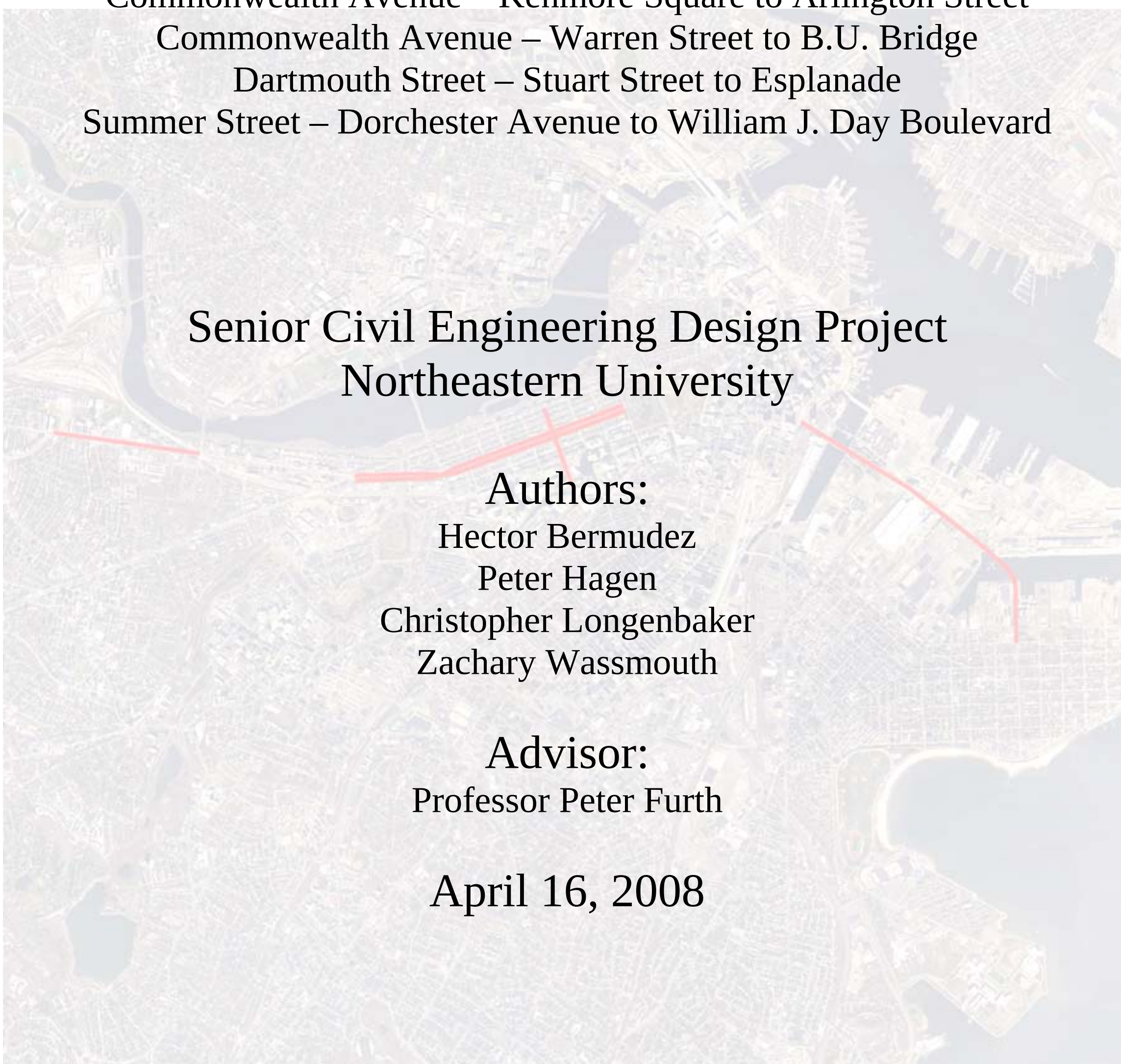
Spokes Engineering
City of Boston Bicycle Lane Plan

Included Streets:
Commonwealth Avenue – Kenmore Square to Arlington Street
Commonwealth Avenue – Warren Street to B.U. Bridge
Dartmouth Street – Stuart Street to Esplanade
Summer Street – Dorchester Avenue to William J. Day Boulevard



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I. Introduction

The City of Boston is well-known as America's Walking City but is lacking in its accommodation for bicycles. While several bicycle paths do exist throughout the city, there are many places and instances when cyclists must use the streets of Boston for their cycling needs. Boston, with its urban climate and high traffic volumes can give cyclists a high stress environment when it comes to in-street cycling.

One way to reduce that stress and improve safety is to provide bicycle lanes. With bicycle lanes, both motorists and cyclists are allowed their own space, and overtakings become less stressful. Bicycle lanes increase awareness in motorists that cyclists will be sharing the road. Bicycle lanes also provide the opportunity to guide cyclists in the right direction to give them a safer path of travel to navigate city streets.

Many streets in prime locations are wide enough to incorporate bicycle lanes. With a simple re-striping of a city street, lane widths can be adjusted to accommodate both cyclists and motorists. Boston can join other cities like Portland, OR, New York City, and neighboring Cambridge by following their example to become a leader in its initiative to become a more bicycle-friendly city.

With input from the City of Boston's bicycle coordinator, Nicole Freedman, and other bicycle organizations, four street sections were selected to be considered for bicycle lane restriping due high bicycle demand, critical location in the city's bicycle network, and overall appearance of sufficient width to include bicycle lanes. The four streets chosen for this project were:

- Commonwealth Avenue from Warren Street to the B.U. Bridge
- Commonwealth Avenue from Kenmore Square to Arlington Street
- Dartmouth Street from The Esplanade to Stuart Streeet
- Summer Street from Dorchester Avenue to William J Day Boulevard

These streets were chosen for their location and overall usability for cyclists. They also help to provide and accommodate missing links in Boston's network of bicycle paths and the selected street sections have the proper widths to accommodate bicycle lanes without interrupting vehicular traffic. The section of Commonwealth Avenue from Kenmore Square to the B.U. Bridge is already approved to be re-striped for bike lanes, linking the two sections of Commonwealth Avenue in this project.

Figure 1.1: Bicycle Lane Locations

This map shows the locations of the streets chosen for bicycle lane designs included in this report.

This report includes a written description of each Boston street that was chosen to be striped with bicycle lanes. Written descriptions of each street including any necessary analysis that was done to justify a design is included in each street section. Chapter two, Bicycle Lane Implementation Methods covers the necessary specifics and explains any safety issues that inspired certain aspects of these bicycle lane designs. Chapter three provides a discussion on lane widths and provides justifications for smaller lane widths in areas where roadway width is limited. The street descriptions are covered in Chapters 4-7, respectively. Each chapter provides analysis and justification of the design, including traffic analysis where necessary. Roll-up plans for each street are provided separately.

II. Bike Lane Implementation Methods

Overview

This chapter includes some important discussions about the design for the bicycle lanes for this project. The following sections in this chapter highlight certain design ideas and demonstrate why certain design practices are acceptable and usable for this project. These ideas apply to the bicycle lane design for each one of the streets included in this project.

Bicycle Lane Widths

The following recommended lane widths for cyclists are excerpts from 1999 AASHTO. These standards were used to design the bike lanes.

- Minimum bicycle facility width: "An operating space of 1.2 m (4 feet) is assumed as the minimum width for any facility designed for exclusive or preferential use by bicyclists. Where motor vehicle traffic volumes, motor vehicle or bicyclist speed, and the mix of truck and bus traffic increase, a more comfortable operating space of 1.5 m (5 feet) or more is desirable." *Page 5*

- Minimum width of bicycle lanes, with curb and gutter: "(For a) bicycle lane along the outer portion of an urban curbed street where parking is prohibited, the recommended width of a bicycle lane is 1.5 m (5 feet) from the face of a curb or guardrail to the bicycle lane stripe. This 1.5-m (5-foot) width should be sufficient in cases where a 0.3-0.6 m (1-2 foot) wide concrete gutter pan exists...." *Page 23*

These are recommended widths. In designing bicycle lanes, the ideal width that we aimed to design was 5 feet. However, there are certain instances where the bicycle lane width dropped down to 4 feet. Four feet is the minimum width according to the first bullet above, but according to the second bullet, the minimum width next to a curb and gutter is 5 feet. The exception for 4 foot lanes in our designs is that the bicycle lanes with 4 feet width are either at a curb with no gutter or off a curb with no parking.

Another design goal was to have a combined width of 13 feet for the bicycle lane and parking (8 feet for parking and 5 feet for bike lane). Where the minimum travel lane or lanes of width 10 feet could not be accommodated with the 13 feet needed for bicycle lanes and parking, the parking width was squeezed to no less than a minimum of 7 feet 6 inches. The dimension of 5 feet for the bike lane was not altered in this case. Therefore, the minimum total width of parking and bike lanes was 12 feet 6 inches.

Where the total available roadway width could not accommodate a separate bicycle lane, shared lane markings (sharrows) were used. A sharrow consists of a bicycle symbol followed by two chevrons. Even though it is legal in the state of Massachusetts to ride a bicycle in a travel lane, the sharrow is used to show the recommended riding position on the pavement for bicyclists, as well as to constantly remind motorists that bicyclists deserve space on the road.

Pavement Markings

Sharrow

Figure 2.1 shows the shared lane marking that will be placed according to the drawings. It shall be centered 4’ from the right side of the lane.

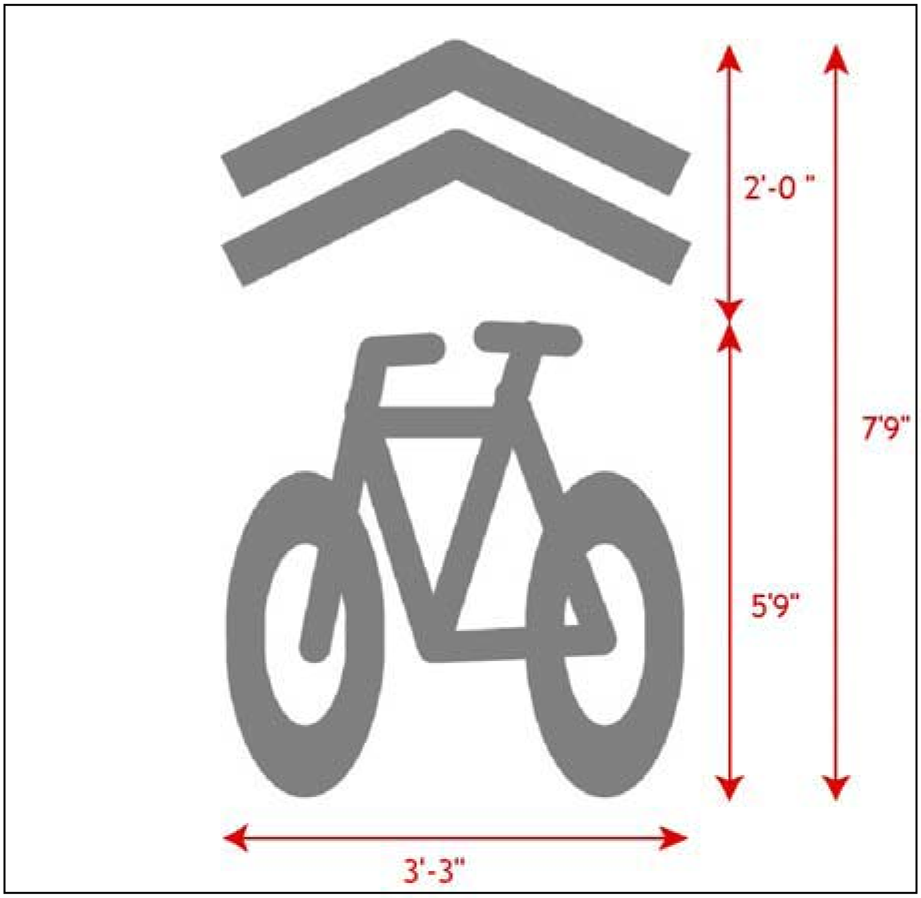


Figure 2.1: Sharrow Dimensions

Bicycle Lane

Figure 2.2 shows the bicycle lane marking that will be placed at the end of each intersection and then every 200 feet. See drawings for clarification.

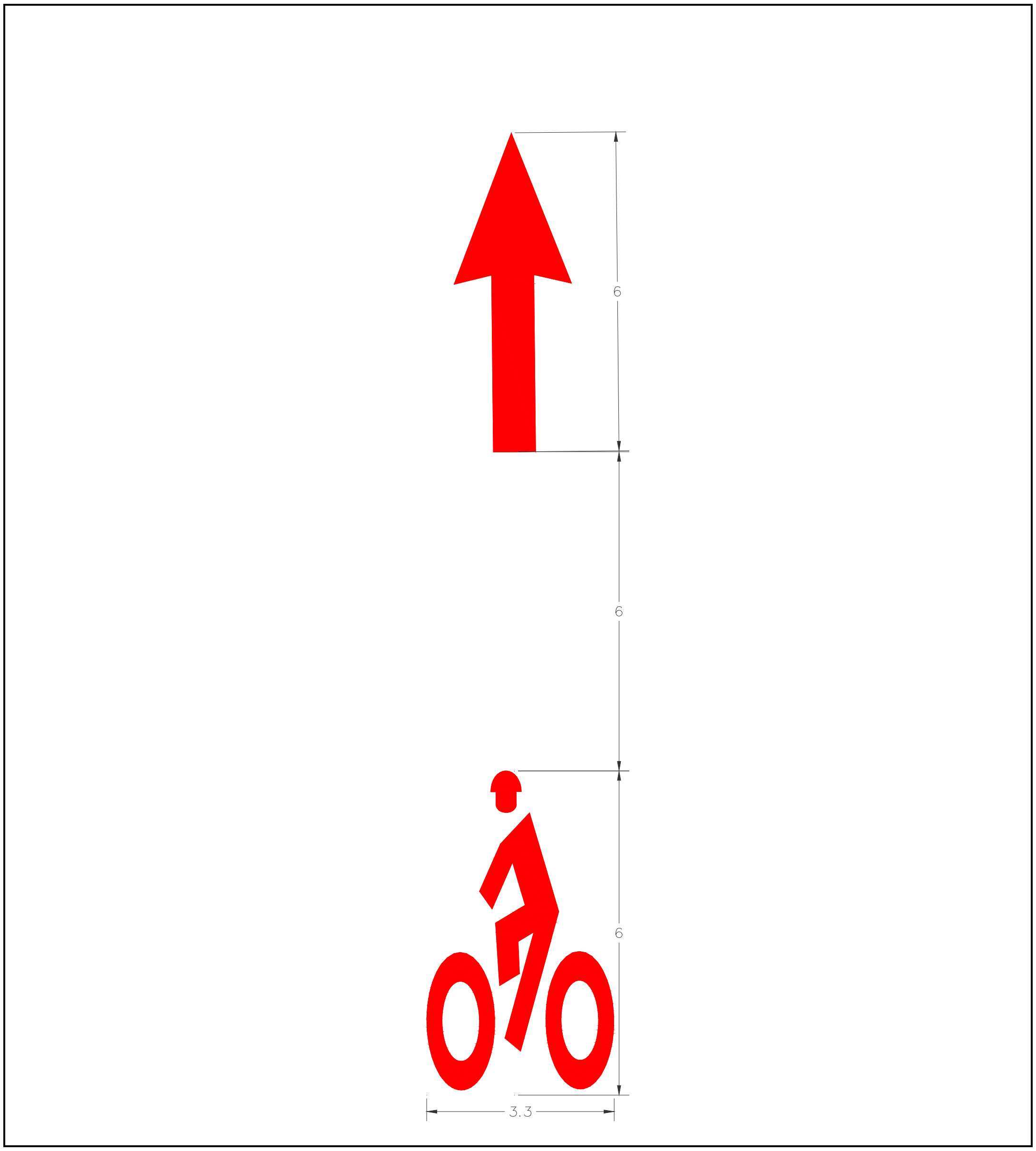


Figure 2.2: Bicycle Lane Marking Dimensions

Bicycle Lanes At Intersections

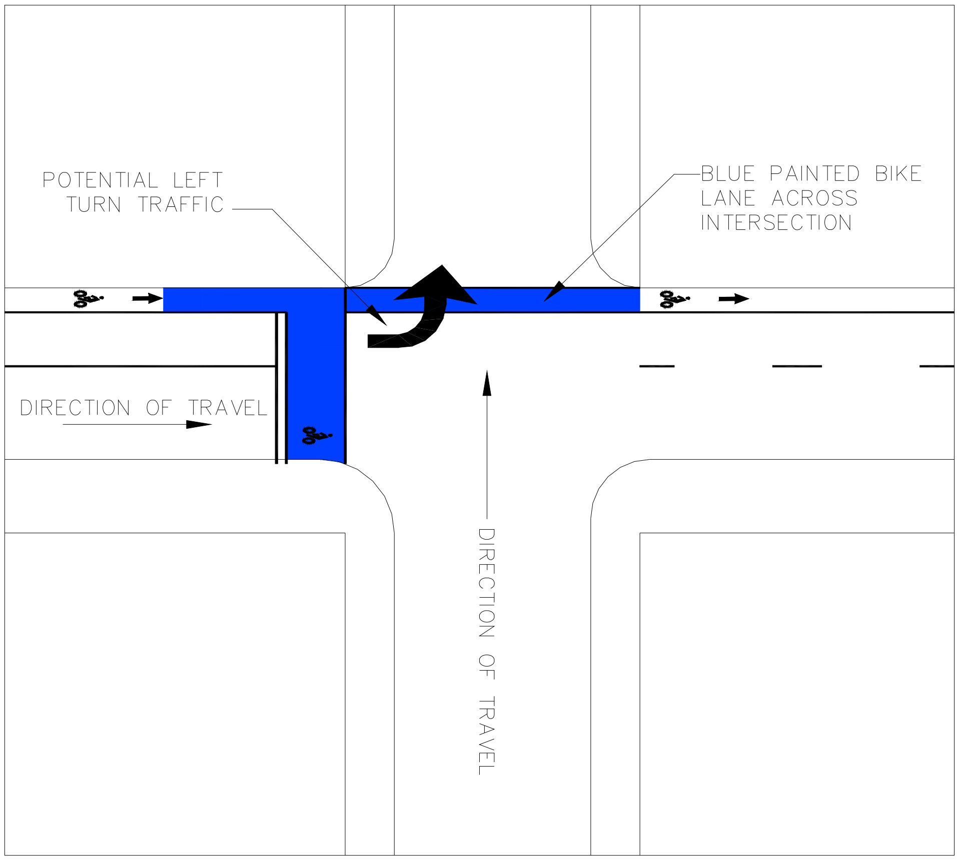
One of the major benefits of bicycle lanes is the increase in overall safety for cyclists. The safety and reduced-stress that bicycle lanes provide cannot be compromised at any point on any of the streets where there are proposed re-striping designs. In many instances, cyclists are forced to cross major intersections where the risk of collision with a vehicle is elevated. To help minimize potential collisions, precautions should be taken to help guide cyclists and also promote motorist awareness of cyclists at intersections.

In the bicycle lane designs for these selected streets, there are two treatments that were used to enhance safety at higher risk intersections. These intersection striping treatments will be described in the following paragraphs. The striping plans for each individual street can be referred to for detailed additional specifications on striping.

Crossings that occur in conflict areas are those where bicycle lanes extend across an intersection with heavy volumes of turning vehicles. Since motorists may not be expecting a cyclist to be traveling alongside them when they are making a turn, increased visibility will be drawn to the bicycle lane by painting across these conflict intersections and painting solid blue between the lines. This solid blue bicycle crossing will appear more obvious to motorists, making them more inclined to look for cyclists crossing in this area. The solid blue crossing will also help to alert cyclists that this intersection may be a more dangerous crossing and to proceed with caution in order to avoid turning motorists.

Figure 2.3 shows a sketch of a solid blue painted bike lane across an intersection where there is potential for conflict with motorists making a left turn, not expecting cyclists to be on the left. The painted lane increases motorist awareness. Such a design will be used on Commonwealth Avenue from Hereford Street to Arlington Street.

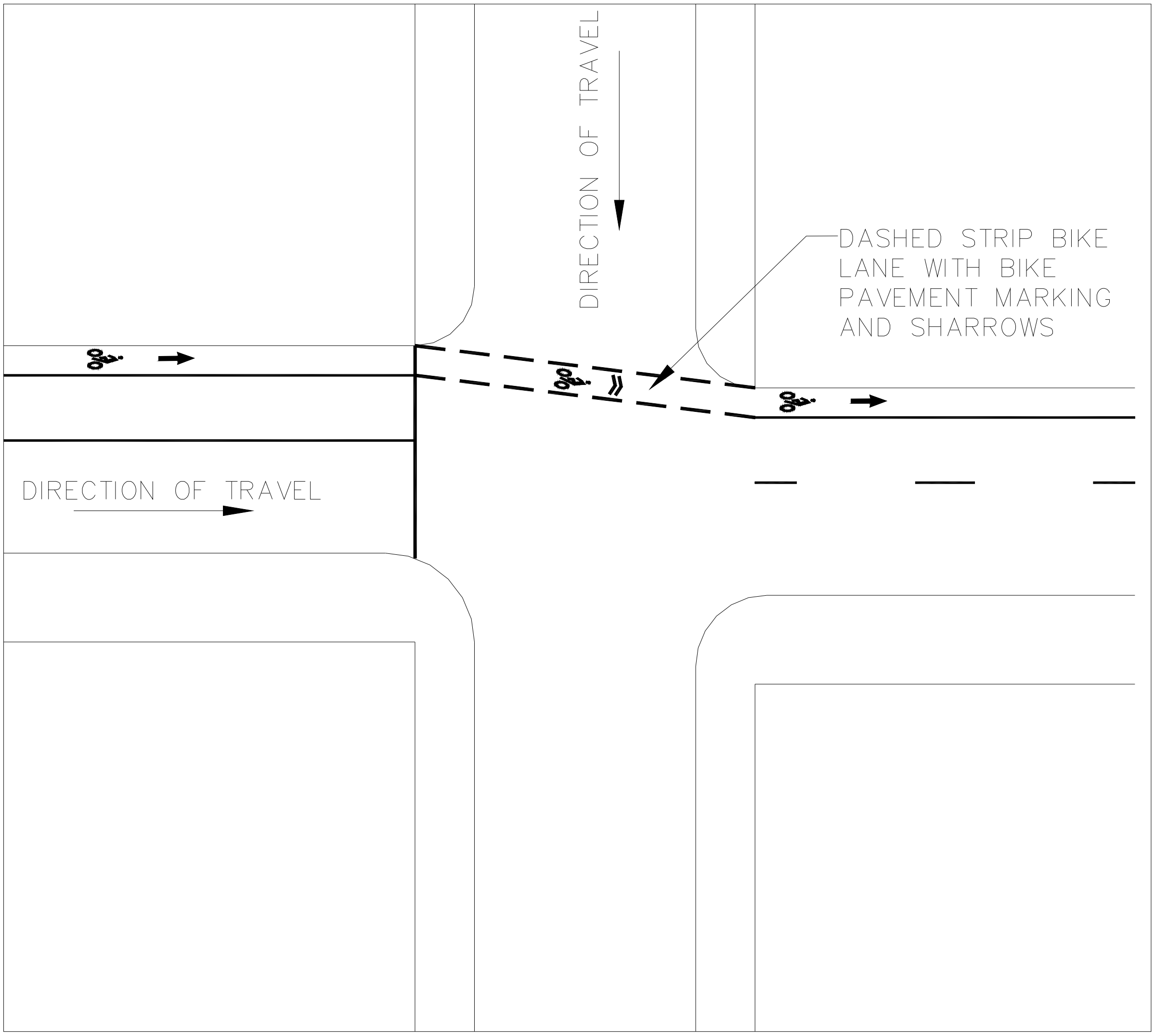
Figure 2.3: Solid Blue Painted Bicycle Lane Crossing (with a Bike Box)



Another crossing treatment used embraces the idea of "sharing the road." No turning vehicles would be in conflict with cyclists traveling straight through an intersection but additional "guiding" of cyclists and motorists through an intersection shows the space that each can occupy to travel through the intersection smoothly and lets cyclists know that the bicycle lane continues further along the road. These types of crossings are denoted with a broken dashed line on either side of the bicycle lane and chevrons pointing in the direction of travel in each of the lanes.

