south and east crossings.

The new phasing retains the same cycle length of 120 seconds to maintain existing coordination. Delays and level of services for the vehicular approaches were kept as close to equal as possible by making the volume to capacity ratios as equal as possible while maintaining the pedestrian level of service.

Table 8.5A Boylston Street and Arlington Street: PM Peak Hour Vehicular and Pedestrian Level of Service					
	Existing				
Approach	Delay (s)	V/C Ratio	95% Queue Length	50% Queue Length	LOS
Boylston EB Thru	26.2	0.38	172	142	C
Arlington SB Thru	31.4	0.7	374	316	C
Arlington SB Left	31.8	0.69	437	298	C
Pedestrians Crossing Boylston West	18	-	-	-	B
Pedestrians Crossing Boylston East	56	-	-	-	E
Pedestrians Crossing Arlington North	18	-	-	-	B
Pedestrians Crossing Arlington South	56	-	-	-	E
Cycle Track Crossing	-	-	-	-	-
Entire Intersection	29.7	0.7	-	-	C
	Existing w/Construction				
Approach	Delay (s)	V/C Ratio	95% Queue Length	50% Queue Length	LOS
Boylston EB Thru	27.8	0.5	247	201	C
Arlington SB Thru	37	0.88	543	442	D
Arlington SB Left	41.2	0.87	643	419	D
Pedestrians Crossing Boylston West	18	-	-	-	B
Pedestrians Crossing Boylston East	56	-	-	-	E
Pedestrians Crossing Arlington North	18	-	-	-	B
Pedestrians Crossing Arlington South	56	-	-	-	E
Entire Intersection	34.9	0.88	-	-	C
	Proposed				
Approach	Delay (s)	V/C Ratio	95% Queue Length	50% Queue Length	LOS
Boylston EB Thru	34.6	0.67	303	245	C
Arlington SB Thru	28.6	0.76	487	396	C
Arlington SB Left	29	0.76	537	375	C
Pedestrians Crossing Boylston West	15	-	-	-	B
Pedestrians Crossing Boylston East	56	-	-	-	E
Pedestrians Crossing Arlington North	22	-	-	-	C
Pedestrians Crossing Arlington South	56	-	-	-	E
Cycle Track Crossing	16	-	-	-	B
Entire Intersection	30.8	0.76	-	-	C

Table 8.5A above shows the changes throughout the intersection. Overall the intersection delay and level of service remained the same as the existing conditions. It is important to note, however, that the delay of the intersection improved by 4 seconds from the current state of the intersection which is under construction and has the same number of lanes as our proposed design.

The delay for the eastbound thru movement increased over existing due to the fact that more time was given to the southbound movements in order to decrease their volume to capacity ratios. The eastbound movement had a volume to capacity of only 0.38 while the southbound approaches were 0.70 and 0.69 which is very

unbalanced, but, by giving more time to the southbound approach the intersection became more balanced and still maintained the existing level of service and delay.

The cycle track crossing has a very low delay and high level of service. The delay is only 16 seconds and the level of service is B. The cycle track runs concurrently with the pedestrian crossing resulting in very good service for bicyclists in both directions.

9.0 Charles Street from Boylston Street to Beacon Street

9.1 Overview of the Section

Charles Street from Boylston Street to Beacon Street is one of four streets around the Public Garden. This stretch is very popular for pedestrians and bicycles because of the proximity of the Public Garden and the Boston Common. Also, many bicycles use the Longfellow Bridge on their routes for commuting or recreational purposes. Many vehicles travel north along Charles Street to Storrow Drive.

Figure 9.1A –Charles Street from Boylston Street to Beacon Street Site Map

9.1.1 Existing Conditions

The existing intersection has wide lanes that induce speeding around The Public Garden. This creates an unsafe intersection for pedestrians to cross. Refer to Figure 9.1B for the existing conditions of the intersection. Figures 9.1C and 9.1D are photos that show the wide lanes and the existing brick median for pedestrians. Two large central islands offer pedestrian refuge, safety, and channelization for vehicles.