Figure 2.4 shows an intersection that is not perfectly aligned. The dashed bike lane helps to guide cyclists and marks off the space that is to be used for bicycles, letting cyclists know that the lane continues and where to go and it also alerts motorists of potential bicycle travel.

Figure 2.4: Dashed Bike Lane Through an Intersection



These two striping patterns for through intersections will assist in providing low-stress travel for cyclists using these bicycle lanes in busy traffic at intersections.

Bike boxes

At certain intersections, a "bike box" will be painted to allow a separate stop line for cyclists that is 12' ahead of the stop line for motorists. Bike boxes will be painted solid blue for increased awareness and visibility as noted on the plans. With this advanced stop line and crossing area for bicycles, motorists that are queued up at a traffic signal will see the cyclist in front of them, reducing the risk of a collision. Bike boxes will also give cyclists a "head start" to get out of the way of any turning drivers. Since cyclists know they are in plain view of drivers, bike boxes offer reduced-stress for cyclists wishing to cross or turn at busy intersections. An intersection is equipped with a bike box if there is a high turning flow across the bike lane or a high demand for bikes to transition from one side to the other. Some of the design plans for a large section on Commonwealth Avenue call for a bike lane on the left side of the one-way section of road.

Figure 2.5 shows a picture of a bike box. Note the cyclist is out ahead of the truck stopped behind the stop line, making the cyclist more visible. Also refer to Figure 2.3 which illustrates how a bike box makes cyclists visible for motorists making a left turn by providing an advanced stop line.

Figure 2.5: Photograph of a Bike Box

Line Striping Specifications

The plan of each street shows both existing striping, if any, to be removed (in gray) and proposed striping (in black). If a proposed pavement marking overlays an existing marking and does not need repainting, it will be noted on the plan.

All lines will be white unless noted on the plan. Proposed striping is to be painted in the following manner.

- All pavement marking lines are to be 4” wide unless otherwise specified.
- Dashed pavement marking lines are to be 10’ in length and have 20’ in between.
- Solid lines separating lanes at intersections will extend back approximately 100’ from the stop line as noted on the plans.
- Existing crosswalks not shown on plans are to remain. Stop lines or bicycle stop lines are to be set back 3’ from any existing crosswalk line, unless specified to be set back further.
- All crosswalks, stop lines, bike lane lines crossing intersections shall use 1’ wide white thermoplastic.
- Any other specific striping patterns will be specified within the appropriate section for the street in this report and on the furnished plans.

Contra-flow Facilities in Urban Settings

The use of contra-flow bike lanes can be an efficient and safe way for bicycles to get around an urban environment.

Many cities around the country and the world have implemented contra-flow bicycle facilities. In Belgium, all one-way streets in 50 km/h (31 mph) zones are by default two-way for cyclists. Cambridge, Massachusetts currently has four contra-flow lanes providing service from Follen Street to Waterhouse Street on Concord Ave, on a section of Waterhouse Street, from Beacon Street to Bryan Street on Scott Street, and on Norfolk Street south of Broadway.

The City of Cambridge has successfully designed these facilities according to the following criteria [2]:

- Cyclist can enter and exit the traffic stream safely
- There are no or few intersecting driveways
- Contra-flow lane must provide a more direct route for cyclist compared to routes used by motor vehicles
- Contra-flow lanes must be placed on the correct side of the street, to the drivers' left
- Signage warning motorist to expect cyclist should be present at any and all intersections
- Existing traffic signals should be modified to accommodate cyclists

The City of Brussels, Belgium has many years experience with contra-flow bicycles lanes. Their guidelines show that having a contraflow lane on the same side of parallel parking is in fact safer for cyclist than a with flow lane next to parallel parking. This is because of the "dooring" hazard that exists for cyclist. Dooring is the scenario that arises when a cyclist rides next to a parked vehicle just as the vehicle door opens causing a collision between the rider and the vehicle door. In a contraflow scenario, cyclist and driver are facing each other rather than a cyclist approaching a vehicle from behind. This increases the visibility for both parties. Another reason safety is increased in this scenario is that the cyclist is on the same side as the passenger door. This decreases the number of "dooring" incidents that a cyclist might encounter since single occupant trips are more frequent than multi passenger trips. Furthermore, a cyclist hitting a door in this scenario will cause the door to close rather than open thus decreasing the chances of injury to the cyclist. For these reasons, the City of Brussels permits contraflow bike lanes to be 16" (40 cm) narrower when marked as a contraflow lane in a 30-km/h (19 mph) zone, and 12" (30 cm) otherwise.

The City of Brussels also suggests intermittently marked contra-flow lanes on streets that:

- Have an 85-percentile speed less than 27 mph
- Peak hour volumes do not exceed 200 veh/hr
- Have only one traffic lane for motorized traffic
- Have a cross section of at least 26.5’ with parking permitted on both sides

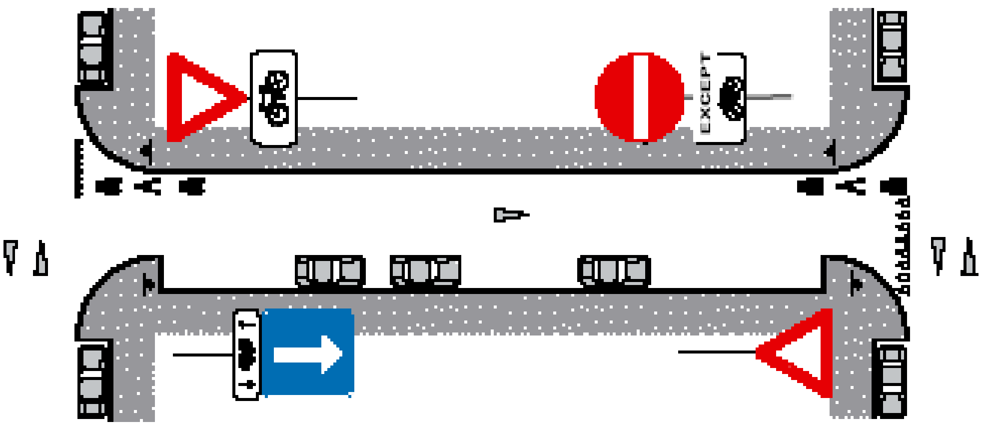


Figure 2.6: Sketch of an intermittently marked Contra-flow Lane

The figure above shows a typical plan view of a local one way street very much similar to the entrance to Back Street from Dartmouth Street. Notice that bicycle markings only appear at the beginning and end of the street. There is no continuous marking for the bike lane.

We have found that the City of Boston has the potential to utilize this facility type in areas around the city increasing rider safety and accessibility. Therefore, Spokes Engineering endorses the use of contra-flow facilities when necessary in urban settings.

References

[1]*Marquage et Signalization dans les Contresens Cyclable.* Brussels Capital Region, Belgium, 2006.

[2]On-Road Bicycle Facilities for Children and Other "Easy Riders": Stress Mechanisms and Design Criteria. Peter G. Furth, Department of Civil & Environmental University, Northeastern University Boston, MA, 2007

Hazardous Catch Basin Covers

Some drain covers have slots that run parallel to the curb, and a bicycle tire could potentially get caught in them, causing a crash (see Figure 2.7). Since many of these slotted drain covers are square, they should be identified and rotated 90°, which will allow bicycle tires to traverse the cover perpendicular to the slots, avoiding accidents. While not within the scope of this design, it is recommended that these covers eventually be replaced with bicycle-safe grate covers.

Figure 2.7:

Source: Kane, Mike. Seattle Post-Intelligencer. <http://seattlepi.nwsource.com/photos/photo.asp?PhotoID=164043>.

This photo demonstrates how a bicycle wheel can get caught in the slots of a catch basin cover.

III. Automotive Lane Widths (10' Lane Justification)

Justification of 10-ft Lanes

While cross-sectional space is a limited commodity on city streets, it is still important that space be available for improvements to bicycle safety. In order to find 5' of width for bicycle lanes on urban streets, one relatively simple option is to narrow vehicular travel lanes. In situations with 8' wide parallel parking, the bike lanes need to be 5' to provide a combined width of 13' to prevent incidence of "dooring". Also, since there is a high volume of parking, it is recommended that the combined width of bicycle and parking lanes be raised an extra foot from 12' to 13' (*2* p.22). According to the AASHTO Green Book, travel lanes can have a width as low as 10' for urban arterials (*1* pp. 472-3) and turning lanes at intersections can be as narrow as 9' (*1* p.393). So, using 10' travel lanes could make a huge impact, since it may allow for the addition of bicycle lanes without timely or expensive curb adjustments or roadway rebuilding. When narrowing is done in conjunction with bike lane addition, motor vehicle traffic will not be negatively affected. Adding bicycle lanes and thus increasing bicycle safety can potentially be done through a low-cost solution of restriping a roadway's lanes.

On winding, higher-speed rural (or rural feeling) roads, narrow lanes are not desirable because drivers require extra space to maneuver curves at higher speeds. In 2000, Douglas Harwood's research team found that narrower travel lanes did indeed increase the frequency of collisions on rural roads (*5*). In 2007, however, Douglas Harwood, Ingrid Potts, and Karen Richard found that, unlike their rural highway research, narrow lanes did not increase collision frequencies on urban roads (*7* p.63). Since there seems to be a notion that lanes less then 12' are less safe, the 2007 study examines whether or not this is actually true on suburban and urban arterials. Using crash data from Michigan and Minnesota, this 2007 Transportation Research Record study found that, "There was no indication that the use of 3.0- or 3.3-m (10- or 11-ft lanes) rather than 3.6-m (12-ft) lanes for arterial intersection approaches led to increases in crash frequency." (*7* p.81). The conclusions of the Potts study are further supported by Robert Noland's 2002 report which states that"…lane widths of over 11 ft do not contribute to a safer road environment." (*6* p.16) The Potts article also mentions that the, "Use of narrower lanes in appropriate locations can provide other benefits to users and the surrounding community, including shorter pedestrian crossing distances and space for additional through lanes, auxiliary and turning lanes, bicycle lanes…."(*7* p.81).

Success Stories

Ten-foot lanes are actually fairly common, and as Douglas Harwood states in National Cooperative Highway Research Program (NCHRP) Report 330, “Four percent of highway agencies have used 8 ft lanes on urban arterials, while 42 percent of agencies have used lanes of 9 ft or narrower, and 88 percent of agencies have used lanes of 10 ft or narrower.” (*4*)

Here are some places where 10’ lanes are currently in use…

- In Washington DC, many of the arterials with 10’ lanes are also heavily used routes for bus and truck traffic. Here are a few examples: 16th Street, Connecticut Ave, Wisconsin Ave, Pennsylvania Ave, Florida Ave, U Street, 14th Street.

- In Chicago, these roads have four 10’ lanes that work well, even while carrying heavy bus and truck traffic:
  - North Sheridan Rd, with 42000 ADT
  - N. Ridge Ave, with 50000 ADT

- Florida DOT striped some lanes less than 10’ on US-41 in the 1980s. There was no difference in crash rates compared to 12’ lanes.

- Missouri DOT restriped I-44 to 10’ lanes, and there have been no reports of problems.

- According to an Association of Pedestrian & Bicycle Professionals (APBP) survey, the following is a partial listing of other cities that are using 10’ lanes on arterials, including major arterials with trucks and busses. In several of these cases, travel lanes were re-striped to 10’ to allow for the addition of bicycle lanes--something that may prove useful in Boston, too.

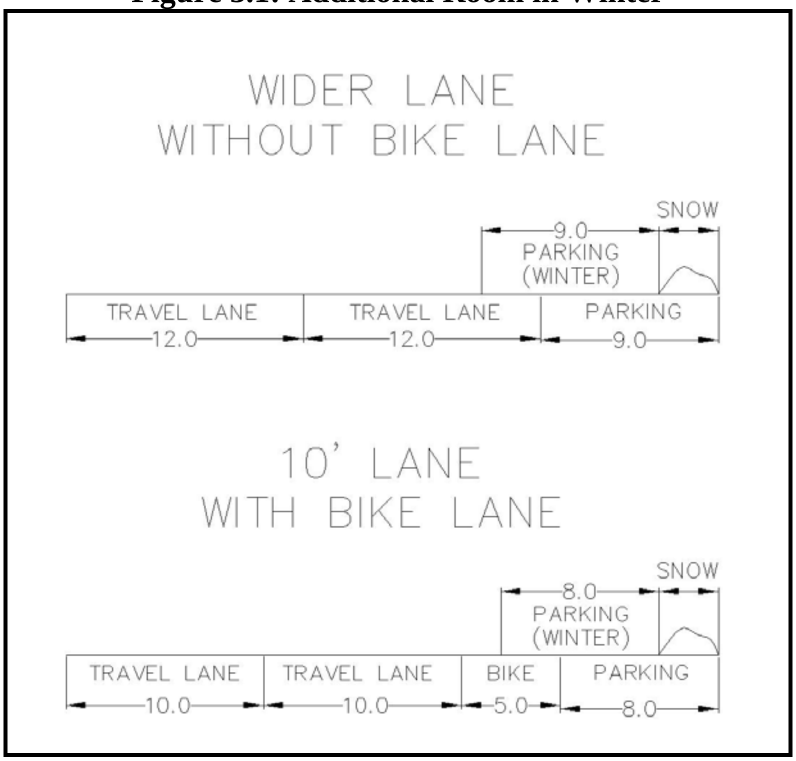
  Arlington, VA; Cincinnati, OH; Colorado Springs, CO; Charlotte, NC; Eugene, OR; Houston, TX; Lawrence, NJ; cities near Los Angeles, CA; Portland, OR, Rochester, NY; San Jose, CA; Scottsdale, AZ; Tucson, AZ; Philadelphia, PA

Addressing Perceived Operational Issues

The concept of narrowing travel lanes naturally brings up some concerns regarding negative effects on the operation of a roadway in situations with snow removal, parallel parking, double-parking, and busses in travel lanes. However, when the narrowing of travel lanes allows for the addition of a bike lane or buffer, these concerns are no longer valid, and motorists will actually gain some benefits as discussed in the following paragraphs.

First, with narrower lanes, there might be initial concern that there would be less space for cars after snow has been removed to the right side of the road. However, as long as the road is still of the same cross-sectional width, there will be the same amount of space with snow removal as there would be for wider lanes. With the addition of right side bike lanes, the space available for motorists after snow removal is actually increased—even with narrower travel lanes (see Figure 3.1).

Figure 3.1: Additional Room in Winter



With narrower lanes, a bike lane or buffer can be added between parked cars and the travel lanes. With the additional space/bike lane, snow storage will take up the same amount of space, but it will not cause parked cars to intrude upon the right travel lanes.

If bike lanes are not added, the narrowing of travel lanes would reduce the space available for motorists to pass double-parked vehicles. However with bike lanes, the travel lane traffic will have more space to pass double-parked cars. This is similar to the way by which winter lane space can be expanded as just described.

Along similar reasoning is the case of cars in the process of parallel parking. With the narrowing of lanes, more space can be set aside in the form of a bike lane on the right (for example). With the extra space, motorists who are parking will block less of the right travel lane while they are performing parking maneuvers, and they will not intrude upon the next travel lane to the left. As a result, parkers may have an easier time parking, and through-traffic will be less disrupted by parallel parkers.

While cars are typically 6' wide, trucks and busses can be as wide as 8.5'. One concern with the use of 10-ft travel lanes on urban arterials is that there may be increased incidents of side-swiping due to the proximity of large vehicles in the lanes. However, there are several reasons to believe that this fear is at least partially unfounded, and that the benefits of using 10-ft lanes outweigh the risks.

Bicycle professionals have discussed the reasons for why 10' lanes can be successfully used. The highlights of their discussions are as follows:

- When narrower lanes are located next to bike lanes, even wider vehicles such as busses can still travel without issue. A 10' lane can certainly hold an 8.5' bus, but if busses desire more comfort space, they can travel partially in the bicycle lane (while bicycles are not present). This is something that is done successfully in Chicago. If a situation arises where a bus or truck needs to pass a cyclist in the bicycle lane, these larger vehicles are able to slow down and pass the cyclists carefully due to the higher level of driver training required for bus and truck operators.

- When it comes to the issue of mirror swiping, at least one professional mentioned that there does not seem to be any proof of mirror swiping being a big problem. Smaller vehicles can simply shy away from larger ones on a street with 10' lanes.
- Also, since 10' lanes cause traffic to move more slowly, the number of sideswipes may or may not increase, but the reduction in speed may help lower the intensity of more serious crashes.
- Further, when traffic is heaviest, cars will be moving more slowly. This should allow them to travel more closely without colliding.

It is evident that 10' lanes work well on urban arterials when bike lanes are added along with the narrower lanes. This makes for an ideal solution to Boston's issue of limited cross-sectional roadway space. By striping narrower travel lanes with bike lanes, bicycle safety can be improved while simultaneously adding benefits for motorists.

References

1. American Association of State Highway and Transportation Officials. A Policy on Geometric Design of Highways and Streets. 5th ed. 2004.
2. American Association of State Highway and Transportation Officials. Guide for the Development of Bicycle Facilities. 1999.
3. Association of Pedestrian and Bicycle Professionals. 2008. <http://www.apbp.org/website/>.
4. Harwood, Douglas W. NCHRP Report 330: Effective Utilization of Street Width. NCHRP, TRB, NRC. Washington, DC: TRB, August 1990.
5. Harwood, Douglas W., et al. Prediction of the Expected Safety Performance of Rural Two-Lane Highways. US Dep. of Transportation. Federal Highway Administration. Dec. 2000.
6. Noland, Robert B. Traffic Fatalities and Injuries: The Effect of Changes in Infrastructure and Other Trends. 25 January 2002. < http://www.cts.cv.ic.ac.uk/staff/wp22-noland.pdf>.
7. Potts, Ingrid B., Douglas W. Harwood, and Karen R. Richard. "Relationship of Lane Width to Safety on Urban and Suburban Arterials." Transportation Research Record. 2023 (2007): 63-82.

IV. Commonwealth Avenue – Kenmore Square to Arlington Street

Introduction

With a simple re-striping of the roadway, Commonwealth Avenue has the potential to provide bike lanes from Kenmore Square to Arlington Street. These bike lanes, in conjunction with other plans for lanes along Commonwealth Avenue stretching back from Warren Street in Allston could allow for a reduced-stress route for cyclists wishing to utilize one of Boston's most traveled streets and allowing cyclists to access many important destinations along the way. Providing bike lanes on Commonwealth Avenue provides a relatively low-cost method to facilitate Boston's initiative to become a more bike friendly city.

The following sections provide detail on each segment of Commonwealth Avenue that has potential for a bike lane. The segments included are the following:

- Section A: Arlington Street to Charlesgate East (Except for around Massachusetts Avenue)
- Section B: Commonwealth Avenue Underpass
- Section C: Westbound Charlesgate West to Charlesgate East
- Section D: Eastbound Charlesgate West to Charlesgate East
- Section E: Eastbound Charlesgate West to Charlesgate East
- Section F: Eastbound Kenmore Street to Charlesgate West
- Section G: Kenmore Square

All necessary figures and analysis for each section are provided. Figure 4.1 shows an overview map of this section of Commonwealth Avenue.

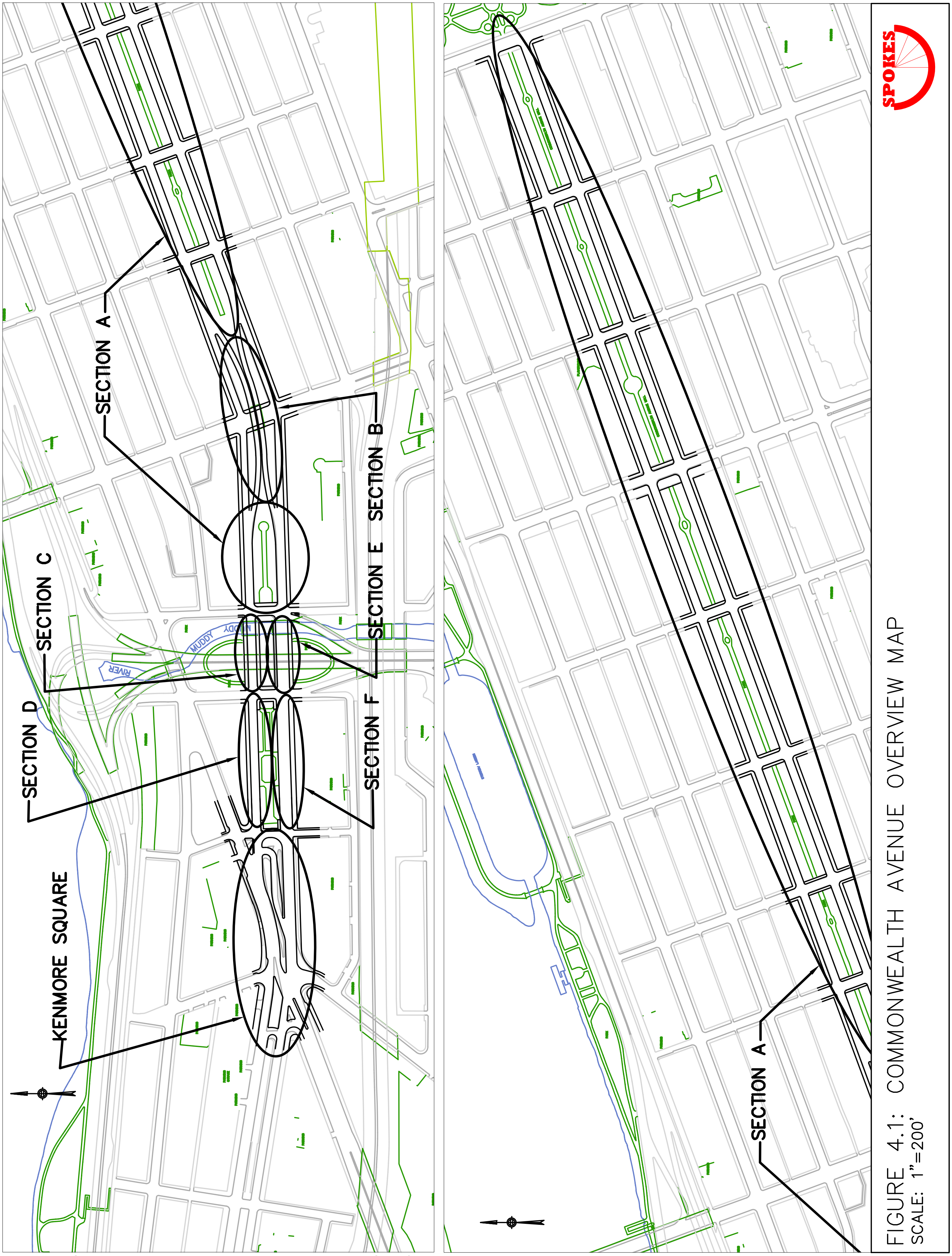


FIGURE 4.1: COMMONWEALTH AVENUE OVERVIEW MAP
SCALE: 1"=200'

Section A: Arlington Street to Charlesgate East (Except for Underpass at Massachusetts Avenue)

The section of roadway between Arlington Street and Charlesgate East is consistently 35’ in width in both in the Eastbound and Westbound directions (not counting the Commonwealth Avenue underpass at Massachusetts Avenue). Currently, the roadway is striped for two travel lanes and a parking lane.

Spokes Engineering proposes to re-stripe this section to include a 5’ bicycle lane, two 11’ travel lanes and an 8’ parking lane. An included plan of Section A has a detailed cross-section and striping plan. In both the Eastbound and Westbound directions, the bike lane will be on the left side of the road, along the Commonwealth Avenue mall. A detailed cross-section of Section A is also included in Figure 4.2.

Figure 4.2: Cross-Section A-A

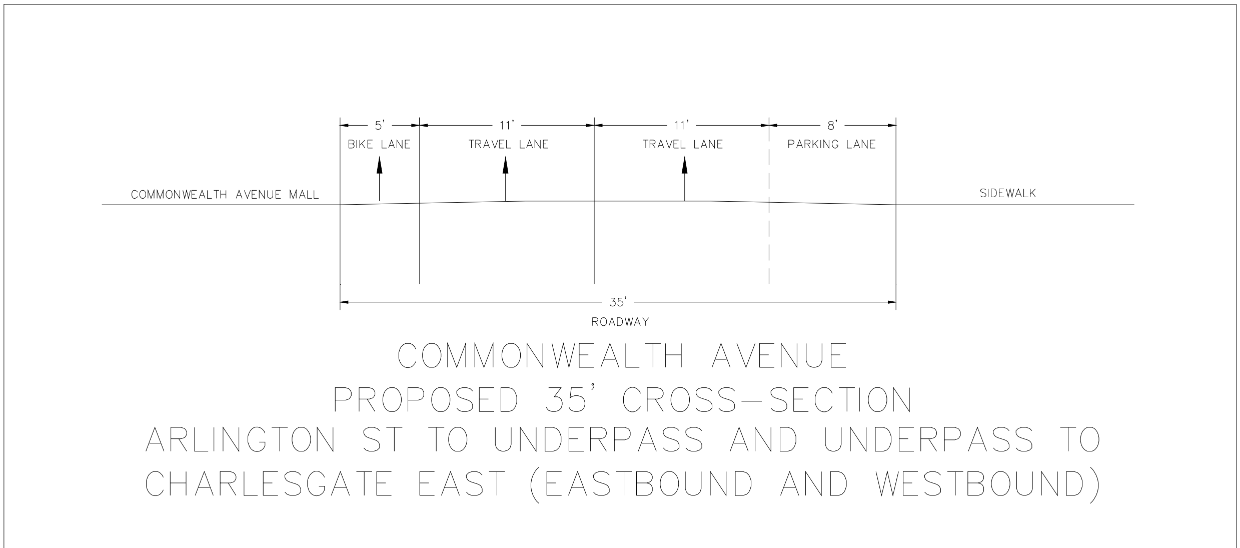


Figure 4.2 illustrates the potential layout for a left side bike lane on Commonwealth Avenue allowing cyclists to avoid double parked cars, avoid “dooring” from parked cars and allow safe access to the underpass at Massachusetts Avenue.

Although it is conventional to find bike lanes alongside the parking lane on the right hand side, Spokes has determined that a left side bike lane is the preferred option for three important reasons.

- No collisions with car doors.
- Avoiding double-parked vehicles.
- Safer transition into the underpass at Massachusetts Avenue.

First, allowing the bike lane to be on the left eliminates the problem of encountering car doors being opened into the bike lane and potentially causing a collision. Since drivers would be exiting their parked cars on the left side, car doors would open right into a right side bike lane, causing a potential risk of “dooring” that is avoided by placing the bike lane on the left, away from parked cars.

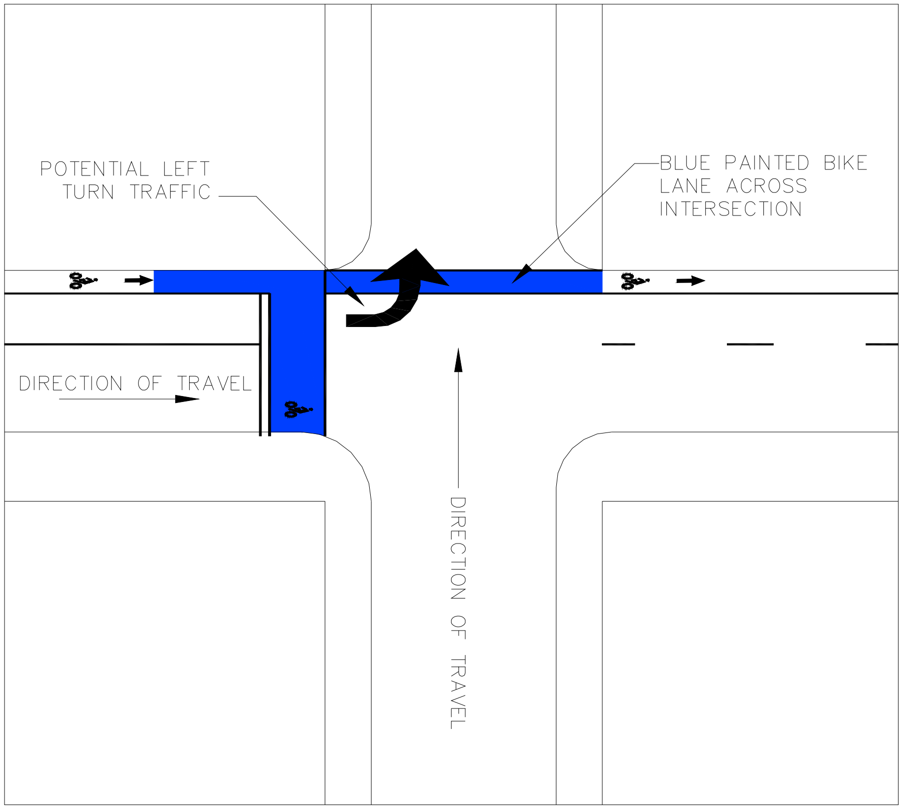
Second, having the bike lane on the left also allows cyclists to move more freely as they avoid the problem of double-parked cars blocking the bike lane that would force cyclists out into the travel lanes. If located on the right, the bicycle lane might become frequently blocked forcing cyclist to either move out into the moving traffic of the adjacent lane or come to a dead stop and wait for an opportunity to navigate around the double-parked vehicle. With a left side lane, double-parking would occur on the opposite side of the street, allowing unobstructed travel for cyclists.

Finally, left lane travel also allows for a safer transition for cyclists to and from the underpass underneath Massachusetts Avenue. A right side bike lane would force cyclists to cross two lanes of traffic to access the underpass while many vehicles are either taking the underpass or continuing straight on the service road to Massachusetts Avenue. With a left side bike lane, cyclists are already on the same side as the underpass, allowing cyclists to enter directly into the underpass without having to enter into traffic.

As a side benefit, having the bike lane on the left requires only one new lane line, while a bike lane on the right would need two lanes, one on the traffic side and one on the parking lane side.

The section from Arlington Street to Hereford Street in Section A will feature a special treatment at intersections with permitted left turns These intersections will feature a “bike box” since drivers are not accustomed to having a cyclist on their left when they are making a left turn. The bike box gives cyclists a safer place to queue when the light is red because it puts cyclists in plain view in front of drivers and gives cyclists a head start at intersections. Cyclists wishing to turn right at intersections with a permitted right turn can simply use the crosswalk to get across to make their right turns. In addition to bike boxes at permitted left turn intersections, bike lanes will be painted across each of these intersections in a solid blue color so that when the light is green, this will make drivers more aware that cyclists may be crossing at this intersection and to proceed in their turns with more caution. Figure 4.3 shows such the permitted left turn treatment as mentioned in Chapter 2.

Figure 4.3: Solid Blue Bicycle Lane Crossing (with a Bike Box)



To illustrate what this bike box and painted lane would look like on Commonwealth Avenue, a rendering of the intersection of Commonwealth Avenue and Gloucester Street is shown in Figure 4.4.

Figure 4.4: Rendering of a Bike Box at Commonwealth and Gloucester

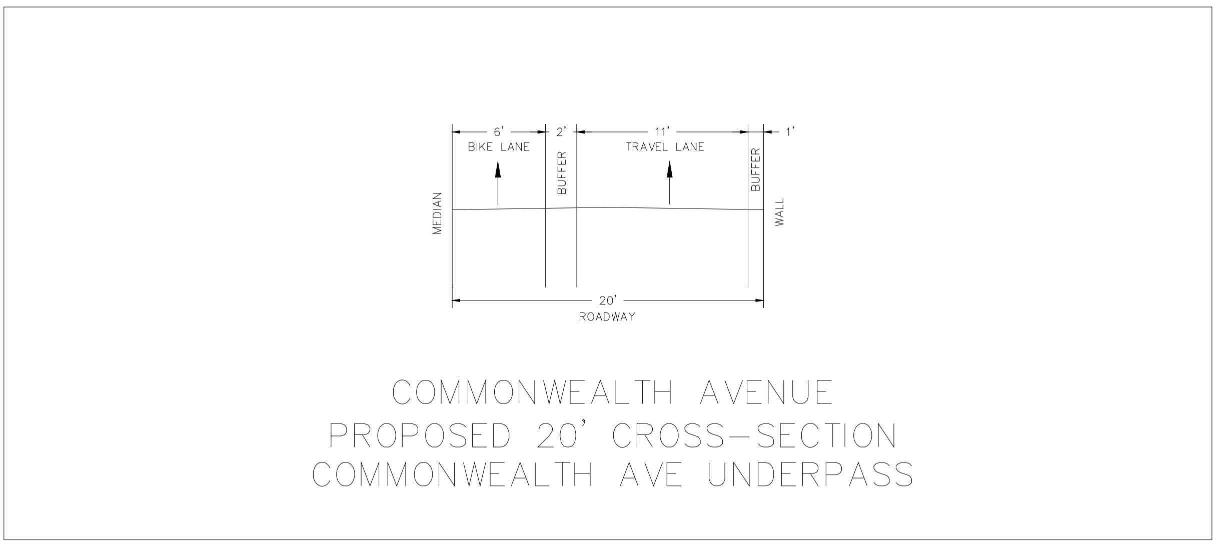
This figure shows a rendering of a bike box on Commonwealth Avenue. Note the painted bike lane extending across Gloucester Street to alert drivers of cyclist travel on the left.

Section B: Commonwealth Avenue Underpass

Many cyclists that currently use Commonwealth Avenue prefer to travel in the underpass at Massachusetts Avenue, rather than use the service road and be forced to wait at a traffic signal. Since the underpass has relatively low traffic usage, this is an attractive travel route that cyclists currently utilize on a regular basis.

In order to better protect cyclists who already legally using the underpass and to promote bicycle use in the underpass by giving cyclists a quick and safe bypass to Massachusetts Avenue, Spokes Engineering proposes eliminating one of the travel lanes in order to accommodate a bicycle lane traveling into the underpass as shown in the Figure 4.5.

Figure 4.5: Cross-Section B-B



Left side bike lanes from Section A allow for a safe transition into the underpass, which will be reduced to one travel lane to incorporate a proposed bike lane.

The current layout is a 20’ cross-section with two 9’ lanes offset 1’ from each other. This would make for an 11’ travel lane and a 6’ bicycle lane traveling along the left side of the underpass in each direction with a 2’ painted buffer in between. With an 11’ proposed travel lane, motorists would have the option of driving fairly close to right down the middle of the underpass, adding comfort as drivers will not be driving too close to the barriers in the middle or the walls on either side, while cyclists will have the comfort of being protected from motorists.

Traffic analysis was performed at the Commonwealth Avenue underpass in order to determine the feasibility of reducing the underpass to one lane. A traffic count to capture the AM peak volume was taken from 7:30 AM to 8:30 AM on 2/7/08 for the traffic traveling through the underpass in the Eastbound direction. To compare these underpass volumes to volumes on the service road to Massachusetts Avenue, a count on the service road were done for two 15 minute periods. The results from this count are summarized in Table 4.1.

Table 4.1: AM Traffic Counts for Commonwealth Ave Underpass & Service Road Eastbound

Traffic Counts For Commonwealth Avenue		
Time	Underpass Volume	Service Road Volume
7:30-7:45	97	-
7:45-8:00	123	-
8:00-8:15	114	122
8:15-8:30	128	118
Total	462	240
Flow Rate (veh/hour)	462	480
Peak 15 min period	128	122

Table 4.1 shows that the traffic in the Commonwealth Avenue underpass is very low and could easily be handled by one travel lane.

It is clear from the data collected that the number of cars using both lanes of the underpass in one hour is far less than the capacity of one lane of approximately 1800 veh/hour. The traffic in the underpass arrived in platoons and there were many instances of dead time in the underpass. Because of the light traffic and narrow lanes, vehicles tended to drive close to or straddle the painted centerline, preventing overtaking. Bikes were already using the underpass as a means of travel.

This data indicates that travel in the underpass and travel on the service road approaching Massachusetts Avenue is approximately 1:1 for motorists. About half of the motorists that travel along this stretch of Commonwealth Avenue use the underpass and the other half use the service road to Massachusetts Avenue.

During two of the 15 minute periods, the lane of choice was analyzed for motorists. The results for this analysis are summarized in Table 4.2.

Table 4.2: Traffic Counts By Lane in Underpass Eastbound

Traffic Counts by Lane in Underpass		
Time	Outside Lane	Inside Lane
7:45-8:00	96	27
8:00-8:15	79	35
Total	175	62
Percentage	73.8%	26.2%

Motorists in the underpass prefer to travel in a single-file manner, effectively traveling in one lane.

This study indicates that motorists prefer to travel in a single-file line in one lane. Motorists, when in the lane, would often straddle the centerline tending to drive closer to the center of the underpass.

A PM peak count was also made to ensure that the underpass use was equally low in each direction. The results are compiled in the chart below. Since nearby Beacon Street is one-way outbound, Commonwealth Avenue has less Westbound traffic than Easboutnd traffic. These numbers in Table 4.3 show that there is fairly low use in the afternoon in the westbound direction and there appears to be slightly less volume using the underpass in the afternoon peak than in the morning peak.

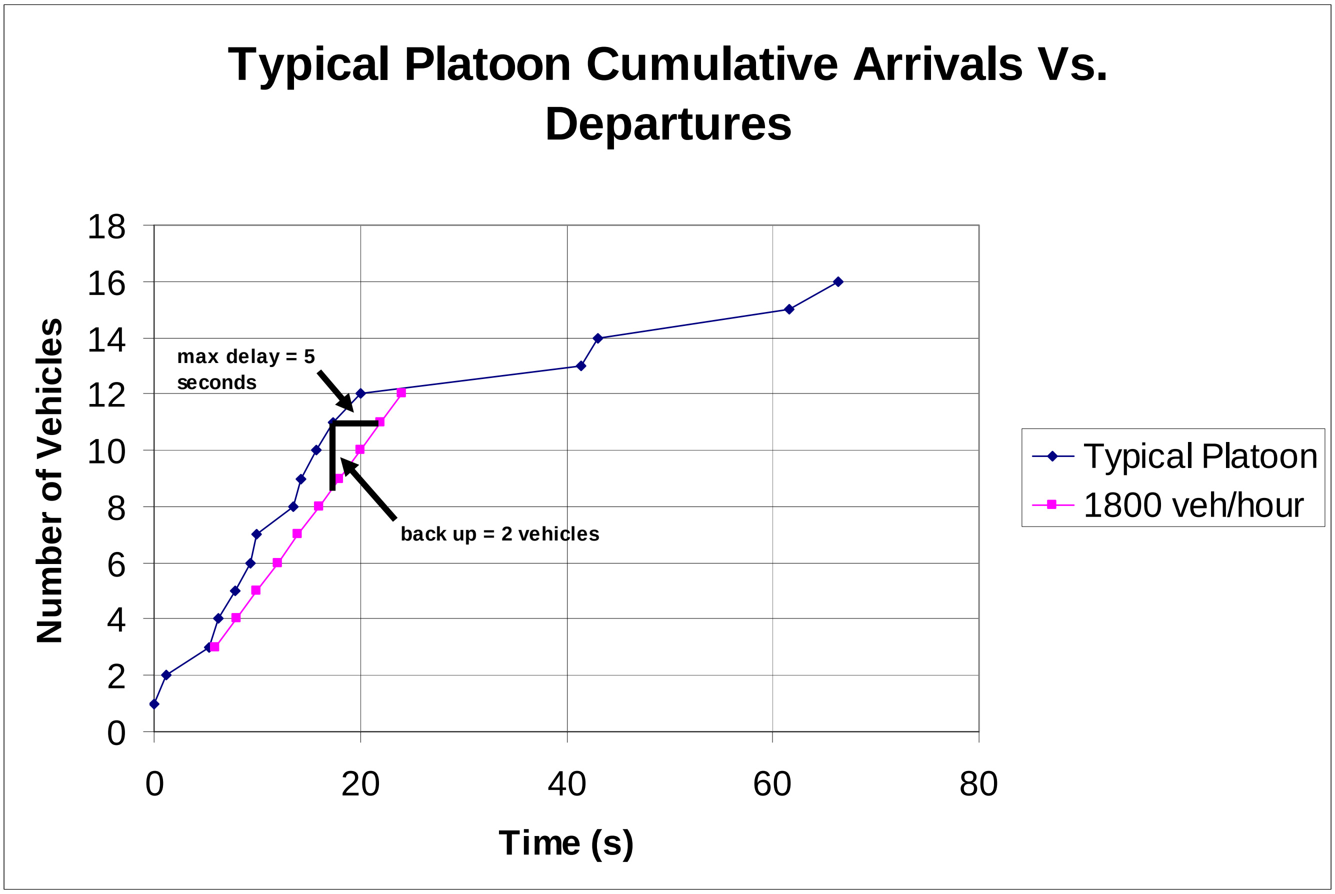
Table 4.3: PM Traffic Counts for Commonwealth Avenue Underpass Westbound

Traffic Counts For Commonwealth Avenue Underpass Date: 3/6/08	
Time	Count
3:45-4:00	99
4:00-4:15	94
4:15-4:30	71
4:30-4:45	100
Total for hour:	364

The PM peak traffic volume is even less than that of the AM peak traffic volume.

The main impact of reducing the underpass to a single lane is the bottleneck effect it will have when platoons released from the intersection at Charlesgate East arrive. In order to determine the impact, an analysis of vehicle arrivals was done during the peak travel time at 8:20 AM on 2/14/08. The traffic was monitored as 12 platoons of traffic traveled through the underpass and the arrival time of each car entering the underpass was recorded. The time that each car arrived in the underpass was recorded. This input data of arrival times was plotted against an output time of the steady 2 vehicle per second output rate that would occur with a flow of 1800 veh/hour. On the chart, any bottlenecking of traffic is clearly shown as vehicles are arriving more frequently than one car every 2 seconds during heavier platoons. A typical case is plotted in Chart 4.1.