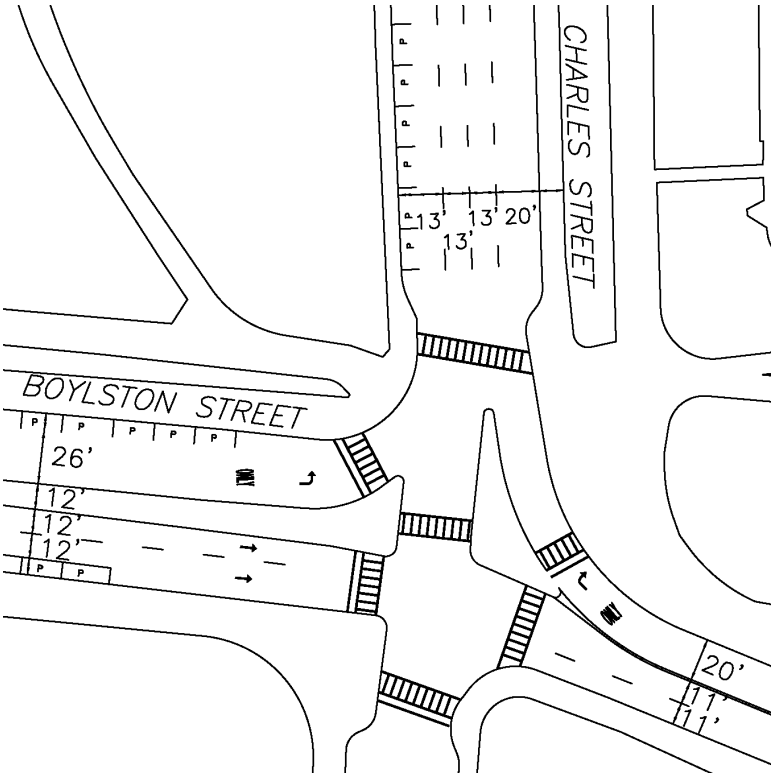


Figure 9.1B – Charles Street at Boylston Street Intersection

Figure 9.1C - Charles Street Looking North

Figure 9.1D - Boylston Street Looking East

9.2 Recommended Design

9.2.1 Charles Street

In order to accommodate a cycle track the group had to consider how to reduce the width of the vehicular travel lanes without changing existing curb lines. See figure 9.2A for the proposed cross-section and figure 9.2B for the proposed plan.

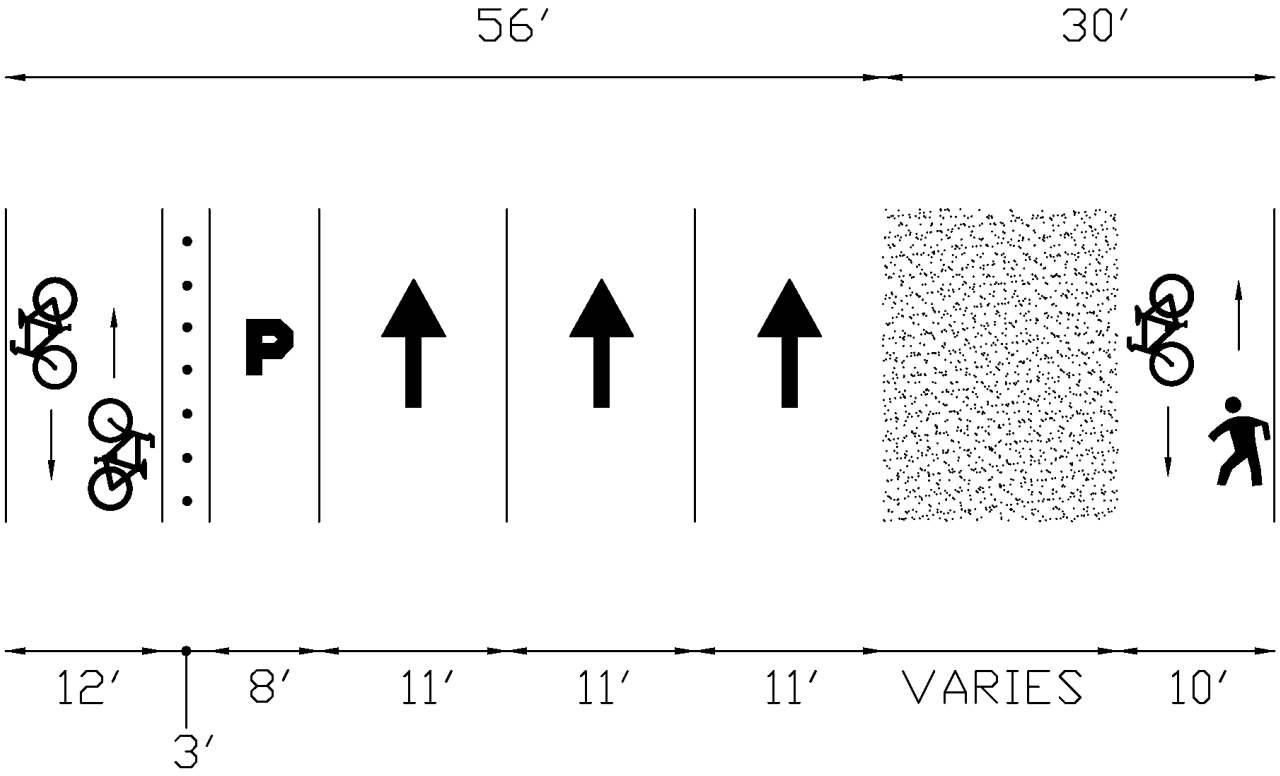


Figure 9.2A - Proposed Cross-Section – Charles Street from Boylston Street to Beacon Street