Chart 4.1: Typical Platoon Cumulative Arrivals Vs. Departures

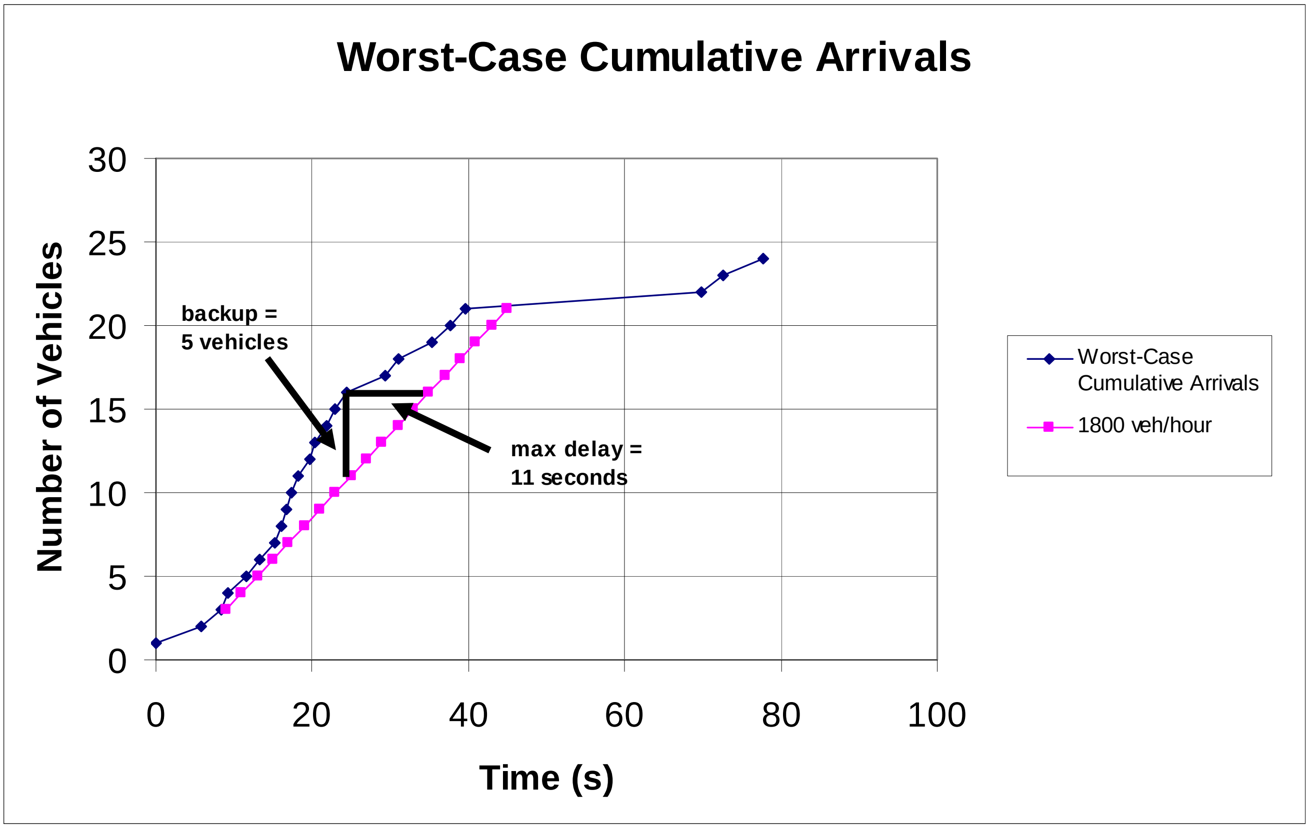


In a typical case during the AM peak, reducing the traffic in the Commonwealth Avenue underpass only causes a potential 2 car backup, causing approximately 5 seconds of delay.

This case represents the average delay and queue backup that would result from bringing the underpass down to one lane. An analysis of a typical case shows approximately 5 seconds of delay for the most delayed car, and an average delay of 3 seconds; it would also cause a backup of only 2 vehicles in the lane approaching the underpass.

From among the 12 signal cycles observed, the worst case for bottlenecking was noted and plotted in Chart 4.2, comparing against cumulative departures in a single lane, one can see that bringing the traffic down to one lane in this worst-case situation would back up the traffic by 5 vehicles, causing approximately 11 seconds of delay to the most delayed car. Over the signal cycle, worst-case average delay is only 5.5 seconds.

Chart 4.2: Worst-Case Cumulative Arrivals



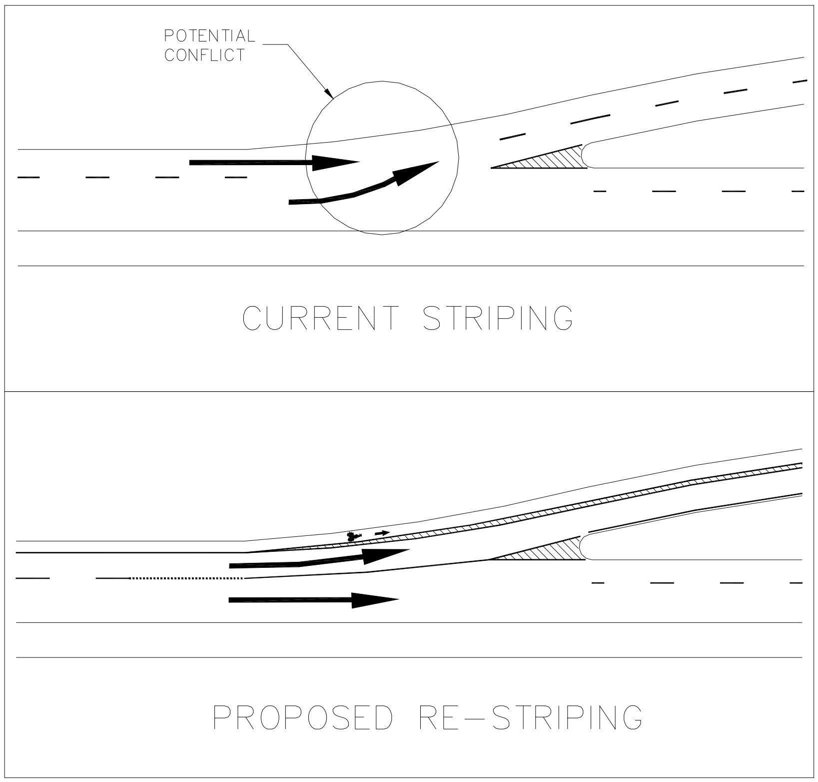
In the worst case scenario a backup of 5 vehicles may occur in the Commonwealth Avenue underpass, causing approximately 11 seconds of delay.

Please refer to the section titled *Queue Length Expansion Factor* which explains the logic behind determining queue length on the approach to the underpass and the calculated backup that would occur from the delay in the worst-case scenario. After the analysis, it was determined that even in the worst case scenario the queue would not back up into the previous intersection.

In order to ease this new transition to the underpass a new striping pattern will occur right before the underpass, making the left lane left-turn only into the underpass and the right lane through traffic only to the two lanes that travel to the service road to Massachusetts Avenue.

The incorporation of a bike lane in the underpass not only allows for not only safer and easier travel for cyclists but less ambiguity for motorists. Currently, vehicles in both lanes traveling along Commonwealth Avenue have the option of entering the underpass. This creates a conflict if someone in the right lane wishes to transition into the underpass but someone in the left lane wishes to go straight. With the incorporation of the bike lane, comes a split in the Commonwealth Avenue traffic forcing those wishing to use the underpass into the left lane and those wishing to use the service road to Massachusetts Avenue to use the right lane. No longer does this crossover conflict exist. Figure 4.6 shows the current transition and the proposed transition into the underpass indicating the potential conflict area with the current striping.

Figure 4.6: Transition into Commonwealth Avenue Underpass



The current transition to the underpass presents a conflict with drivers in the left lane wishing to continue traveling straight to Massachusetts Avenue and drivers on the right wishing to use the underpass. The proposed restriping eliminates this conflict by making the left lane exclusively for the underpass.

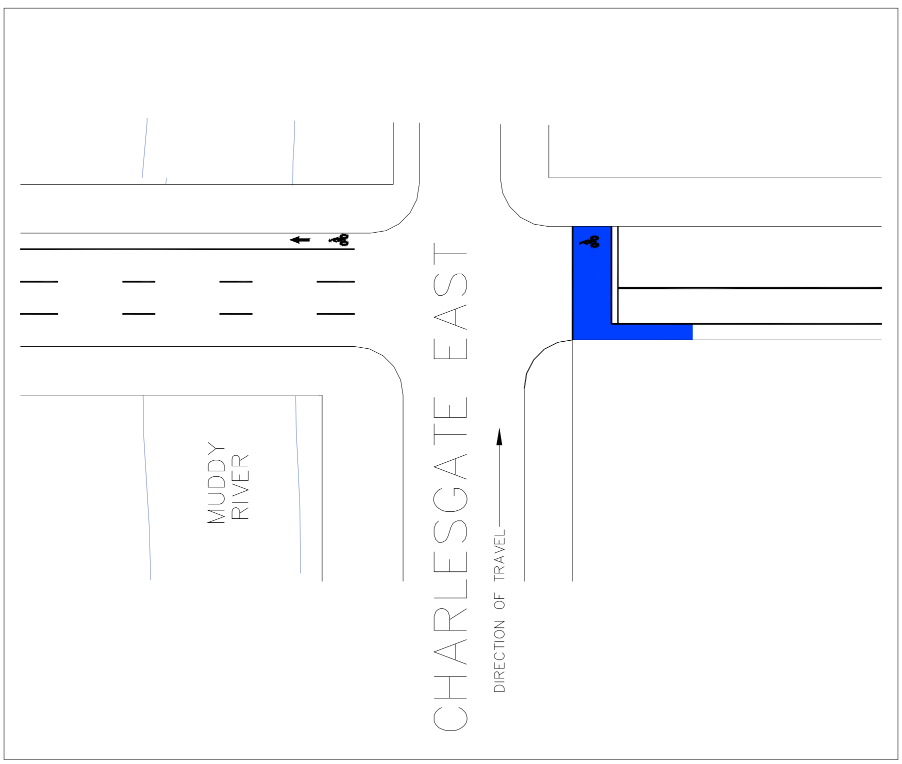
Finally, it is clear from the traffic analysis that was done that the bottleneck effect, even in the worst case is minor. The worst case scenario would not create a queue that would back up into the previous intersection (see Queue Length Expansion factor section for further analysis) and traffic would only experience a small delay.

Section C: Westbound Charlesgate East to Charlesgate West

In order to provide a bike lane through to Kenmore Square, a transition from a left side bike lane to a right side bike lane at the intersection of Charlesgate West is necessary. To assist in this transition, a bike box at this intersection will allow cyclists the opportunity to safely transition to the right side if they arrive at the intersection when the light is red. If a cyclist arrives at the light at green, there is no conflict with left turning drivers as Charlesgate East is one-way. Cyclists can simply cross the intersection on the left and wait on the other side if necessary for the intersection to clear of through traffic and then make the transition to the right side lane.

Included in Figure 4.8 is the Charlesgate East intersection highlighting the transition for cyclists with a “bike box” is provided. The bike box provides a stop line for cyclists ahead of the stop line for vehicular traffic in order to allow cyclists to get out in front of motorists in order to make the transition from the left side to the right side bike lane.

Figure 4.8: Westbound Bike Lane Transition from Left to Right



A bike box allows cyclists to transition from a bike lane on the left to a bike lane on the right if a cyclist arrives on a red light. If a cyclist arrives on a green light, they can safely transition across the intersection on the left without any conflict from left turning drivers and wait for an opportunity to cross.

For section C, the current 35’ layout of 3 lanes will be narrowed to 10’ lanes in order to accommodate the addition of a 5’ bike lane traveling down the right side. Since the block is only about 300’ and traffic will be moving at a fairly slow rate due to traffic signals at these intersections, the more narrow 10’ lanes do not sacrifice much in service for vehicles in order to much better serve cyclists. A cross-section is shown in Figure 4.9.

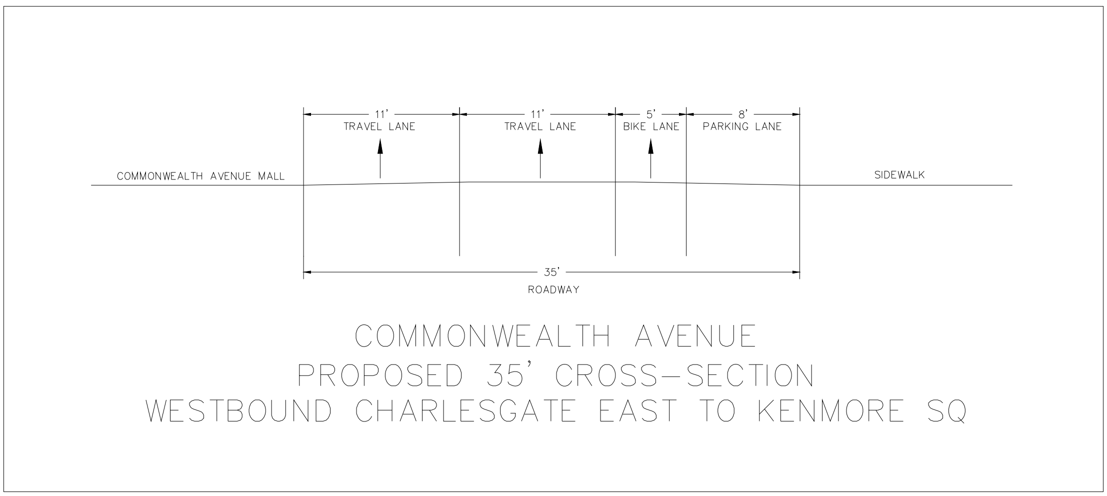
Figure 4.9: Cross-Section C-C

The Westbound section from Charlesgate West to Charlesgate East will consist of three 10’ lanes and a bike lane on the right. Cyclists will have to utilize the bike box at the Charlesgate West intersection to transition from the left to the right.

Section D: Westbound Charlesgate West to Kenmore Square

This section resembles that of Section A with a 35' layout. This section will have an 8' parking lane, a 5' bike lane and two 11' travel lanes. The bike lane in this case will be on the right next to the parking lane, to help cyclists transition into Kenmore Square. Figure 4.10 shows a cross-section for Section D.

Figure 4.10: Cross-Section D-D

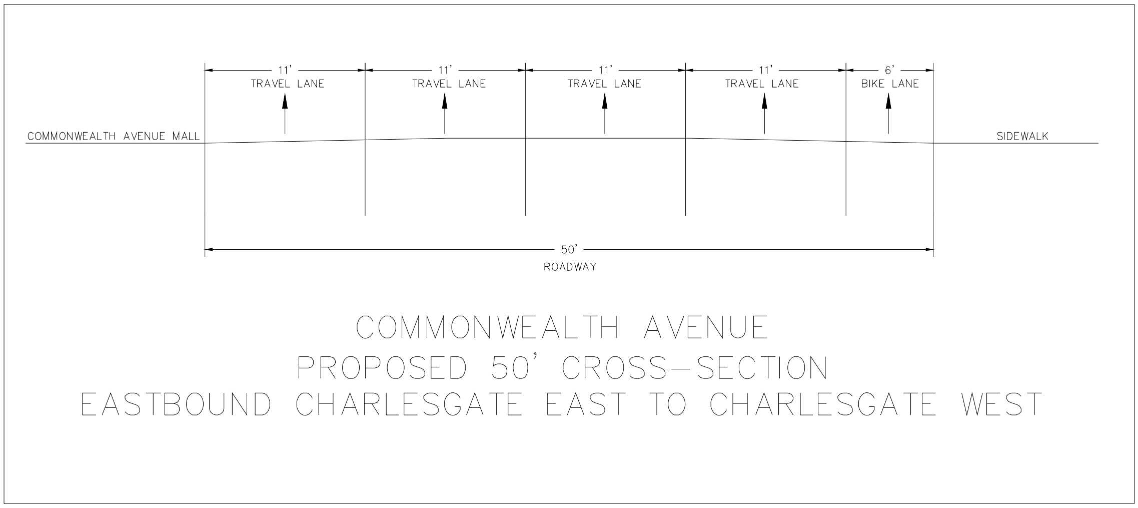


This Westbound section will continue the right side bike lane into Kenmore square.

Section E: Eastbound Charlesgate West to Charlesgate East

This is a 50' section that currently contains 4 lanes. By bringing the lane widths down to 11' allows for a 6' bike lane along the right side. A cross-section of Section E is shown in Figure 4.11.

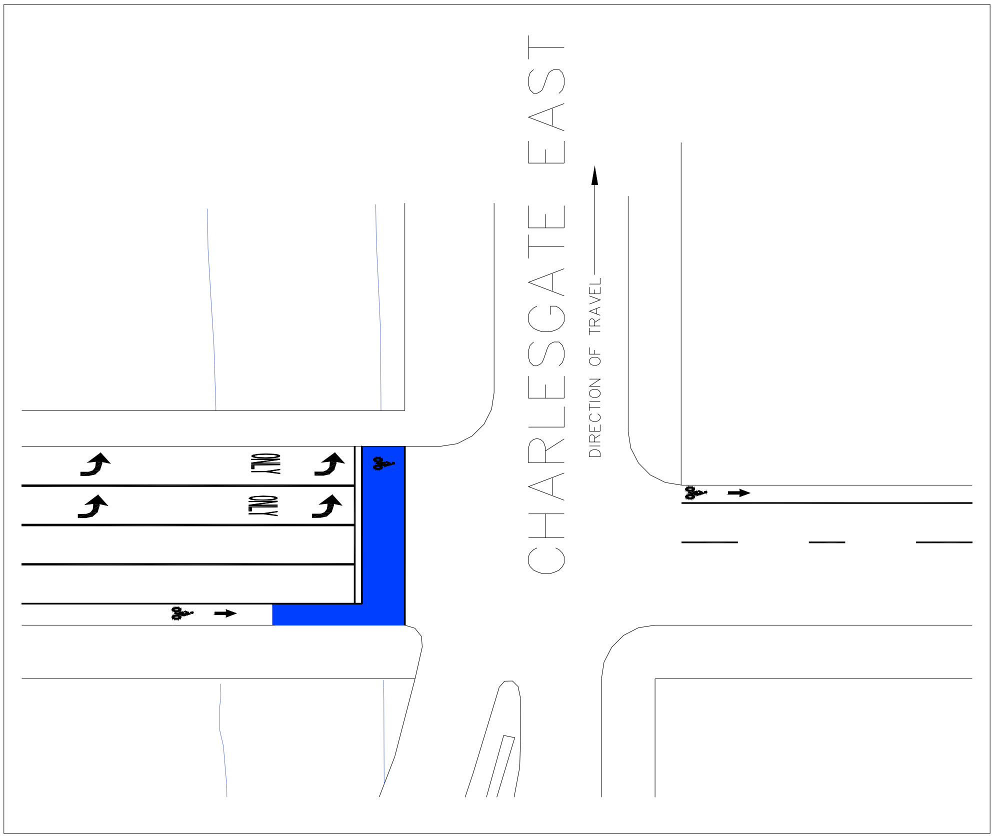
Figure 4.11: Cross-Section E-E



The section of Commonwealth Avenue Eastbound from Charlesgate East to Charlesgate West is wide enough to hold it's current four lane layout with the addition of a bike lane

Because the bike lane transitions from the right side to the left side at the Charlesgate East intersection this intersection features a "bike box" as mentioned in Sections A and C to help cyclists make the transition from the lane on one side to the lane on the other. A cyclist can easily transition from right to left on a red light, or simply make the transition later after crossing the intersection with through traffic. The transition from the right side to the left side is illustrated in Figure 4.12.

Figure 4.12: Eastbound Bike Lane Transition from Right to Left



A bike box at the intersection of Commonwealth Avenue and Charlesgate East on the Eastbound side allows for a transition from the left to the right as in Section C.

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Section F: Kenmore St to Charlesgate West Eastbound

This section is a 50’ layout that currently has 4 lanes of traffic and a parking lane. A common occurrence on this stretch of roadway is double-parking because traffic volumes are easily accommodated in 2 or 3 lanes. Whether it be for deliveries at stores or for cabs bringing passengers to and from the hotel on this stretch, the right lane next to the parking lane is often blocked. Analysis was done on the intersection of Commonwealth Avenue and Charlesgate West in order to ensure that bringing the roadway down to 3 travel lanes would not be detrimental to the current traffic flow. A traffic count of the AM peak at this intersection is shown in Table 4.4.

Table 4.4: Traffic Count at Commonwealth Avenue Eastbound and Charlesgate West

Traffic Count at Commonwealth Avenue and Charlesgate West				
Time	Charlesgate West Through	Charlesgate West Left	Commonwealth Through	Commonwealth Right
7:45-8:00	107	36	259	16
8:00-8:15	83	43	284	24
8:15-8:30	76	32	283	24
8:30-8:45	65	39	296	28
Total	331	150	1122	92
Critical Per Lane	166		425	
Critical Sum	591	LOS = A		

The traffic count at Commonwealth Avenue and Charlesgate West shows that Commonwealth Avenue can be brought down to 3 lanes without negatively effecting the service at the intersection.

Doing a critical sums analysis for the intersection a level of service of A, the best possible, is achieved for this two phase intersection indicating that it can function well with 3 travel lanes. In the current AM Peak, the 100 second cycle Commonwealth Avenue currently gets a 62 second split during the AM peak. A Synchro 5 analysis of this intersection with the current timing for 4 lanes and three lanes was done and is summarized in the Table 4.5, showing that no significant loss in service was found by reducing the lanes from 4 to 3 and ensures that traffic will flow through the intersection smoothly without even requiring a change to the signal timing plan.

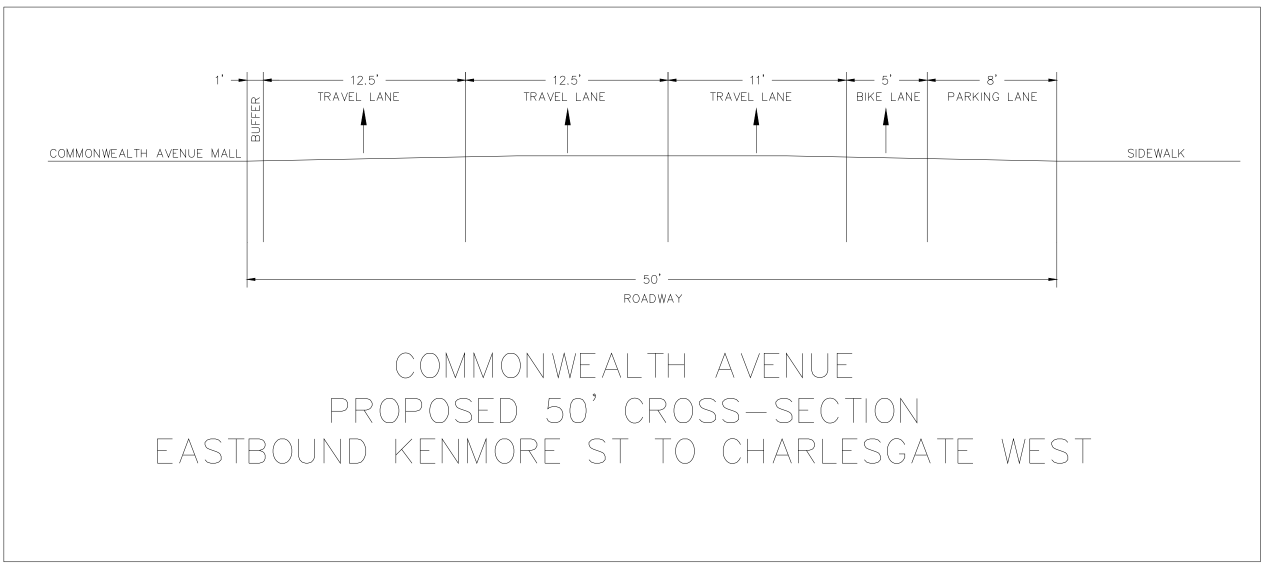
Table 4.5 Synchro 5 Analysis of Signal Timing at Commonwealth Avenue and Chalesgate West

Commonwealth Avenue and Charlesgate West		
	Eastbound Through (4 lanes)	Eastbound Through (3 lanes)
v/c Ratio	0.35	0.44
Delay (s)	10.8	11.7
Level of Service	B	B

Eliminating a lane has a very small effect on the capacity of the intersection with the current signal timing, not requiring any timing changes.

In order to incorporate a bike lane in this section, the roadway may be brought down to 3 travel lanes. Since double parking is so common in this section of Commonwealth Avenue, it is proposed that the cross-section be brought down to a 1' buffer on the left, two 12.5' lanes, an 11' lane, a 5' bike lane and an 8' parking lane. It is anticipated that the 5' bike lane will often be blocked by double-parked vehicles. If so, the 11' lane next to it will also be partially blocked, forcing motorists into the left lanes, making it easier for cyclists to navigate out of the bike lane around double-parked cars. Keeping the lane next to the bike lane down to 11' is thus a deliberate attempt to counteract the double-parking issue. A cross-section of Section F is shown in the Figure 4.13.

Figure 4.13: Cross-Section F-F



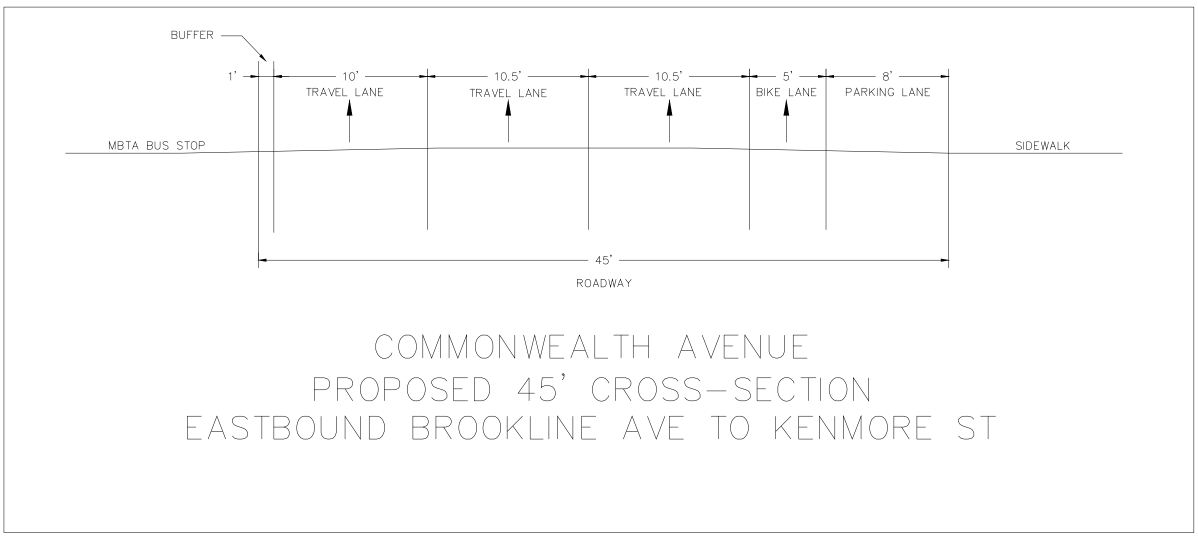
This section will be brought down to three lanes. If double parking in the bike lane occurs, it will block not only the bike lane but the adjacent travel lane as well, allowing cyclists a free lane to navigate around double-parked vehicles.

Section G: Kenmore Square

The section of Commonwealth Avenue beyond Kenmore Square toward the B.U. Bridge is scheduled to be striped with bike lanes To give cyclist an uninterrupted connection, in order to help cyclists transition, two more cross-sections were designed to get cyclists further through Kenmore Square.

On the Eastbound side, Figure 4.14 shows the 45’ roadway layout from Brookline Avenue to Kenmore Street for Commonwealth Avenue. This section will allow cyclists entering from Kenmore Square to pick up a bike lane immediately as they travel down Commonwealth Avenue.

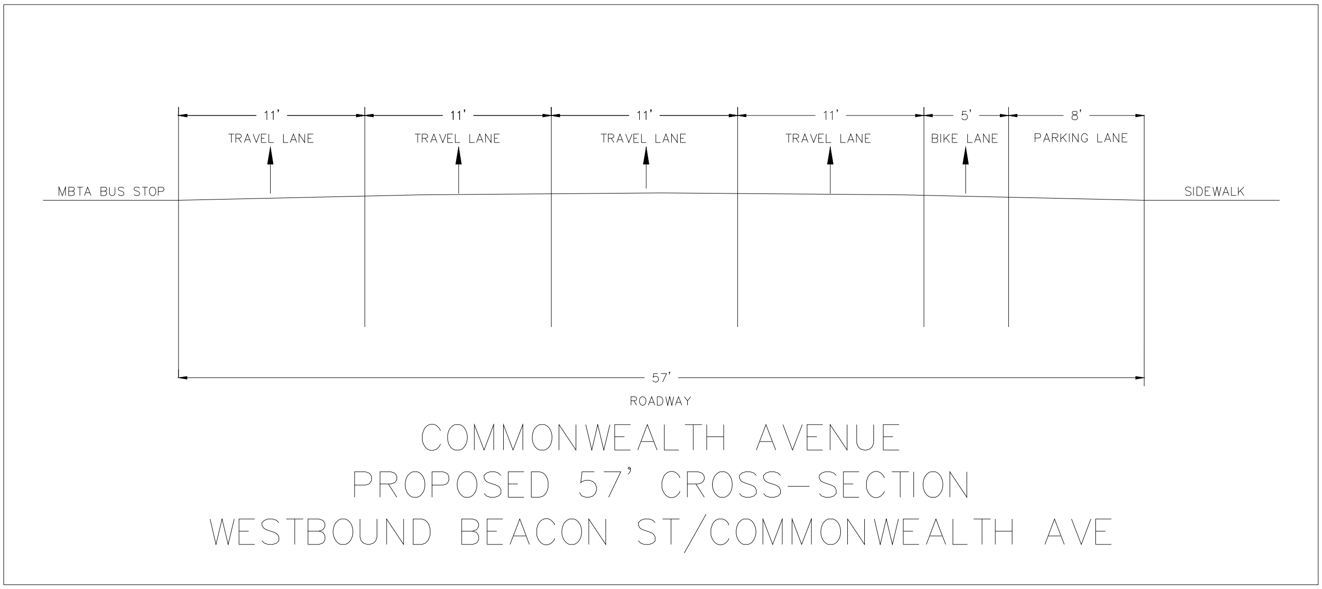
Figure 4.14: Cross-Section G-G



The section of Commonwealth Avenue from Brookline Avenue to Kenmore Street has enough space to allow for three travel lanes a bike lane and a parking lane.

On the Westbound side, cyclists will be guided across the Beacon Street approach by a checkered bike lane crossing the street shown in Figure 4.16. This will allow for 4 travel lanes through Kenmore Square with a bike lane and a parking lane as shown in figure 4.15. Also shown in Figure 4.16 is bike box at the stop line on Commonwealth Avenue/Beacon Street to help cyclists wishing to make a left to continue onto Beacon Street or Brookline Avenue to get over to the left and be easily seem by motorists. Sharrows are included in the left lanes for left turning cyclists that arrive on a green light.

Figure 4.15: Cross-Section H-H



This figure shows that the current geometry on Commonwealth Avenue/Beacon Street allows for four travel lanes, a bike lane and a parking lane.

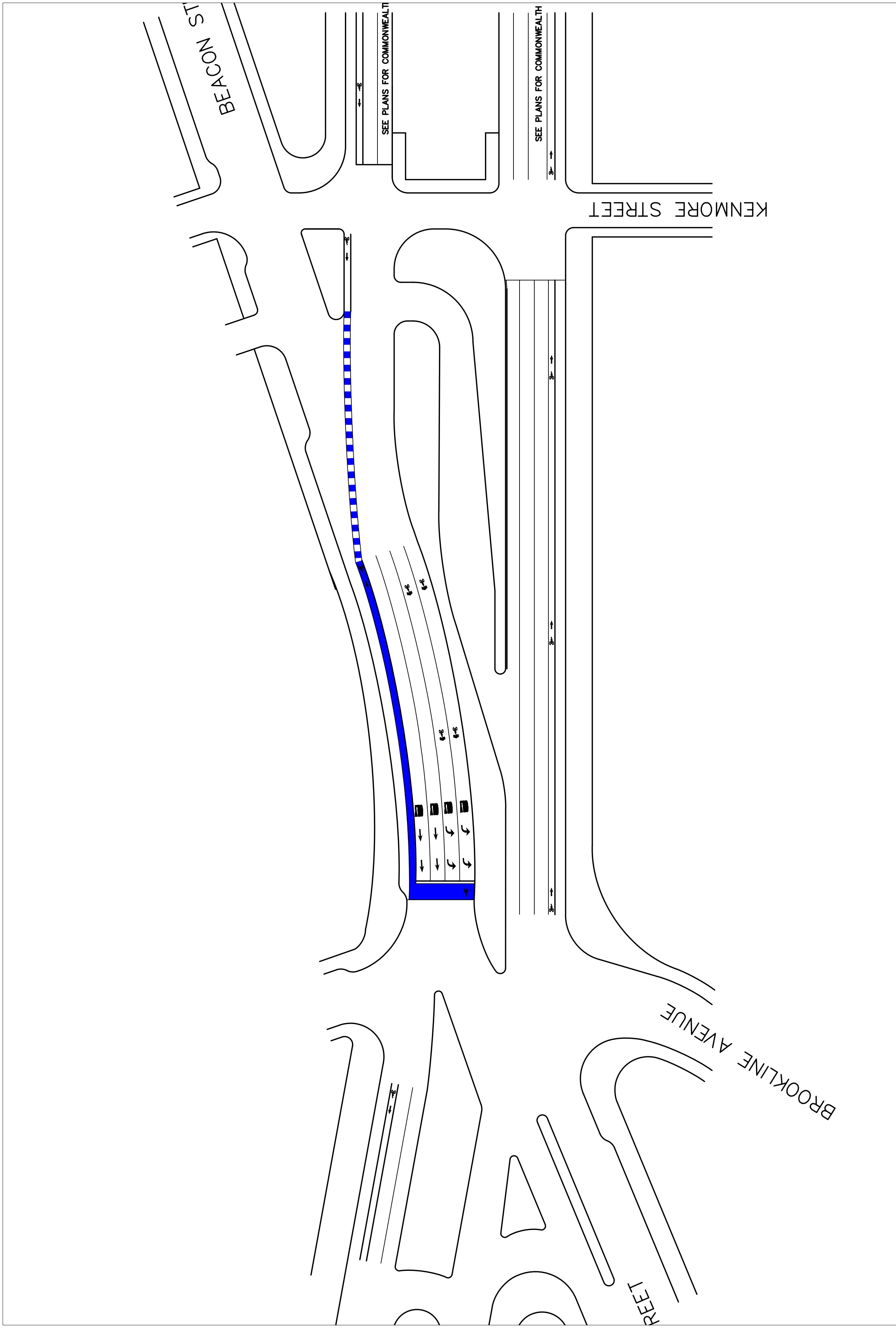


FIGURE 4.16: KENMORE SQUARE
SCALE: 1"=75'

Queue Length Expansion Factor

These results are seemingly minimal as far as queue backup entering the underpass, however, some sort of adjustment does need to be taken into consideration to account for the overall effects of bottlenecking. At a bottleneck, the difference between cumulative arrivals and cumulative departures at any point in time is the number of vehicles in the queue, if the space occupied by those vehicles can be neglected. This is the estimate given by the "stacking model" (imagining that cars in queue stack vertically at the bottleneck). Of course, the space occupied by cars in a queue is not negligible; as the queue spills back, it "swallows" arriving cars that have not yet arrived at the bottleneck, making the queue longer than the nominal queue length as indicated by the stacking model. This note shows how to calculate an expansion factor that, when multiplied by nominal queue length, yields the actual length of the queue as one would observe from overhead. Suppose stacking model gives a queue length (number of vehicles) of Q, and that cars in queue are spaced at a distance L (center to center) L. So the space occupied by those Q vehicles is QL.

If arriving volume is v and arriving speed is u, arriving density is v/u. The initial queue will "swallow" up as many cars are would be in their space; that's QL*(v/u). Those swallowed up cars will join the back of the queue, lengthening the initial queue by QL*(Lv/u). Let r = Lv/u; then the second iteration queue length is QL(1+r).
The cars added to the queue in the second iteration will in turn "swallow up" more arriving cars. The number swallowed up in the next iteration is the added distance multiplied by arrival density, or QLr*(v/u), and the space they will consume is QLr*(Lv/u) = QLr^2.

With additional iterations, the final queue length will be the infinite sum $QL(r^0 + r^1 + r^2 + \dots)$. The sum in parentheses is a geometric series equal to 1/(1-r) (assuming $r < 1$; otherwise the queue will be infinitely long). Therefore, 1/(1-r) = 1/(1 – Lv/u) is the expansion factor to expand nominal queue length (either in number of cars in queue, or as a distance), as determined from the stacking model, into actual queue length. Actual queue length in distance, given an initial queue length QL, is QL/(1 – Lv/u).

For our Comm. Ave. application, during discharge from the upstream traffic signal at Charlesgate East, L = 25 ft, u = 40 ft/s (estimated between 25 and 30 mph), v = 0.128 veh/sec (462 veh/hour), and so the expansion factor is approximately 1.09, making a corrected queue backup for the average case about 54’ long and for the worst case approximately 136’ long.

Note: Above taken from P. Furth, unpublished notes on Traffic Engineering.

Because the distance between the Charlesgate East intersection and the underpass is about 250’ (almost twice the length of the worst queue), it is feasible to bring the underpass down to one lane without any significant impact. Reducing the underpass to a single lane provides more than double the needed capacity, increases delay by less than 5 seconds per car and causes only small backups during platoon flows that don’t spill back into the upstream intersection.

V. Commonwealth Avenue - Warren St. to BU Bridge

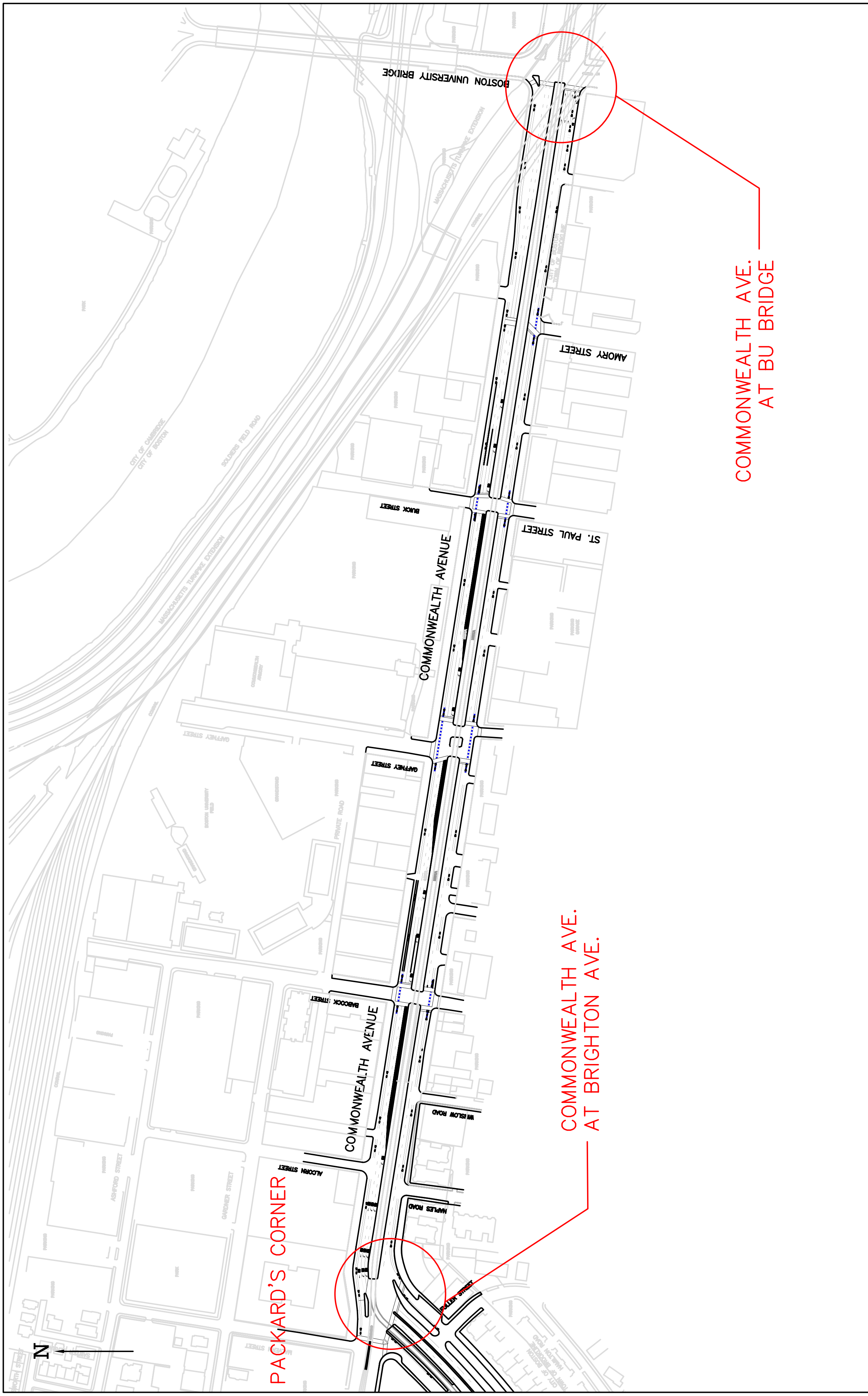
Introduction

Commonwealth Avenue is an ideal street for bike lanes because of its potential to provide crucial east-west connections for cyclists. This report section describes the recommendations for striping bike lanes along the portion of Commonwealth Avenue beginning at its intersection with Warren Street in Allston through Packard's Corner and extending east to its intersection with the Boston University Bridge (BU Bridge) (for Packard's Corner to BU Bridge, see Figure. 5.1; for Warren St. to Packard's Corner, see Figure 5.6). The striping of bike lanes would be an important improvement to cycling in the area, which is already used heavily by cyclists (around 36 bikes/hr during westbound peak). The proposed lanes will link to other lanes that extend east from the BU bridge to Kenmore Square, where additional proposed lanes continue all the way east to Arlington St.

The following is a brief overview of topics covered in this section of the report:

-*Existing and Proposed Typical Cross-Sections:* For the most part, the street is of uniform cross-sectional width. These cross-section dimensions are referred to in Figure 5.2.
-*Intersection of Brighton Ave. and Commonwealth Ave. :* This intersection is more complicated than the typical cross-section, and requires explanation in its own section.
-*Connections between Warren St. and Packard's Corner:* This subsection discusses the parking situations on the service roads for this portion of Commonwealth Ave. and how the parking dictates where bike lanes or sharrow pavement markings will be used.
-*Intersection of Commonwealth Ave. and Boston University Bridge:* This intersection has some unique features as well, and is discussed further in this chapter subsection.
-*Pavement Markings:* This subsection briefly describes the pavement marking design.
-*Justification of 10' Lanes:* This is a brief explanation of why 10' lanes are justified for this specific roadway section.
-*Other Considerations*: This subsection describes additional reasoning and some information pertaining to adjoining project designs.

The CAD drawings associated with this proposed design can be found on roll plans which cover the overall pavement marking plan as well as the Packard's Corner and BU Bridge intersections. A general overview of the proposed project area is shown in Figure 5.1.



SPOKES

FIG. 5.1: OVERVIEW OF COMMONWEALTH AVE. FROM PACKARD'S CORNER TO BOSTON UNIV. BRIDGE

By changing the width of travel lanes to 10', bicycle lanes can be added to Commonwealth Ave. between Packard's Corner and the BU Bridge.

Existing and Proposed Typical Sections

This proposed addition of bicycle lanes can be accomplished without any modification to the existing curb and highway geometry of Commonwealth Ave. By simply re-striping the street, 5’ bicycle lanes can be added to improve bicyclist safety as well as provide cyclists with a better travel route. This added cyclist safety need not come add the expense of motorists, and in some cases the new striping may actually help improve motorist safety and delay.

Figure 5.2 shows typical existing and proposed cross sections for this portion of Commonwealth Ave. These cross sections apply from Naples Rd. all the way east to Amory St. Although the westbound side (42.5’ width) of Commonwealth Ave. is wider than the eastbound side (34’ width), it is the westbound side that has the more constrained cross-section due to the additional presence of left turn lanes.

Westbound:

The westbound cross-section will require 10’ travel lanes for the entire length as well as 9’ turn lanes in order to accommodate an 8’ parking and 5’ bike lane. As is explained in Chapter 3 and *Justification of 10-ft Lanes*, 10’ lanes should be acceptable on this section of roadway. The striping of 10’ lanes will allow for 5’ bike lanes. The 5’ bike lanes are needed to provide a combined width of 13’ for the bicycle and parking lanes, giving cyclists the space needed to avoid “dooring”—a situation in which the door of a parked car is opened into a traveling bicycle without warning, causing the cyclist to fall.

The leftmost lane needs to be addressed as well. At St. Paul St., Babcock St., and Packard’s Corner it is marked as “left turn only”, but at Pleasant St. it is not marked as such. This is an unsafe situation since some motorists will be led to use the leftmost lane as a travel lane, and upon encountering queued left turners, they must suddenly switch lanes to avoid the backup, creating turbulence. Left turners often block the leftmost lane, and therefore it cannot function as a through-lane. The proposed design eliminates this ambiguity and safety concern. In the long run, the curb layout could be tapered out to prevent cars from traveling in the left turn lane as shown in Figure 5.3-B. This would have the added bonus of providing additional space for the MBTA Green Line platforms. In the interim, the leftmost lane should be marked as, “left turn only” all along the Packard’s Corner to BU Bridge portion of Commonwealth Ave, and portions of the lane not needed to store left-turning cars can be hatched out as shown in Figure 5.3-A.