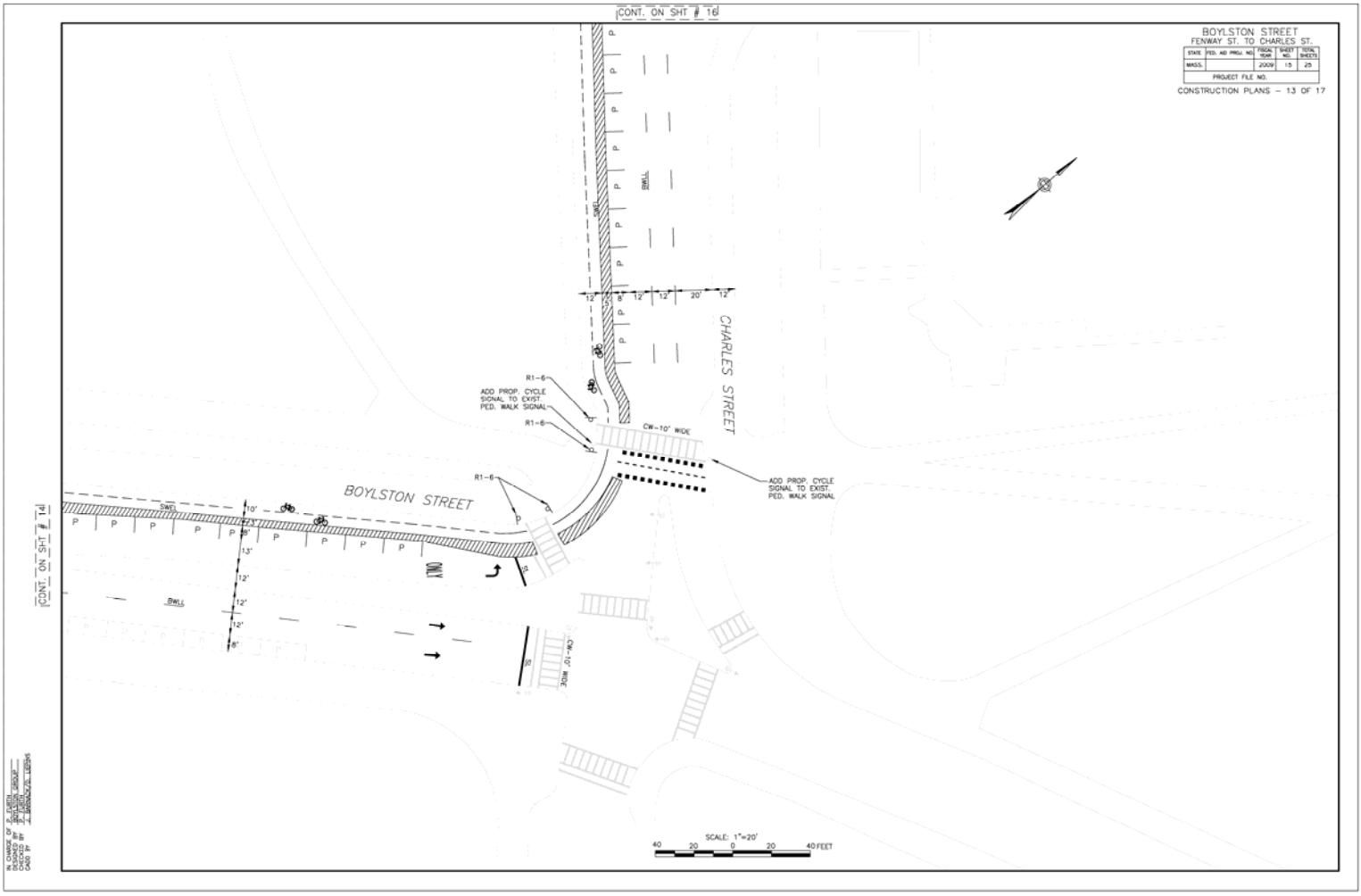


Figure 9.2B - Proposed Plan – Charles Street from Boylston Street to Beacon Street

Figure 9.2A, is for Charles Street after the Boston Common garage. This was not proposed from Boylston Street to the Boston Common garage in order to insure their was enough room for cars to enter the garage entrance. The addition of a cycle track on Charles Street will require the removal of one of the four existing lanes. The elimination of one through lane on the Charles Street needed to be done to include a two-way cycle track to the west side of Charles Street. This alternative reduces the number of lanes from four to three along the entire length of Charles Street. Also, 11-foot lanes were proposed to deter speeding around The Public Garden and Boston Common. This was done because during field visits, it is evident Charles Street is a de-facto three lane urban arterial. Since the fourth lane is under-utilized, it better serves to be converted into a two-way cycle track.

10.0 Beacon Street at Arlington Street

10.1 Overview of the Section

Beacon St at Arlington St has three separate components. It contains the section of Beacon Street, the section of Arlington Street, and the potential connection to the Charles River Pathways.

A lane was removed from both Beacon Street and Arlington Street to provide adequate space for the cycle track. Traffic analysis will show that both sections had more lanes than were needed and one could be eliminated.

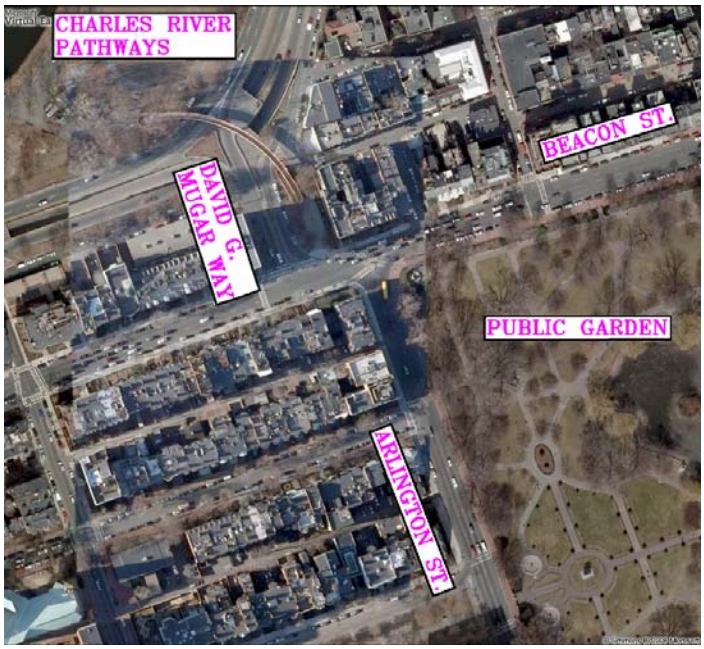


Figure 10.1A – Beacon Street at Arlington Street

This intersection has very heavy traffic movements in all directions and is a major pedestrian crossing. It also has the potential connection to the Charles River Pathways. The intersection was redesigned to provide the same level of service for vehicles as existing conditions and provide an easy crossing for pedestrians and cyclists. In order to provide an easy crossing, the group changed the direction of pedestrian crossings, added a bigger island, and added a new longer and more direct crossing for bicycles.