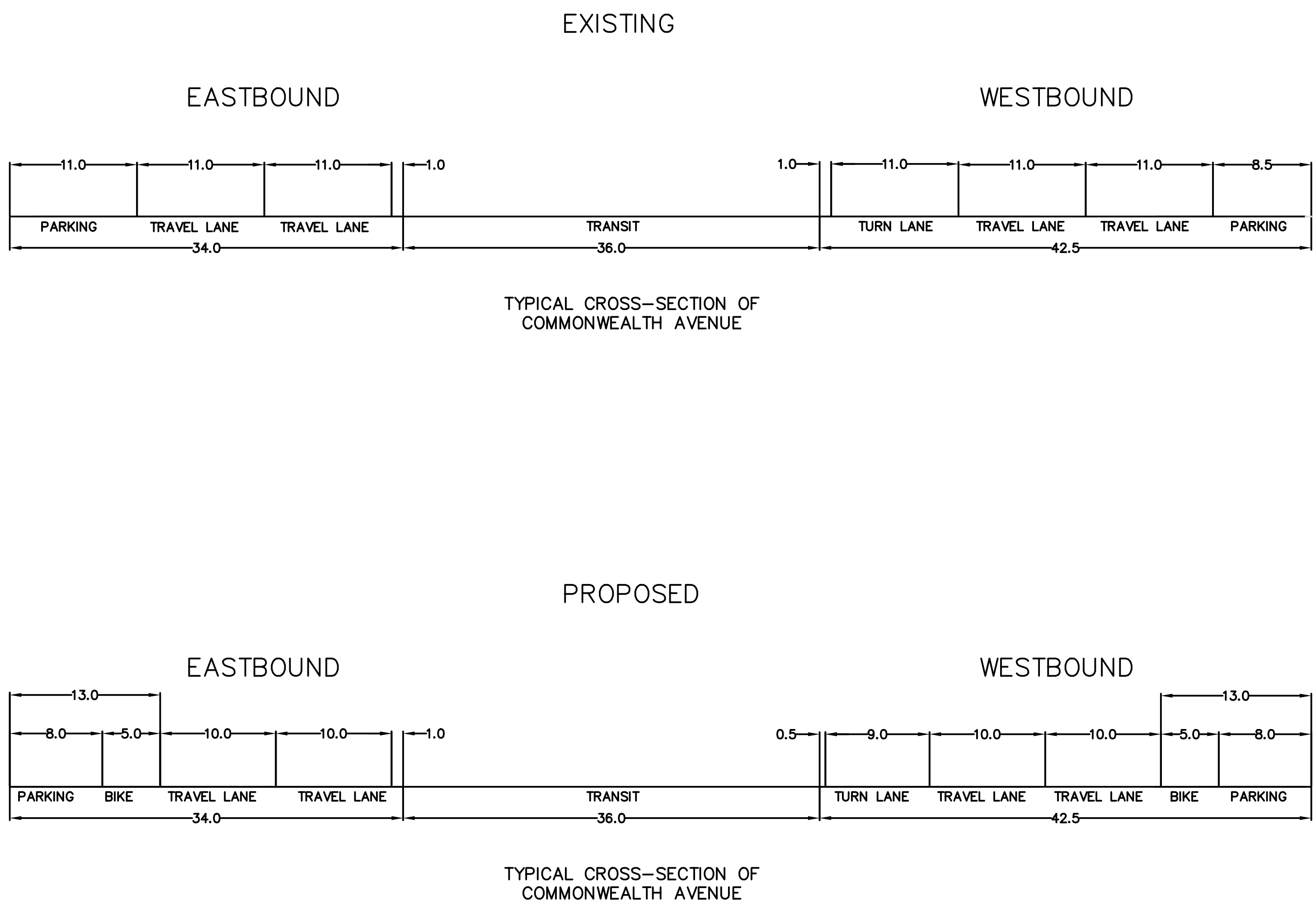
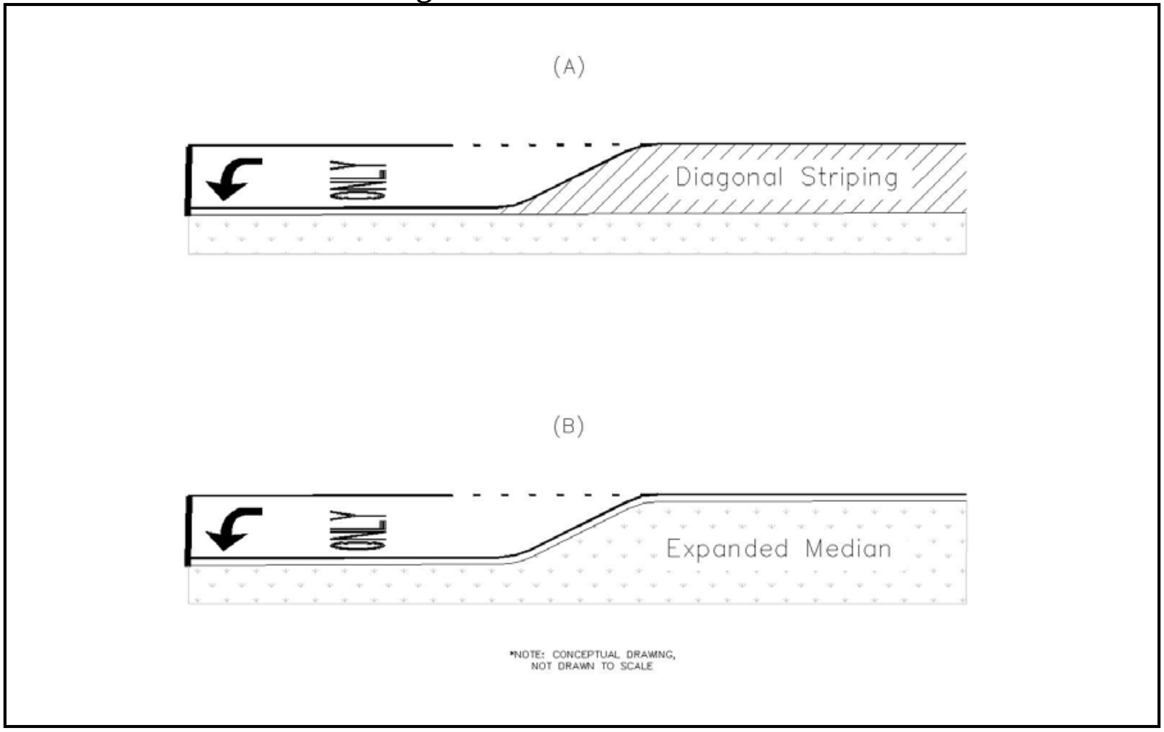


FIG. 5.2: TYPICAL SECTIONS OF COMMONWEALTH AVE. FROM BOSTON UNIV. BRIDGE TO PACKARD'S CORNER

These typical sections apply for most of Commonwealth Ave. between Packards corner and the BU Bridge.
Narrowing the travel lanes allows for the addition of 5' bike lane to improve bicycle safety without sacrificing motorists' safety.

Figure 5.3: Left Turn Lanes



To eliminate ambiguity, left-turn-only lanes should be clearly marked. Any of the left turn lane not needed for storing turning vehicle will be painted out diagonally (A). Eventually, the median and curb can be expanded out into the extra space (B) to make the median wider, which may provide more room at T platforms.

Eastbound:

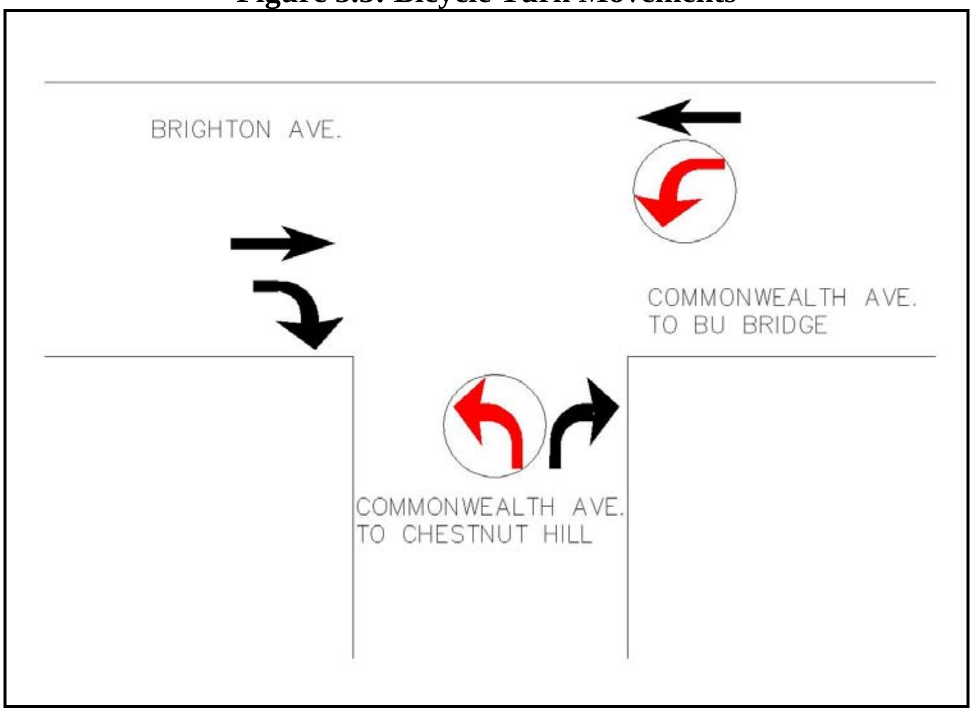
The eastbound side of Commonwealth Ave. can easily accommodate 5' bike lanes with two 10-10.25' travel lanes. The only exception is between Naples St. and Babcock St. which is actually 33' as opposed to 34' elsewhere. For this very short (around 100' long) 33' section, the buffer between the center median and parking lane can be narrowed to ½' and 7.5', respectively to allow for two 10' travel lanes and a 5' bike lane.

Intersection of Brighton Ave. and Commonwealth Ave. (Packard's Corner)

Figure 5.4 shows a plan view of the proposed pavement markings for the Brighton Ave. and Commonwealth Ave. intersection at Packard's Corner. This intersection is somewhat unusual since the MBTA Green Line trains make a left turn at this intersection to follow southwest along Commonwealth Ave., which also turns that direction. The western leg of the intersection is Brighton Ave. Going westbound on Commonwealth Ave., the two leftmost lanes are for left turns only. The right lane continues straight to Brighton Ave., and it is controlled by a separate signal (1 min 30 sec green time, 22 sec red time).

There is a dedicated signal for Green Line streetcars, allowing them to traverse the Packard's Corner intersection with all conflicting traffic stopped. This transit signal gives trains 22 sec to travel through the intersection; crosswalks run during this interval, as well. This interval is not actuated; that is, it runs whether or not there is a train present, which can be used as a benefit for westbound cyclists who wish to turn left.

Figure 5.5: Bicycle Turn Movements



The circled bicycle movements at the Packard's Corner intersection may require cyclists to walk their bikes in the crosswalks. It is recommended that future curb geometry/layout for this intersection be adjusted to allow cyclists to remain on their bicycles while making these movements.

By traversing the intersection in conjunction with the transit signal, westbound left-turning cyclists have additional time during which they may continue west on Commonwealth Ave without conflict. While the current cycle timing acts to the advantage of this turning movement, the current intersection geometry does not have adequate space for a bike lane to be striped for the westbound left-turning cyclists. In the short term, cyclists desiring to make this turn should dismount their bikes at the Brighton Ave. crossing, where they can continue in the crosswalk during the 22 sec

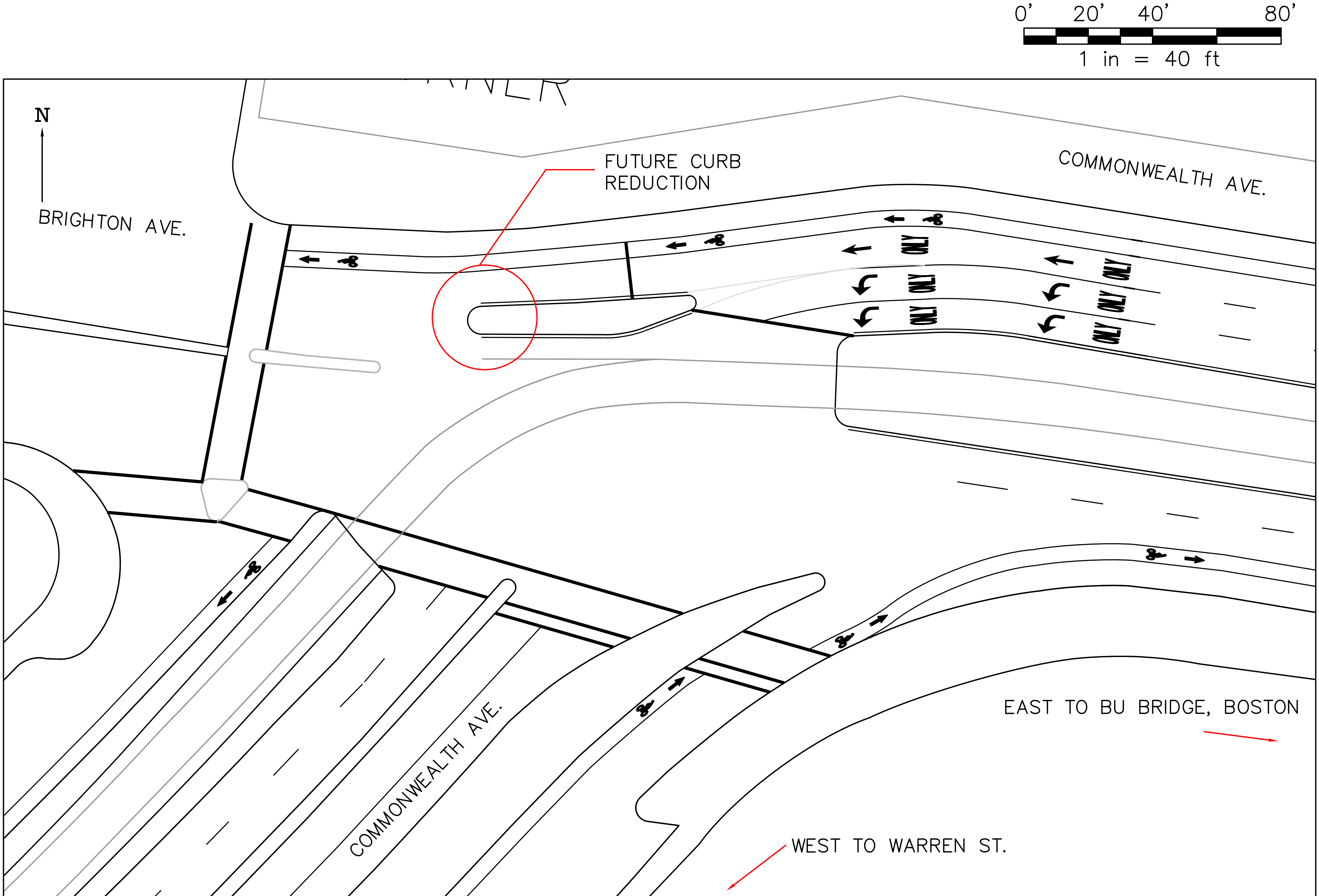


FIG. 5.4: PLAN VIEW OF BRIGHTON AVE. & COMMONWEALTH AVE. (PACKARD'S CORNER) INTERSECTION

While nonstandard, the geometry of the Packard's corner intersection still supports the addition of bicycle lanes. The proposed lanes are shown in the diagram above.

transit/pedestrian phase. In the long run, the west edge of the island between left turn and through lanes should be reduced to allow cyclists to more directly reach the westbound service road (See Figure 5.4).

As for cyclists wishing to make the left turn from the eastbound service road onto Brighton Ave., it is recommended (in the short term) that they also walk their bikes in the crosswalks due to the current intersection layout. All other bicycle connections through this intersection will be relatively direct. Figure 5.5 shows bicycle movements at Packard's Corner; the circled arrows are movements that may require crosswalk use and possible future curb modifications.

Connections between Warren St. and Packard's Corner

Cyclists will be able to travel between Warren St. and Packard's corner by providing bike lanes on the local service roads of Commonwealth Ave. between these two points. While the central road carries faster, higher-volume traffic, the service roads on both the westbound and eastbound sides of this portion of Commonwealth Ave. provide an ideal location for cyclists to ride due to their low traffic volumes and slow-speed local traffic. In most cases, there is more than adequate cross-sectional space for the addition of bike lanes. 5' Bicycle lanes will be located on the left-hand side of access roads to avoid the risk of "dooring" from the right-hand side parallel parking. See Figure 5.6 for sample cross-sections and overviews of bike lane segments from Packard's Corner to Warren St. Figure 5.7 shows a more detailed plan of places where the typical proposed cross-sections apply.

While bike lanes are feasible on most of the service roads, there are some portions that require "sharrow" pavement markings. These segments are shown in Figure 5.8, and "sharrows" will be used in the following situations:

1. Angle parking is present on both the right and left-hand sides of the access road.
2. Angle parking is present on the left-hand side of the access road.
3. The service road cross section is too narrow to add a bike lane.

Using "sharrows" in the first two situations will be safer than placing bike lanes directly besides angle parking, where motorists must back out of parking spots. The "sharrows" will encourage cyclists to ride safely in the center of the service road while simultaneously alerting motorists to the potential presence of bicycles in the shared lane.

While the installation of "Do not pass bicycle" signs was considered, it was decided that pavement markings will likely be more effective at gaining the attention of motorists on the access roads. Since these access roads are carrying slow-moving, low volume, local traffic, motorists should and cyclists should be able to share the road with relative ease.

Entering the Packard's Corner intersection from the southwest will be the 5' bike lane on the left hand side of the Commonwealth Ave. service road. Upon reaching the intersection stop line and crosswalk, the bike lane will switch to the right hand side of the street, which should not be a problem due to the low volume of traffic on this side street.

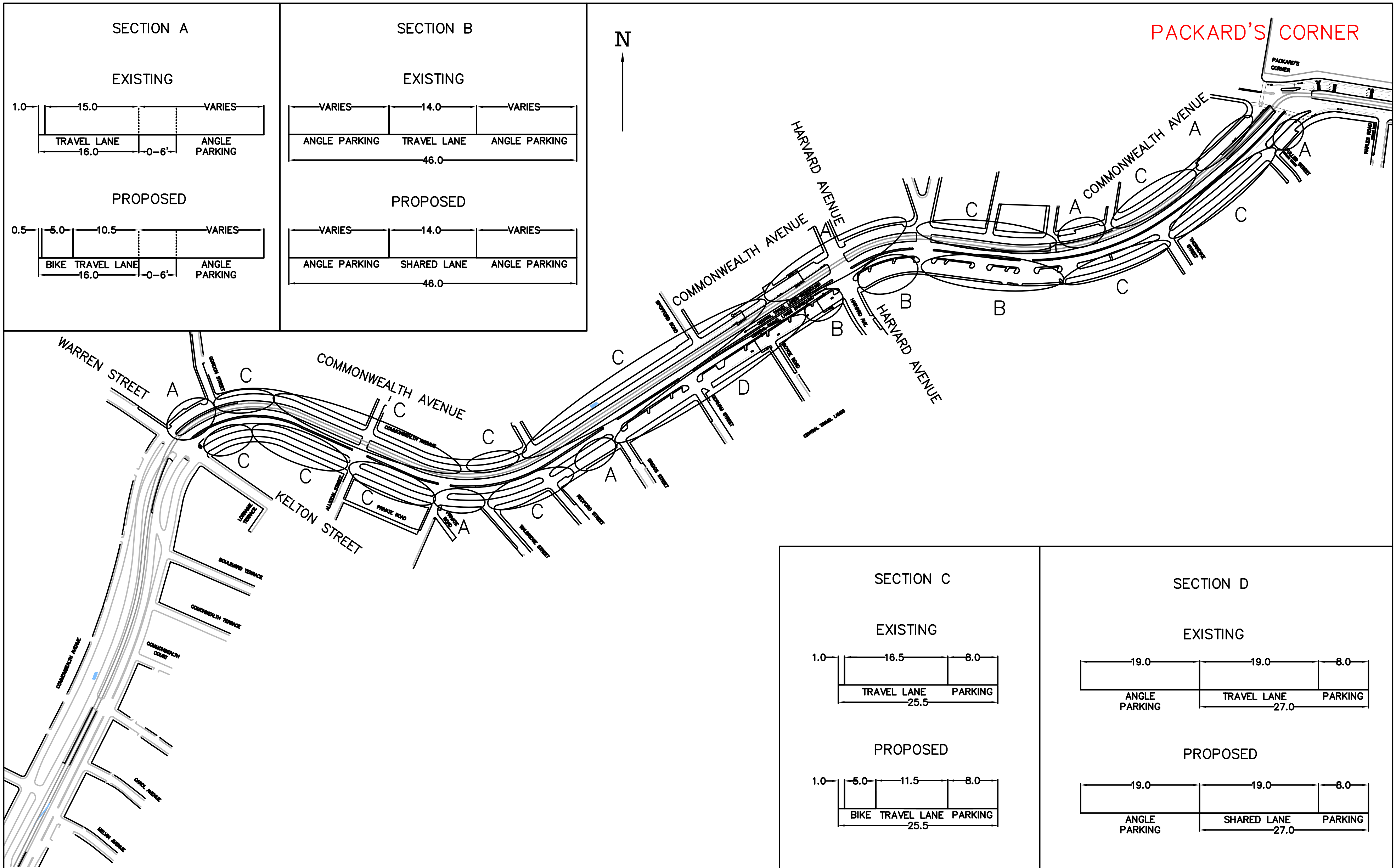


FIG. 5.6: OVERVIEW OF COMMONWEALTH AVE. FROM WARREN ST. TO PACKARD'S CORNER WITH SECTIONS

The portion of Commonwealth Avenue from Warren St. to Packard's Corner has service roads on the eastbound and westbound sides, which can be used for the addition of bicycle facilities.Each cross section applies where indicated and in the direction of traffic.

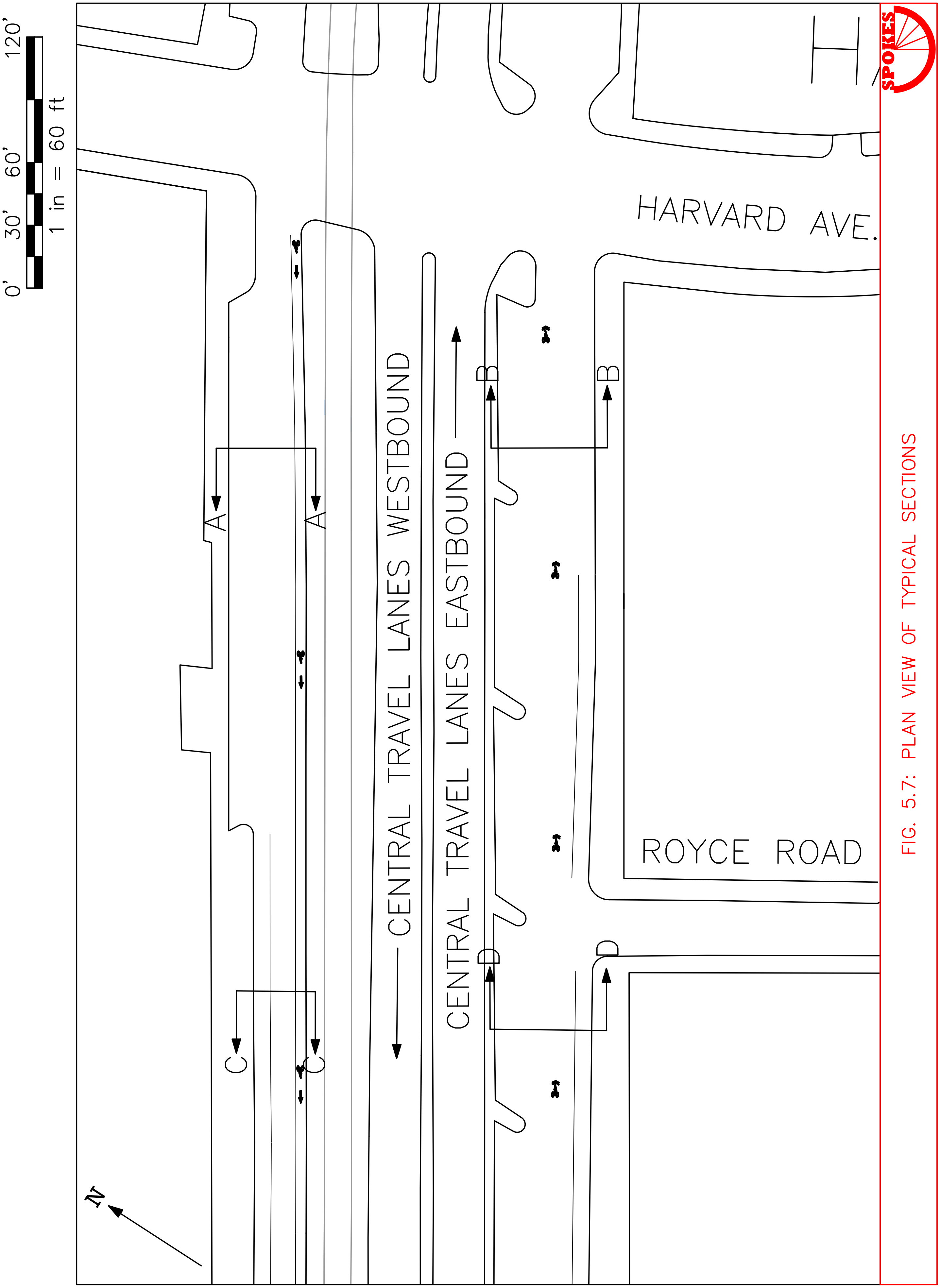


FIG. 5.7: PLAN VIEW OF TYPICAL SECTIONS

This plan view shows places where the typical sections from Figure 5.6 apply.

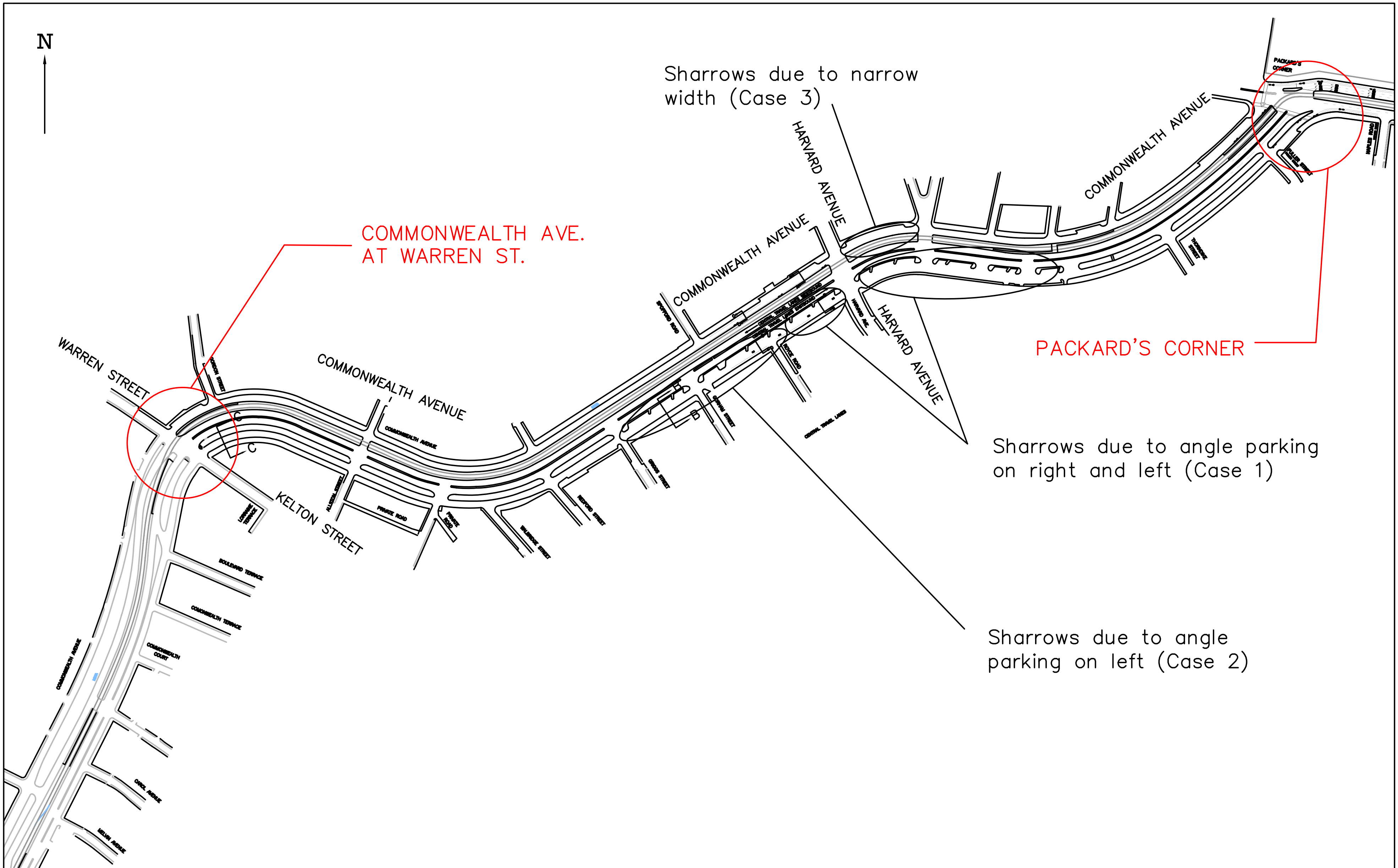


FIG. 5.8: COMMONWEALTH AVE. FROM WARREN ST. TO PACKARD'S CORNER – SHARROW LOCATIONS

This shows where sharrows will be required on service roads.

Intersection of Commonwealth Ave. and Boston University Bridge

The proposed pavement markings for the intersection of Commonwealth Ave. at the BU Bridge are shown in Figure 5.9. One advantage to the area just west of the intersection is that it has a large amount of additional space available. On the westbound side, there is enough space to start with two 12' lanes as the leftmost and have a 22' lane on the right. There is also enough space for a 6' bike lane and 8' parking lane on this section.

On the eastbound side of Commonwealth Ave., there is an area where parking is not permitted (shown in Figure 5.9). In this area, the bike lane will transition from being 8' offset from the curb to being directly against the curb. At the intersection, the leftmost three lanes will continue straight (at 12', 11', and 11' wide). The through bike lane will be 5' wide and between the through and right-turn travel lanes. Cyclists who wish to turn right can simply enter the right-turn lane where it begins.

Immediately east of the BU Bridge will be another set of eastbound and westbound 5' bicycle lanes on Commonwealth Ave. This adjacent project is currently under construction, and it is expected to open in the summer of 2008 (*2*). The project under construction involves the creation of bike lanes going east on Commonwealth Ave. from the BU Bridge to Kenmore Square. Also proposed in this report are bicycle lanes that run east from Kenmore Square all the way to Arlington St. So, through proposed and current bicycle lane projects, cyclists could essentially ride in bike lanes all the way from Warren St. in Allston to the Public Garden at Arlington St.

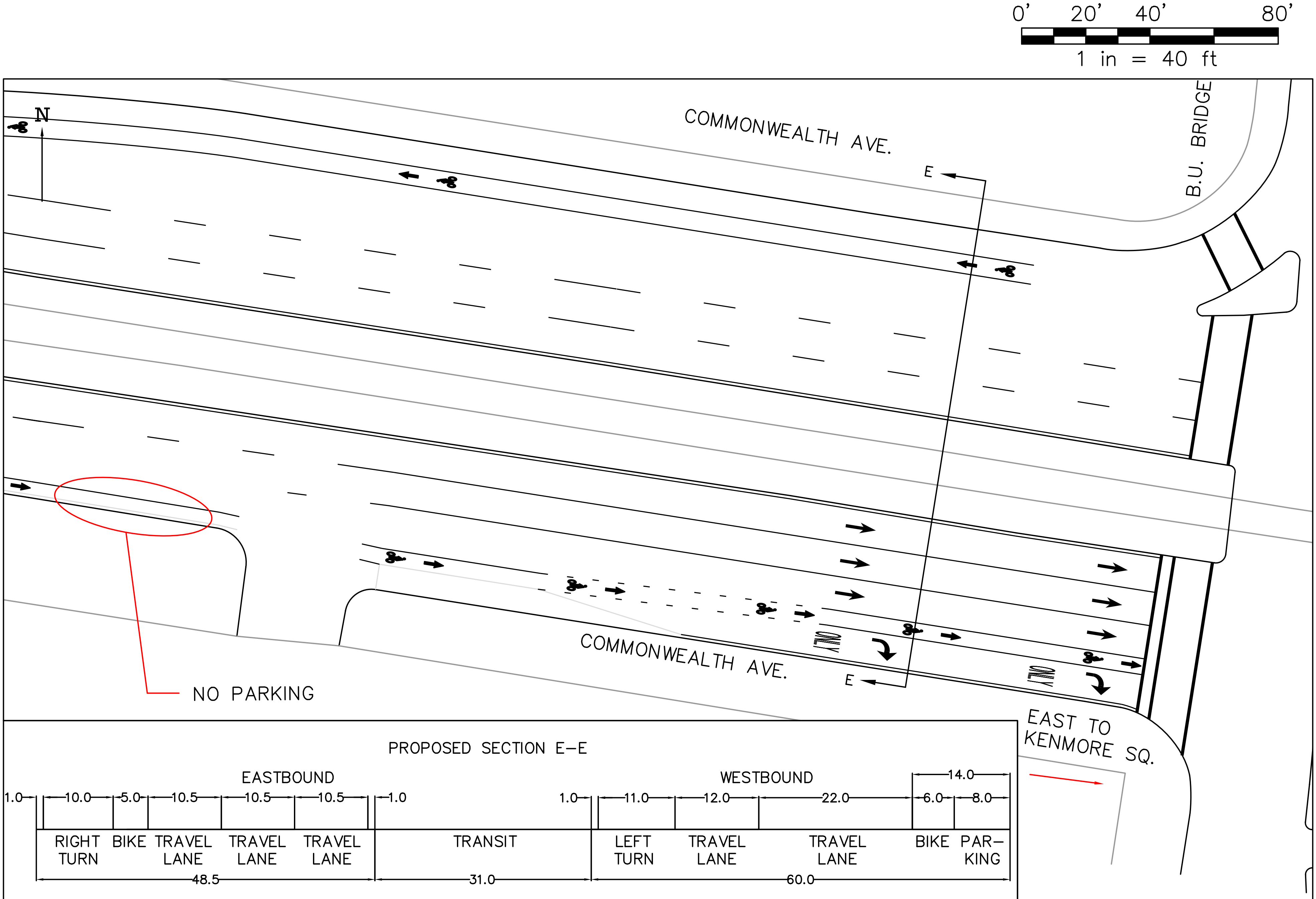


FIG. 5.9: PLAN VIEW OF INTERSECTION APPROACH AT B.U. BRIDGE WITH CROSS SECTION

Above is the west approach to the BU Bridge intersection with Commonwealth Ave. Through-travelling eastbound cyclists will be provided with a 5' lane between the through and right-turn travel lanes. Cyclists who wish to turn right may simply shift to the right-turn lane. To the east of this intersection is the project currently under construction, which will also include bicycle lanes(expected to open in 2008).

Pavement Markings

Aside from the two intersections at Packard's Corner and the BU Bridge, there is some additional discussion of pavement markings required. The Manual on Uniform Traffic Control Devices (MUTCD) provides guidance for many of the pavement markings in this proposed project along with some preferences by the City of Boston.

The existing crosswalks on this portion of Commonwealth Ave. will be retained. As for other pavement markings, all lane lines will be 4" wide, and stop lines are shown as being 1' line width (*1*). Broken lane lanes have a spacing of 10' line, 20' space while broken bike lane lines should be spaced as 2' line, 6' space (bike lane lines as specified in the MUTCD) (*1*). Also, stop lines are located at least 4' before crosswalks in accordance with the MUTCD (*1*). Thus, existing stop lines will be retained. In the case of the signalized westbound crossing at Amory St., the stop line will be also be marked at the same location as the existing, which is much farther back than 4'.

The bike lane pavement markings are of the style preferred by the City of Boston (bicycle with rider), and they are drawn according to the Standard Highway Signs book section 1A and Figure 9C-6 of the MUTCD (*3*). The spacing and dimensions of the turn lane arrows are also according to the MUTCD and Standard Highway Signs book.

Justification of 10-ft Lanes

For a detailed reasoning behind the justification of 10-ft lanes, please see Chapter 3.

There is reason to believe that 10’ lanes could be used successfully in Boston and more specifically on the section of Commonwealth Avenue between Packard’s Corner and the BU Bridge. This section of roadway is an arterial with traffic volume in the same range as those in other cities that have employed 10’ lanes successfully.

This portion of Commonwealth Ave also carries the #57 bus route. Since the MBTA buses are 8.5’ wide, 10’ lanes provide adequate width. When a bus is pulled up to a curbside stop, cyclists will be able to pass the bus on the left due to the bike lanes already being offset 8’ from the curb to allow for parking. As mentioned earlier, busses desiring a little more space can travel near or even partially in the bike lanes as long as there is not a bike present at that time. If a bus must pass a cyclist in the proposed bicycle lanes, the professionally trained bus driver can simply shy away from the cyclist while traveling within the 10’ right lane.

The proposed bike lanes also serve as an increased buffer between buses in the right lane and parked cars. Even assuming that a bus is traveling in the far left of the current 11’ right lane, there will be only 2.5’ of space between the bus and the parallel parking. This is an unsafe situation for a cyclist caught between the bus and parked cars, and it is a risk for parked cars opening their driver-side door. With the proposed combination of 10’ lanes and 5’ bike lanes, a bus traveling to the left side of the right lane will instead be 6.5’ from parallel parking, leaving room for both cyclists and car doors.

Other Considerations

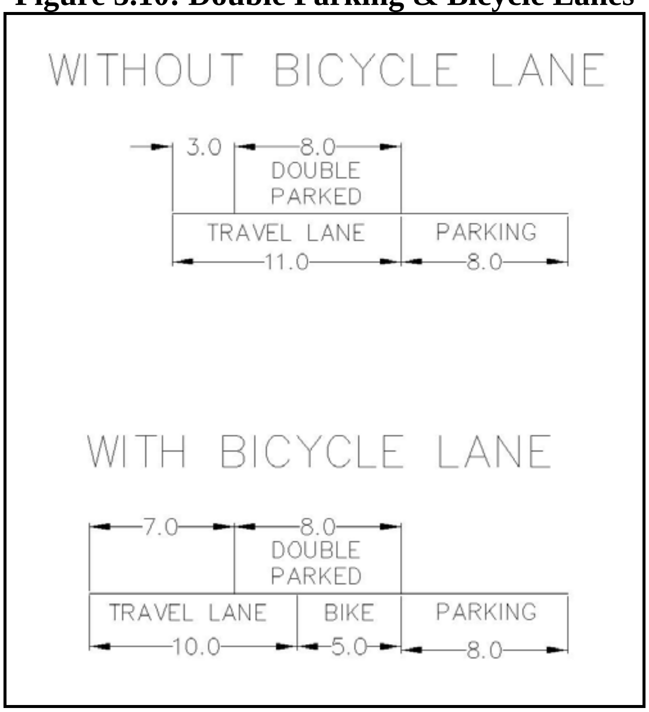
There are a few additional issues that should be considered with this portion of Commonwealth Ave.

First, there is currently no crosswalk on the eastern leg of the Commonwealth Ave. and Brighton Ave. intersection at Packard's corner. Adding this crossing may be beneficial to pedestrians, but further analysis would be required to determine whether or not it would hurt traffic capacity or present a dangerous crossing of the MBTA tracks. This crossing is outside the scope of this project, and is not included in the proposed striping plan.

Second, while doing field research, several instances of double parked cars or trucks were observed. In this situation, some motorists on the westbound side switch from the right-hand lane to the middle lane causing those in the middle lane to switch to travel in left turn lane.

Cyclists will likely have to contend with some double parked vehicles. While increased enforcement of parking laws can help a little, the proposed bike lanes will likely help the most with this problem. When bike lanes are marked, cyclists will be able to pass double parkers without too much trouble as they will actually have more passing space compared to the existing lane striping (see Figure 5.10). The narrower 10' lanes will also likely result in motorists driving slightly slower, which may further aid in passing double parked vehicles and help with safety in general.

Figure 5.10: Double Parking & Bicycle Lanes



This figure demonstrates how adding the proposed bicycle lanes may improve the double parking situation. With the proposed striping plan, double-parked vehicles will block less of the right travel lane, leaving more room for bikes to pass double parkers.

Finally, upon field investigation, it was observed that at least some of the catch basin covers on Commonwealth Ave. need to be rotated 90° to accommodate bicycles as described earlier. Some of the covers' slots currently run parallel to the curb, and a bicycle tire could potentially get caught in them, causing an accident. Rotating them 90° will allow bike tires to traverse the cover perpendicular to the slots, which is not a problem.

References

1. Manual on Uniform Traffic Control Devices (MUTCD). US Dep. of Transportation. Federal Highway Administration. 2004. <http://mutcd.fhwa.dot.gov/pdfs/2003r1r2/pdf_index.htm>.
2. Marotta, Michael. "Easy Riders." Boston Herald 16 Feb. 2008: 3.
3. Standard Highway Signs, English Version (SHS). US Dep. of Transportation. Federal Highway Administration. 2004. <http://mutcd.fhwa.dot.gov/ser-shs_millennium_eng.htm>.

VI. Dartmouth Street – Stuart Street to Esplanade

Introduction

Dartmouth Street provides an important cross-town connection from the Southwest Corridor to the Commonwealth Avenue bike lanes and the Charles River bike path. The objective of this report is to design bicycle facilities that can be easily implemented by simply restriping the roadway. With the exception of the section from Stuart Street to Columbus Avenue, Dartmouth Street is wide enough to house such bicycle facilities. The decision was made to provide the city with a pair of bicycle lanes, one in each direction, along Dartmouth Street. This offers cyclist access from Copley Square and Commonwealth Avenue to the Charles River bike path and vice versa.

Figure 6.1: Clarendon Street facing northbound
notice the Storrow drive off Ramp onto Clarendon St.

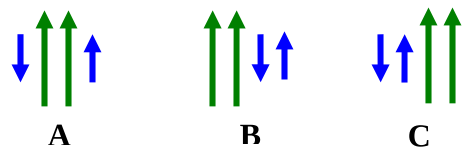
The decision was made to place both the northbound and southbound bicycle lanes along Dartmouth Street after two other options were discarded.

Clarendon Street and Exeter Street were looked at as possible streets to house the bicycle lanes but they fell short of ideal. The problem that was faced with Clarendon Street was the curb to curb width of 36'. Currently Clarendon Street is striped for two 10' lanes and two parking lanes. This geometry leaves no room for bicycle lanes. The problem could have been fixed by either eliminating a parking lane, or reducing Clarendon Street to a single travel lane, but with heavy traffic coming onto Clarendon Street from Storrow Drive this was not possible.

The Second option was Exeter Street. This street was ideal because Storrow Drive does not connect to it and therefore has low traffic volumes. The problems faced here were again the curb to curb width. Like Clarendon Street, it too was 36' wide with the same geometry. The advantage to Exeter Street was that because of the low volumes, Exeter Street could be reduced to one travel lane and have plenty of room for two bicycle lanes. The bigger problem with Exeter Street was the access cyclist would have once they reached the intersection with Huntington Avenue. Cyclist would arrive at a confusing 5-way intersection with little options on where to go from there. It was decided to opt for Dartmouth Street because it was wide enough for a double bike lane as well as good access to Copley Square and the Charles Rive path.

Once the decision to use Dartmouth Street was finalized, three options arose as to the possible layouts for the street. Layout C was chosen as the best possible option because it offered the most protection to the contra-flow bicycles by having a bike lane to the right of it (blue).