10.1.1 Existing Conditions

At the intersection of Beacon Street and Arlington Street, Beacon Street is one way to the west and Arlington is one way to the south. The traffic movements can be seen in Figure 10.1B. Cars traveling on Beacon Street can use any one of four lanes. The left lane is an exclusive left onto Arlington Street. This lane is very wide and is often used as a two lane turn by more aggressive drivers. There are two through lanes that continue straight onto Beacon Street. The right lane is a right turn only lane. This lane turns North onto David G. Mugar Way, which continues onto Storrow Drive. Traffic exiting Storrow Drive onto David G. Mugar way to the south can turn right onto

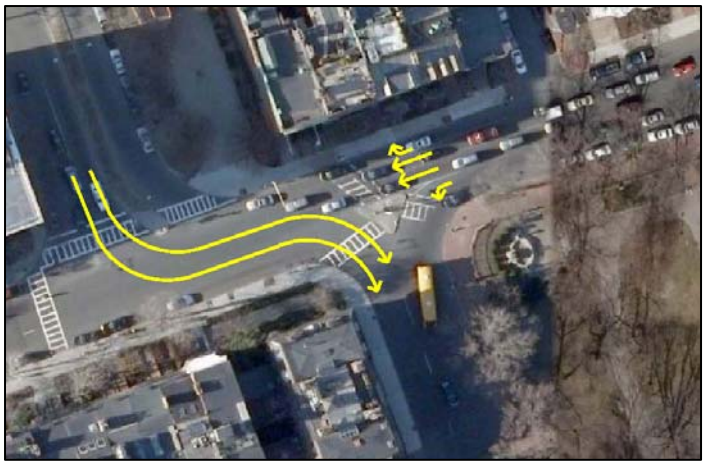


Figure 10.1B – Beacon Street at Arlington Street – Traffic Movements

Boylston or turn left, then immediately right to continue south on Arlington.

Arlington Street heading south has four travel lanes and parking on the west side. See figure 10.1C for the existing cross section.

Beacon Street approaching Arlington Street is four lanes in one direction and parking on both sides. See figure 10.D for the existing cross section.

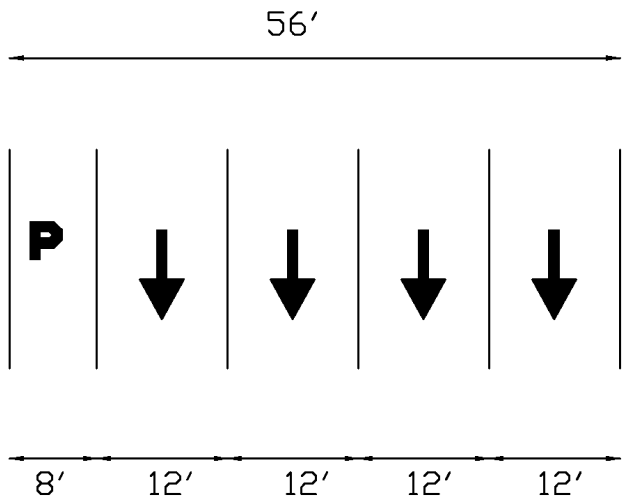


Figure 10.1C – Arlington Street Existing Conditions

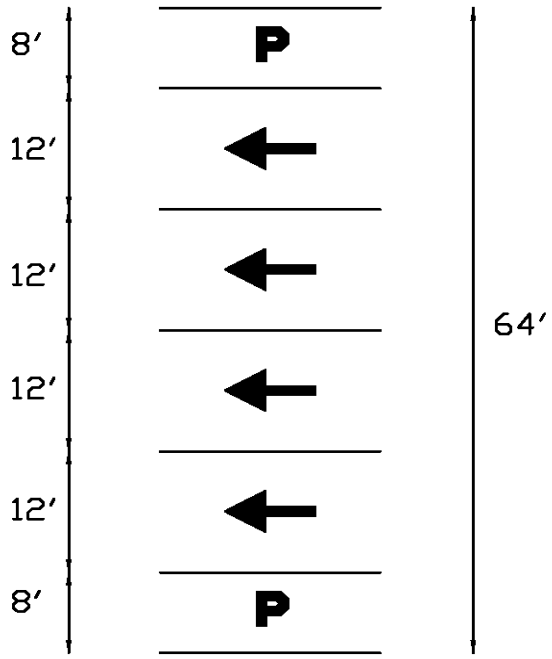


Figure 10.1D – Beacon Street Existing Conditions

10.2 Beacon Street at Arlington Design Alternatives

10.2.1 Introduction to the Design

In order to accommodate a cycle track, the group had to consider how to minimize travel lanes without changing existing curb lines. Widening the road would be very expensive, and would require reduction of sidewalk space around the public garden. As a result, the ideal solution was to remove a lane of traffic and to reduce the lane width to fit the desired cycle track and buffer. In section 10.2.2, an alternative will be discussed and in sections 10.3 through 10.5, the selected design will be discussed and analyzed.

10.2.2 Alternative Considered

In this alternative, one lane of westbound traffic was removed to make room for a one way cycle track in both directions. Each cycle track would include a three foot buffer separating it from traffic. This alternative would keep the existing curb to curb dimension intact and would not affect the amount of on street parking spots.

This alternative is similar to alternatives considered in other sections along the cycle track.

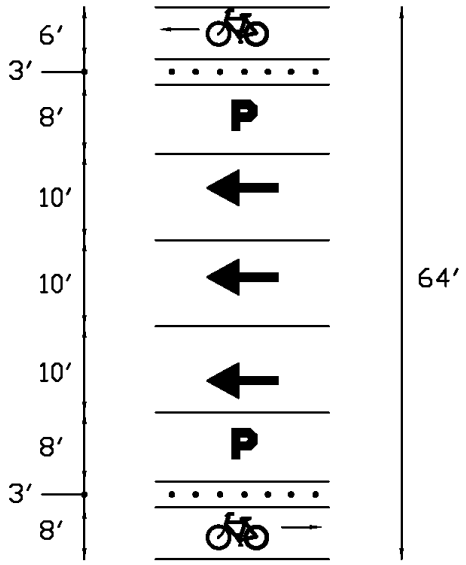


Figure 10.2A – Non-Recommended Alternative – Beacon Street

Viability

This alternative would be viable if only Beacon Street was being considered. However, this cross section does not match up with other cross section designs earlier in the cycle track. It would be impossible for other designs to transition into this alternative. This also would make connectivity to other cycle tracks very difficult. For example, a cyclist traveling from Beacon Hill to Commonwealth Ave would have to cycle through the common, cross onto the north side of Beacon and into the cycle track. The cyclist would then have to cross back to the south onto Arlington Street and continue to Commonwealth Ave. This would be difficult and promote non-compliance. For these reasons, this alternative was not a viable option for Beacon Street.

10.3 Recommended Design

The selected design will remove one lane of westbound traffic from Beacon Street to accommodate a two lane cycle track adjacent to the public garden. Parking will remain on both sides, with three westbound lanes, a buffer, and a two-way cycle track. This two-way cycle track will continue around the public garden onto Arlington Street, using the same general design: reduced from four travel lanes to three, with the parking lane remaining intact, a buffer, and a two way cycle track. See figures 10.3A and 10.3B below.

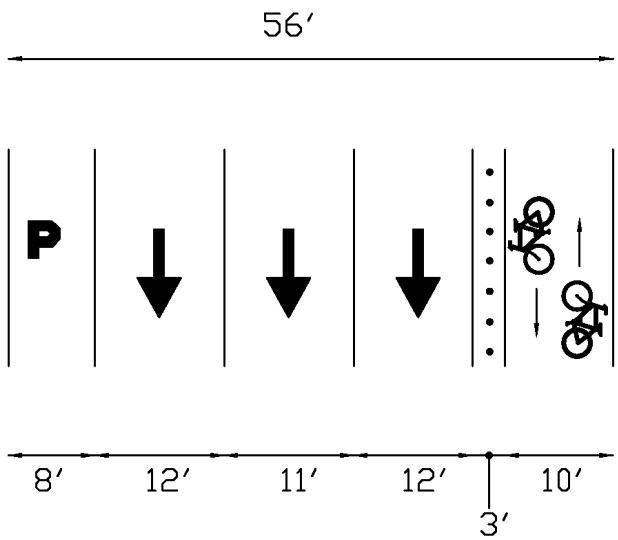


Figure 10.3A – Proposed Cross Section – Arlington Street

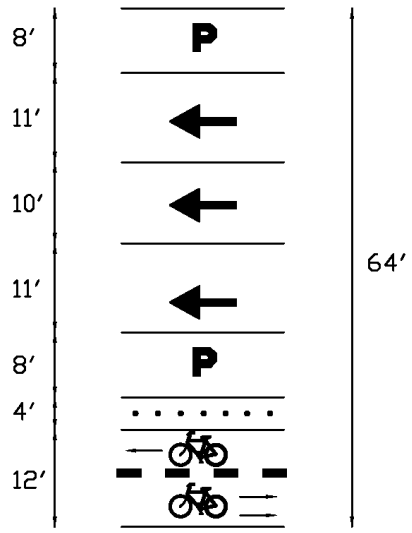


Figure 10.3B – Proposed Cross Section – Beacon Street

Figure 10.3D shows the proposed intersection design. Because the cycle track was designed to be adjacent to the public garden, this created a challenge connecting the cycle track to the Arthur Fielder footbridge at the intersection of Beacon Street and Arlington Street. The bridge spans across Storrow Drive and connects to the Charles River Pathways. In order to fit the cycle track and connection, the intersection had to be redesigned. The left turn lane on Beacon Street was reduced in width, while the far right hand lane, previously right turn only, was converted into a combination straight and right turn. For the David G. Mugar Way traffic traveling onto Arlington, the island was expanded to make two defined right hand turn lanes with lane stripping. This expanded island will be an ideal refuge for both pedestrians and cyclists crossing

Figure 10.3C – Existing Beacon Arlington Intersection

Beacon Street or Arlington. The pedestrian crossings are made shorter while cyclists have a longer but more direct route to the Arthur Fielder footbridge. Figure 10.3C shows the location of the direct crossing for cyclists during existing conditions.

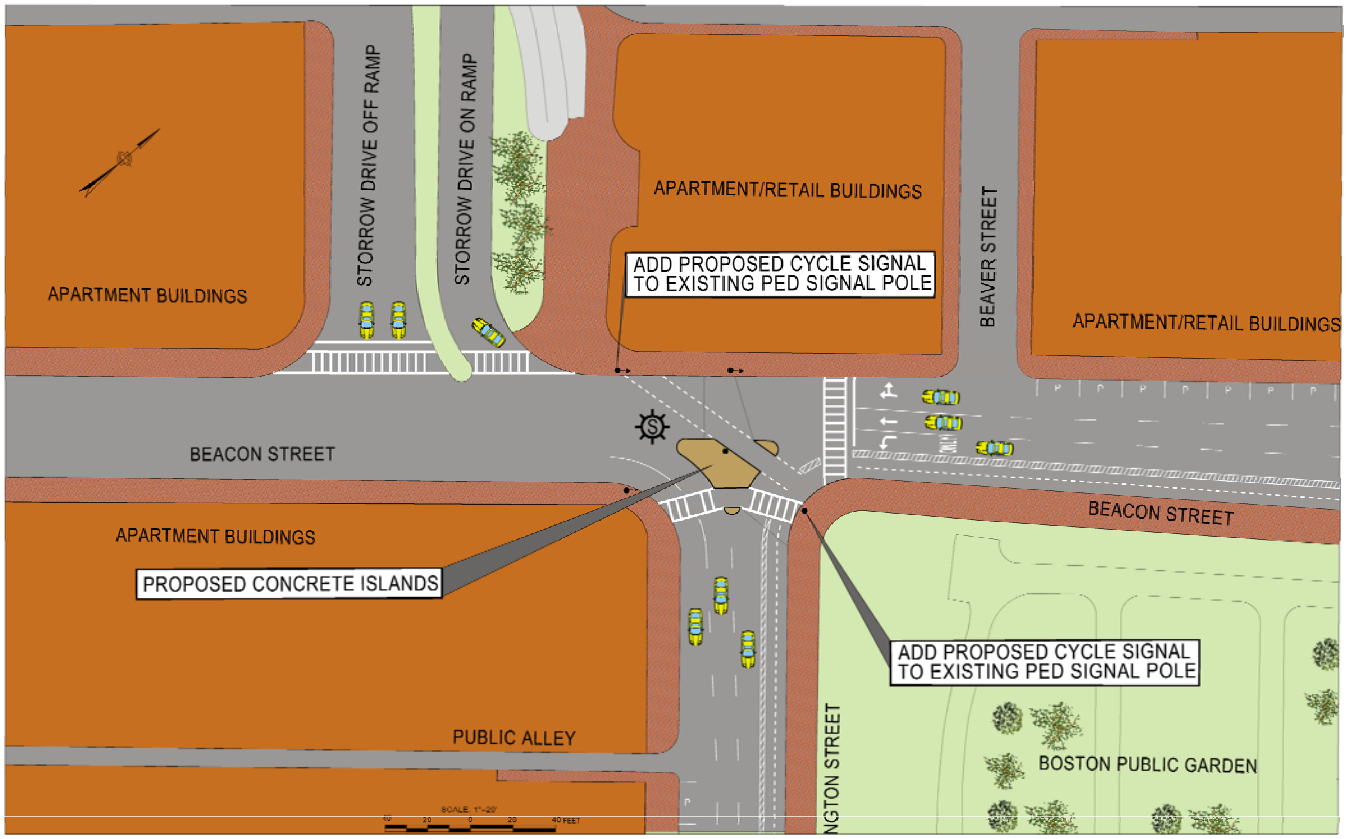


Figure 10.3D – Proposed Plan of Beacon Street and Arlington Street Intersection

10.4 Existing Vehicular and Pedestrian Traffic Analysis

10.4.1 Field Measurements and Observations

To analyze existing traffic conditions, traffic counts were conducted during the peak pm hour of 4:30 p.m. through 5:30 p.m for all directions on Beacon Street and for vehicles coming from David Mugar Way turning onto Arlington. Street.

During field visits to the intersection, it became evident that vehicles coming from David G. Mugar Way onto Arlington Street do not have a defined path. Passive drivers often had trouble negotiating the lanes with other more aggressive drivers. Also during field visits, it was obvious that vehicles turning left from Beacon onto Arlington were taking advantage of the amount of space in the left turn lane. The lane is designed for one vehicle at a time and more aggressive drivers used the middle lane to get closer to the intersection before using the extra space in the left turn lane, creating a potential for accidents.

10.4.2 Existing Conditions

The current timing plan heavily favors vehicular traffic. All pedestrian crossings are two stage crossings and require push button activation. The result is a very low level of service for pedestrians. Also, vehicles turning left from Beacon Street onto Arlington Street have a continuous green light. Pedestrians cannot cross unless they push the button and wait for vehicles to receive a red. These conditions result in a good level of service for vehicles, but a poor level of service for pedestrians and bikes. The intersection could be redesigned to have a similar level of service for vehicles, but also have an improved level of service for pedestrians.

10.5 Modification of Vehicular and Pedestrian Traffic

The he timing plan for Beacon Street and Arlington Street was modified to accommodate the changes in roadway layout and crossing needs.

10.5.1 Signal Timing Modification PM Peak Hour

The new signal timing includes a one stage crossing for cyclists and pedestrians crossing Beacon Street. Crossing Arlington is still a two stage crossing. Pedestrian and cycle crossings are also set to recall, so anyone wanting to cross does not have to push the button. As a result of this, the continuous green for Beacon Street turning left was removed. In the intersection, a lane was removed from Beacon Street and Arlington Street, pedestrian and cycle signals were set to recall, and the level of service for the intersection did not change.

The new phasing plan retains the same cycle length as existing to maintain the existing coordination throughout the network. See Figure 10.5A for the signal phasing plan and Appendix A for the Synchro 6 analysis report.

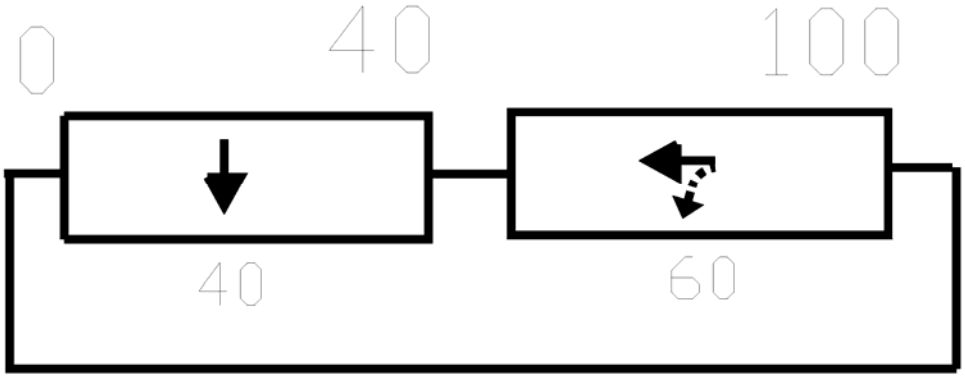


Figure 10.5A - Signal Phasing Ring Diagram

Table 10.5A
Beacon Street and Arlington Street: PM Peak Hour Vehicular and Pedestrian Level of Service

	Existing				
Approach	Delay (s)	V/C Ratio	95% Queue Length	50% Queue Length	LOS
Beacon WB Left	0	0.4	0	0	A
Beacon WB Thru	19.3	0.51	244	188	B
Beacon WB Right	0	0.23	0	0	A
Arlington South	19.9	0.56	276	215	B
Pedestrian Crossing Beacon SB	16.6	-	-	-	B
Pedestrians Crossing Beacon NB	17.3	-	-	-	B
Pedestrians Crossing Arlington EB	42.8	-	-	-	E
Pedestrians Crossing Arlington WB	50.5	-	-	-	E
Peds. Crossing Beacon & Arlington EB	42.8	-	-	-	E
Peds. Crossing Beacon & Arlington WB	41	-	-	-	E
Cycle Track Crossing	-	-	-	-	-
Entire Intersection	12.3	0.56	-	-	B
	Proposed				
Approach	Delay (s)	V/C Ratio	95% Queue Length	50% Queue Length	LOS
Beacon WB Left	16	0.72	444	297	B
Beacon WB Thru	15.6	0.65	324	253	B
Beacon WB Right	-	-	-	-	-
Arlington South	28	0.72	333	261	C
Pedestrian Crossing Beacon SB	26	-	-	-	C
Pedestrians Crossing Beacon NB	26	-	-	-	C
Pedestrians Crossing Arlington EB	49.5	-	-	-	E
Pedestrians Crossing Arlington WB	49.5	-	-	-	E
Cycle Track Crossing	22	-	-	-	C
Entire Intersection	19.8	0.72	-	-	B

Table 10.5 above shows the changes throughout the intersection. Overall, the delay of the intersection increased, from 12.3 seconds to 19.8 seconds. This was expected because a lane was removed from the Beacon Street and the continuous green was removed for left turning traffic. The delay for left turning traffic was increased from 0 seconds to 16 seconds as a result. However, through traffic delay was actually decreased, from 19.3 seconds to 15.6 seconds, an overall improvement.

The changes in this intersection added cycle track crossing and changed all crossing to recall. Although the delay gets a little worse for pedestrians, not having to push the button for a walk signal will increase the convenience. Also the a delay for pedestrians at the intersection is typical for an urban setting and considered acceptable. See Appendix A for Synchro reports and pedestrian delay calculations.

11.0 Cost

The total cost of the cycle track, from Fenway to the Public Garden, was estimated to cost approximately $2,348,642. This estimate was calculated using quantity take-offs from our proposed design drawings and contains a 10% contingency increase. All unit prices were taken from the 2009 Massachusetts Highway Department Project Construction Estimator. This gives the weighted bid prices in region 5. For a detailed table of the cost estimate, including quantities and unit prices, please see figure 11A.

11.1 Analysis

This cost estimate was calculated assuming the cycle track was to be done resulting in the best possible appearance. This is evident by the highest cost items in the estimate. First, the existing asphalt along the length of the cycle track must be excavated using a cold planer. The same length would then be repaved using Hot Mix Asphalt. These two items cost approximately $1,800,000.

It would be possible to complete the project without these two items. In this case, all existing pavement markings would need to be removed in order to make space for the new markings and eliminate confusion. It would cost an estimated $30,000 to remove all pavement markings. The resulting price for the entire project would be $401,641.90.

Careful consideration was taken to keep cost down outside of asphalt pavement excavation and Hot Mix Asphalt repaving. Throughout the entire project, existing curb to curb dimensions were kept the same. As a result, the highest cost items were the traffic signal relocations and the addition of cycle signals to existing traffic signals and pedestrian signals. These items cost $90,000 and $39,600 respectively. In the small sections where curb was added, the quantity was low and the cost was lower by comparison.

Table 11A – Detailed Cost Estimate

Commonwealth of Massachusetts

Highway Department

10 Park Plaza - Boston, MA

ENGINEER'S ESTIMATE

2-Way Boylston Cycle Track

Fed. Aid #

Prepared By: **NU Transpo Capstone. - BOSTON, MA**

DATE: 3-Apr-09

Cal Bk. # xxxx

*** Included in Special Provisions**

ITEM	UNIT	QTY	ITEM DESCRIPTION	UNIT PRICE	TOTAL PRICE
129	SY	67,020	ASPHALT PAVEMENT EXCAVATION BY COLD PLANER	3.00	201,060.00
127	CY	76	CONCRETE EXCAVATION	200.00	15,200.00
460	TON	15,029	HOT MIX ASPHALT	105.00	1,578,045.00
482	FT	164	SAWING ASPHALT PAVEMENT	2.20	360.80
506.0	FT	1,168	GRANITE CURB TYPE VB - STRAIGHT	30.00	35,040.00
506.1	FT	136	GRANITE CURB TYPE VB - CURVED	40.00	5,440.00
509	FT	61	GRANITE TRANSITION CURB FOR WHEELCHAIR RAMPS - STRAIGHT	38.00	2,318.00
509.1	FT	36	GRANITE TRANSITION CURB FOR WHEELCHAIR RAMPS - CURVED	42.00	1,512.00
701	SY	696	CEMENT CONCRETE SIDEWALK	50.00	34,800.00
701.2	SY	29	CEMENT CONCRETE WHEELCHAIR RAMP	75.00	2,175.00
748	LS	1	MOBILIZATION	50,000.00	50,000.00
816.01	LS	3	TRAFFIC SIGNAL RELOCATION	30,000.00	90,000.00
816.8	LS	0	TRAFFIC CONTROL SIGNAL REMOVED AND STACKED	3,300.00	0.00
853.21	FT	95	TEMPORARY CONCRETE BARRIER REMOVED	10.00	950.00
864.04	SF	532	PAVEMENT ARROWS AND LEGENDS REFL. WHITE (THERMOPLASTIC)	4.00	2,128.00
865.1	SF	8,804	CROSSWALKS AND STOP LINES REFL. WHITE (THERMOPLASTIC)	1.50	13,206.00
866.04	FT	31,935	4 INCH REFLECTORIZED WHITE LINE (THERMOPLASTIC)	0.50	15,967.50
866.06	FT	444	6 INCH REFLECTORIZED WHITE LINE (THERMOPLASTIC)	0.59	261.96
866.08	FT	0	8 INCH REFLECTORIZED WHITE LINE (THERMOPLASTIC)	1.00	0.00
866.12	FT	1,776	12 INCH RELECTORIZED WHITE LINE (THERMOPLASTIC)	1.50	2,664.00
867.04	FT	8,216	4 INCH REFLECTORIZED YELLOW LINE (THERMOPLASTIC)	0.50	4,108.00
867.06	FT	1,274	6 INCH REFLECTORIZED YELLOW LINE (THERMOPLASTIC)	0.59	751.66
868	SF	342	GORE LINES - REFLECTORIZED WHITE (THERMOPLASTIC)	1.92	656.64
1000	EA	21	SIGNAGE	125.00	2,625.00
1001	EA	22	CYCLE SIGNAL - 3" SEC 12" LED W/MOUNTING	1,800.00	39,600.00
1002	LS	850	CYCLE TRACK BOLLARDS (POST, PINS, AND BASE)	21.06	17,901.00
1003	LS	34	EPOXY ATTACHMENT FOR BOLLARD BASE	239.95	8,158.30

1004	LS		BOLLARD SHIPPING		1,200.00
			SUBTOTAL		$2,126,129
			TOTAL		**$2,126,129**
999.1	HR	200	TRAFFIC POLICE	45.00	9,000.00
			GRAND TOTAL		**$2,135,129**
			WITH 10% CONTINGENCY		**$2,348,642**

12.0 Conclusion

The feasibility of our proposed design is based on our understanding of transportation systems, traffic analysis and that the segregation of cyclists is needed to ensure safe cycling. The recommendations outlined in this report are to include a two way cycle track on Boylston Street from Fenway to and around the Public Garden, maintain existing curb width and increase the level of safety and comfort for all cyclists. Our design demonstrates and conveys that these recommendations can be a marquee project for the City of Boston to show that they are leader in sustainable projects.

13.0 Acknowledgments

The Boylston Boneshakers would like to thank everyone that has helped us conclude our capstone design during our last semester at Northeastern University. We would like to thank our client, Nicole Friedman, for proposing the idea to re-design Boylston Street. We would like to thank our advisors, Professor Peter Furth and Professor Dan Dulaski, for their insight and knowledge in preparing and guiding us through our capstone design. We would also like to thank our parents, Mr. & Mrs. James Barnack, Mr. & Mrs. Mike Carr, Mr. & Mrs. Leo Leduc and Mr. & Mrs. Kaspar Liepins for their support and love throughout our capstone design.