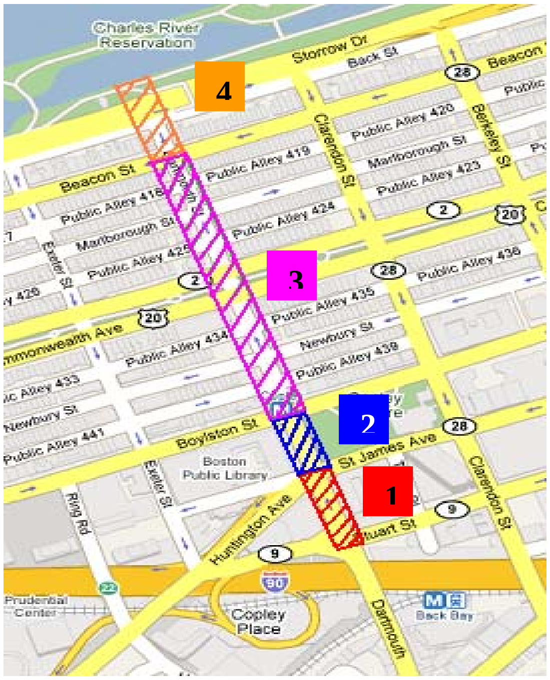
Figure 6.2: Possible layouts for Dartmouth Street



The section of Dartmouth Street this report will cover begins at the intersection with Stuart Street and ends at the entrance to the Esplanade. Note that traffic flow is one way on Dartmouth Street towards the Charles River and the driveway from Back Street to Beacon Street is one way away from the river. For clarity purposes, this report will view the roadway in the same direction as traffic and the descriptive terms used are relative to this point of view.

The report divides this segment of road into four sections:

Figure 6.3: Section Map of Dartmouth Street



- **Section 1** the section of road between Stuart Street and Huntington Avenue.
- **Section 2** the section from Huntington Avenue to Boylston Street.
- **Section 3** the segment from the intersection at Boylston Street to the intersection with Beacon Street.
- **Section 4** the connection from Beacon Street to the Esplanade.

The northbound lane spans from Stuart Street to the intersection with Beacon Street. The southbound bike lane starts at the intersection with Beacon Street and comes to an end at the intersection of Stuart Street because of space limitations on the roadway. In order to make room for the bicycle facilities, the northbound lane from Columbus Avenue to Stuart Street would have to be reduced to one lane as well as eliminating parking along one side of the road. Also, the median along this stretch of road would have to be shifted over. These operations go beyond the scope of this report and therefore will not be included.

Section 1: Stuart Street to Huntington Street

The section of Dartmouth Street between Stuart Street and Huntington Avenue is consistently 73'in width (all widths are curb to curb) with traffic flowing in one direction towards the Charles River. Currently, the roadway is striped for five travel lanes and a parking lane on the right side of the road. Of these five, three are for thru traffic continuing on Dartmouth Street and two are for protected left turns to either Huntington Avenue, Bladgen Street or the I-90 on ramp.

This report proposes to re-stripe this section by adding a single bicycle lane heading towards the river on the right side of the road. Currently the rightmost lane is 16' in width. This report proposes to simply insert a 4' bicycle lane between the thru lane and the parking lane along with a 3' buffer between the parked cars and the bicycle lane. This configuration will narrow the thru lanes to 11'.

The design for Dartmouth Street North of Huntington Avenue calls for the bicycle facilities to be on the left hand side of the road. This was not possible on this block because of the configuration of the road along with the heavy turning traffic onto the I-90 on ramp.

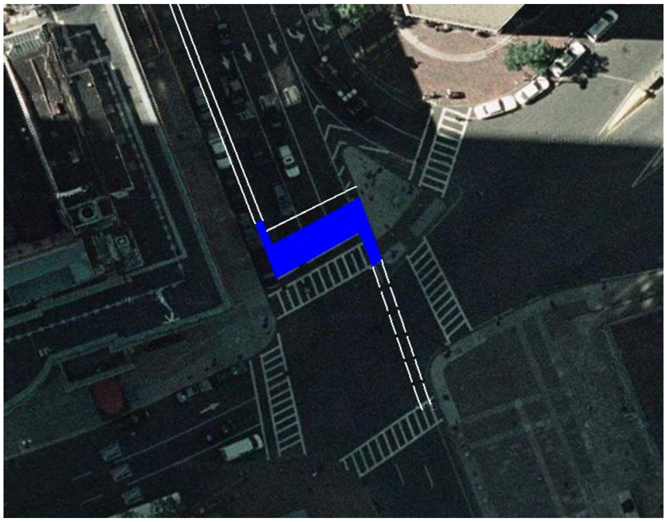
Figure 6.4: View of Intersection of Dartmouth Street at Huntington Avenue

Note the turning movement conflicting with bicycle lanes on the left hand side

The parking lane (shown above in blue) will remain unchanged as well as the left turn only lanes (red). The bulk of the modifications have to do with the three thru lanes (green).

Spokes is proposing marking a bicycle box at the intersection with Huntington Avenue. The main reason for this is because for the remainder of the street heading towards the river, the bicycle lane will transition from the right to the left side of the road. For this reason, it is advised that a bike box is installed to not only serve as a guide for cyclist approaching the intersection, but also as an aid for drivers to identify that there are potential cyclist nearby and to proceed with caution.

Figure 6.5: Rendering of Proposed Transition at Dartmouth and St. James Ave.
Note location of stop line to allow for better vision of cyclists



To accommodate the bike box, the stop line will be moved back 15'. This should have no significant on queue lengths since the difference is less than the length of an average vehicle.

Also, it is intended to have broken lines through the Huntington Avenue intersection again to serve not only as a guide for cyclist to follow the lane onto the next section of road, but also as protection for them.

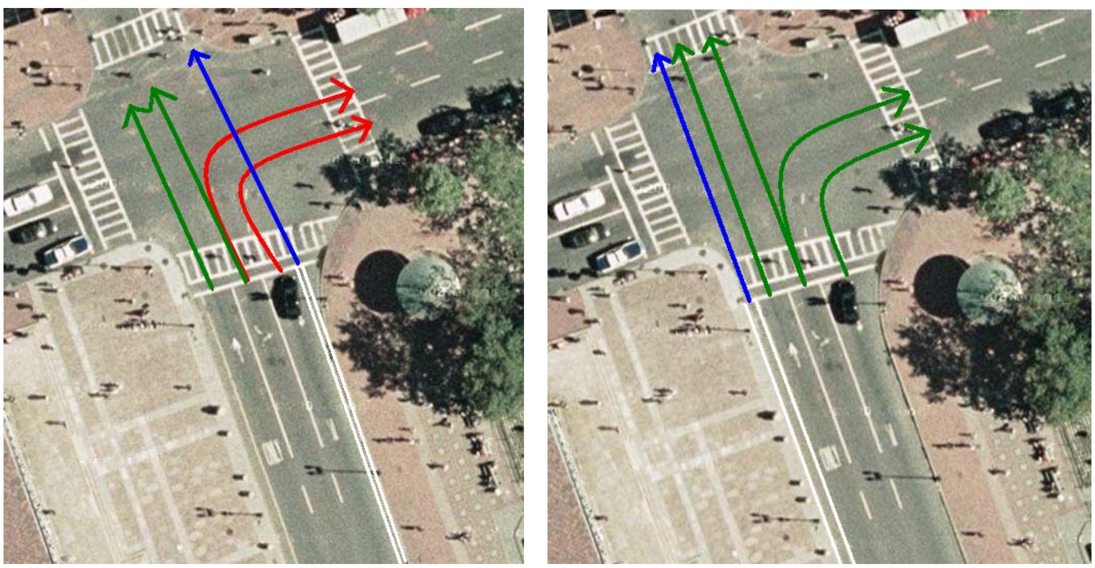
Cyclist will be able to safely transition from the right side of the road to the left while the approach has a red light. Also, this intersection has an all pedestrian phase that will allow cyclists to transition without any conflicts with vehicular traffic. For cyclist arriving at the intersection while the approach has a green light, they can either stop to wait for one of the two scenarios stated above, or transition from one side to the other when they see fit as they would when transitioning to make a left turn at any other intersection. See Plans for a complete striping plan of this option.

Section 2: Huntington Avenue to Boylston Street

The section of Dartmouth Street between Huntington Avenue and Copley Square is consistently 42' in width with traffic flowing in one direction towards the Charles River. Currently, the roadway is striped for three travel lanes and a narrow shoulder on the left side of the road with no parking permitted.

The proposed design includes a pair of bicycle lanes on the left side of the road and three travel lanes. Although it is conventional to find bike lanes on the right hand side of the road, it was determined that a left side bike lane is an excellent option (See Figure 6.6). Allowing the bike lanes to be on the left takes care of the hazard presented by the heavy right turn traffic onto Boylston Street. During the AM peak hour, there were 305 right turns made at this intersection. Having the bike lane on the left also allows cyclists to essentially travel on the same phase as vehicles. Essentially it would be equivalent to adding a third through lane and thus avoiding the risk of collisions.

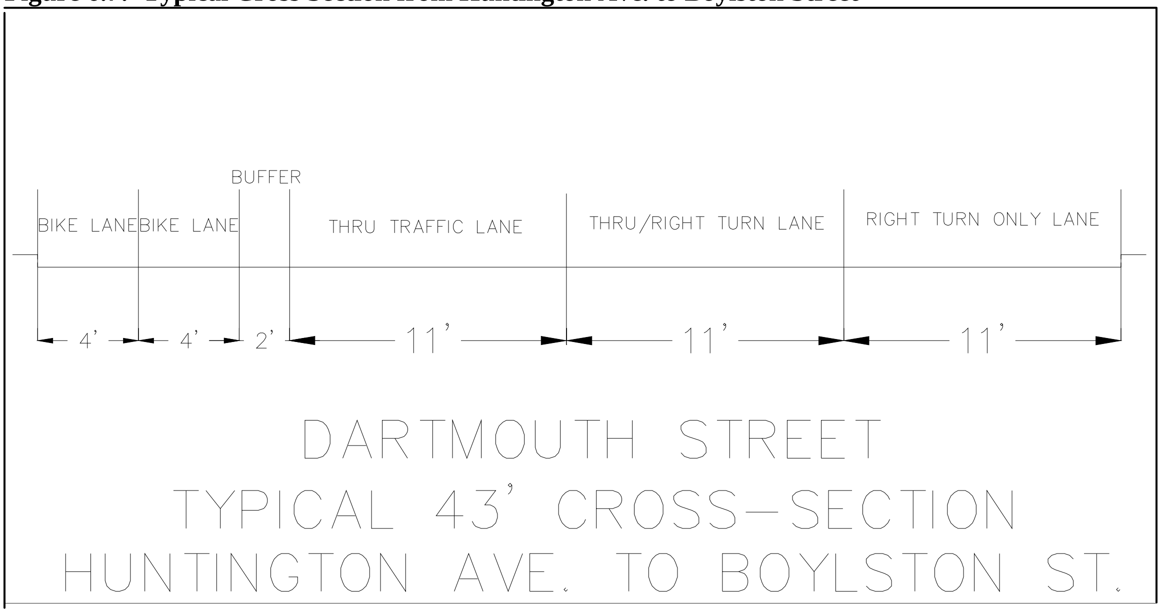
Figure 6.6: Conflict Comparison - Intersection of Dartmouth Street and Boylston Street
Note the conflict between the right turning traffic and the bike lane located on the right hand side of the road



Right Turn Conflict with Bikes — No Conflict with Bikes

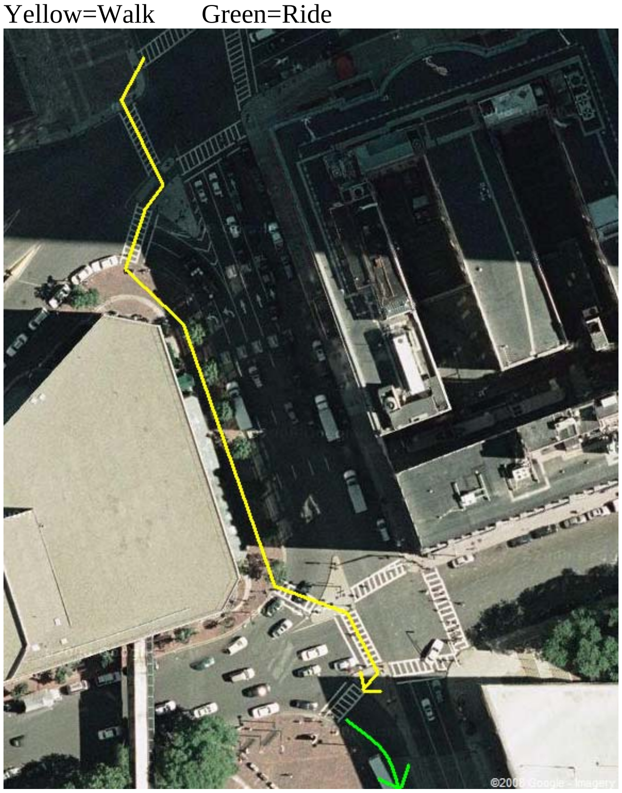
In order to make room on this roadway for double bike lanes and a 2' buffer, the traffic lanes will be reduced to 11'. It is intended to use the 4' shoulder on the left hand side of the road as the bike lane traveling away from the river towards Huntington Avenue thus having a total of 8' for a two way bicycle lane (See Figure 6.7)

Figure 6.7: Typical Cross Section from Huntington Ave. to Boylston Street



Due to the complexity of the intersection of Dartmouth Street and Huntington Avenue, the bike lane traveling away from the river ends at Huntington Avenue. A sign reading "Bike Lane Ends" will be installed at the intersection. At this point a rider is expected to become a pedestrian and follow the rules of pedestrians on the road to get across this intersection. From there a cyclist can either turn onto Huntington Avenue and share the road with vehicular traffic, or walk south along Dartmouth Street for 250 feet until Dartmouth Street becomes a two way road, as shown in Fig. 6.8. At this point a rider can again simply join vehicular traffic. In the long term, a complete redesign of this section including curb and traffic changes need to take place in order to continue the southbound lane. Unfortunately this goes beyond the scope of this report.

Figure 6.8: Walking Path for Cyclist Traveling Away From River
Yellow=Walk Green=Ride



Section 3: Boylston Street to Beacon Street

Introduction

This report proposes a drastic change to the geometry of this section of Dartmouth Street. Right now, with the exception of the area affected by the T stop, the road houses two lanes of parallel parking. We believe a more efficient set up for Dartmouth Street would be to implement the use of Reverse Angle Parking along the right side of the road and getting rid of parallel parking from Boylston Street to Commonwealth Avenue. Although Reverse angle parking requires a lot more space along the width of the road, it is a far more efficient way to house vehicles. Also, by reducing Dartmouth Street to one lane from Commonwealth Avenue to Beacon Street, a separated bike path is attainable and being proposed.

Boylston Street to Commonwealth Avenue

The cross section in this section changes near the entrance from Boylston Street. This is because the Copley T station is located at the intersection of Dartmouth Street and Boylston Street. Due to the extra space needed to house this facility, the right curb bulbs out extending into the parking lane.

Currently, it is striped for two lanes and a parking lane on the left side. This section has a 35 foot wide curb to curb width. This cross section only applies to approximately the first 90’ of road. From there the cross section widens and the roadway becomes 44’ in width with parking on both sides.

As stated previously, this report proposes to eliminate the left side parking lane and incorporate reverse-angle parking on the right side of the road on the stretch between Boylston Street and Commonwealth Avenue to make room for a pair of 5’ bike lanes and a 1’ buffer on the left hand side of the road. The following table shows the efficiency of this style of parking:

Table 6.1: Parking Efficiency Comparison – note the difference in ft^2/stall in each scenario

Current Conditions (parallel parking both sides)				Alternative (parallel parking right side)				Proposed Conditions (reverse angle parking)			
Number of Stalls	Stall Width	Stall Length	ft^2/stall	Number of Stalls	Stall Width	Stall Length	ft^2/stall	Number of Stalls	Stall Width	Stall Length	ft^2/stall
35	8'	22'	176	17	8'	22'	176	20	9.5'	15'	142.5

One can see from the table above that it requires a lot less space to accommodate a vehicle in this arrangement than it does through parallel parking. Also note that 57% of the current parking available in this stretch was able to be accommodated on one side of the road.

Efficiency is not the only reason reverse-angle parking is so attractive to urban settings. Reverse angle parking is also an easier maneuver to perform for a driver. The table below depicts the actions a driver must perform when parallel parking and when reverse-angle parking:

Steps	Parallel Parking	Reverse Angle Parking
1	Pull past desired stall	Pull past desired stall
2	Reverse into stall on angle	Reverse into stall on angle
3	Pull forward and turn wheel to straighten parallel to curb	

Table 6.2: Parking Maneuver Steps – note R-A parking has one less step

Because parallel parking requires an extra maneuver to successfully enter a stall, it requires more space than reverse-angle parking for the driver to have ample room to park his vehicle. Reverse angle parking is easier than backing into a stall at the grocery stall or into one's own driveway because the angle allows the driver to fully see the stall sooner than one would if the stalls were perpendicular to the road. Not only is it easier for drivers, it is also safer and faster since one is facing the road when pulling out and can see oncoming traffic from a distance, allowing a driver to enter traffic flow much faster(see image below). Cities such as Seattle, Washington D.C, and Montréal have implemented reverse angle parking with great success.

Figure 6.9: View from Parked Vehicle – note driver sight distance

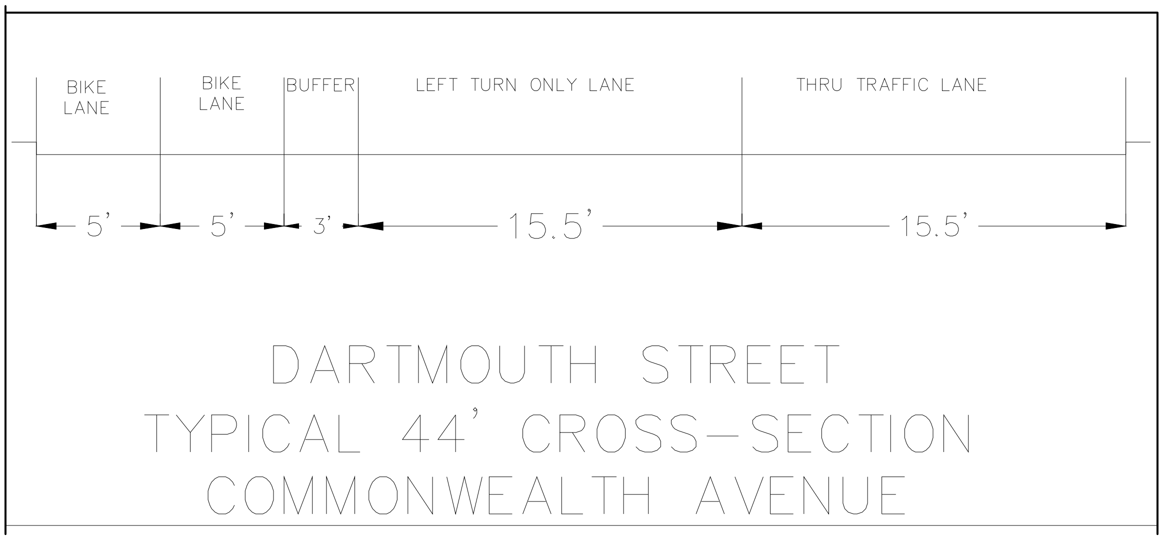
Although space is utilized more efficiently with this arrangement, it is not always the case that one can increase the number of stalls available. The system becomes less efficient the more intersections there are in the stretch of road. For this reason only 20 of the 35 spaces currently available between Boylston Street and Commonwealth Avenue were able to be accommodated on the right side of the road. It is up to the City of Boston to decide if they are willing to sacrifice 15 parking stalls along Dartmouth Street for a little over a half mile of bicycle lanes.

Figure 6.10: Rendition of R-A parking at bulbout at Dartmouth St. and Boylston St.
note cross section changes from 35' to 44'

Commonwealth Avenue East Bound to Commonwealth Avenue West Bound

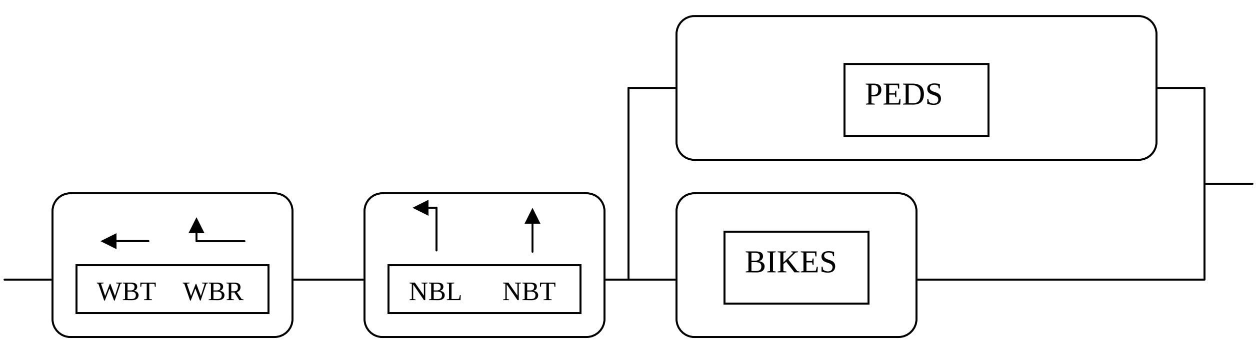
This section of road will be striped for two 15.5' lanes. The left lane will be a left turn only lane for vehicles making left turns onto Commonwealth Avenue. The right lane will be for through traffic only. This configuration allows for a pair of 5' bike lanes and a 3' buffer on the left hand side of the road.

Figure 6.11: Cross Section of area between Comm. Ave. WB and EB



Currently, the intersection of Commonwealth Avenue west bound and Dartmouth has a 3 phase system, the third being a button actuated pedestrian crossing that conflicts with the left turn traffic from Dartmouth Street. To avoid a conflict between left turning traffic and cyclists wishing to continue through the intersection, this report proposes to maintain the button actuated pedestrian phase but also add a fourth automatic 10 second bicycle phase with a bicycle signal head.

Figure 6.12: Timing Plan for Comm. Ave WB at Dartmouth



Commonwealth Avenue West Bound to Beacon Street

Traffic counts were performed from 5:00 pm to 6:00 pm at the intersection of Dartmouth Street and Commonwealth Avenue to examine traffic volumes and determine if Dartmouth Street could be reduced to a single lane from Commonwealth WB to Beacon Street.

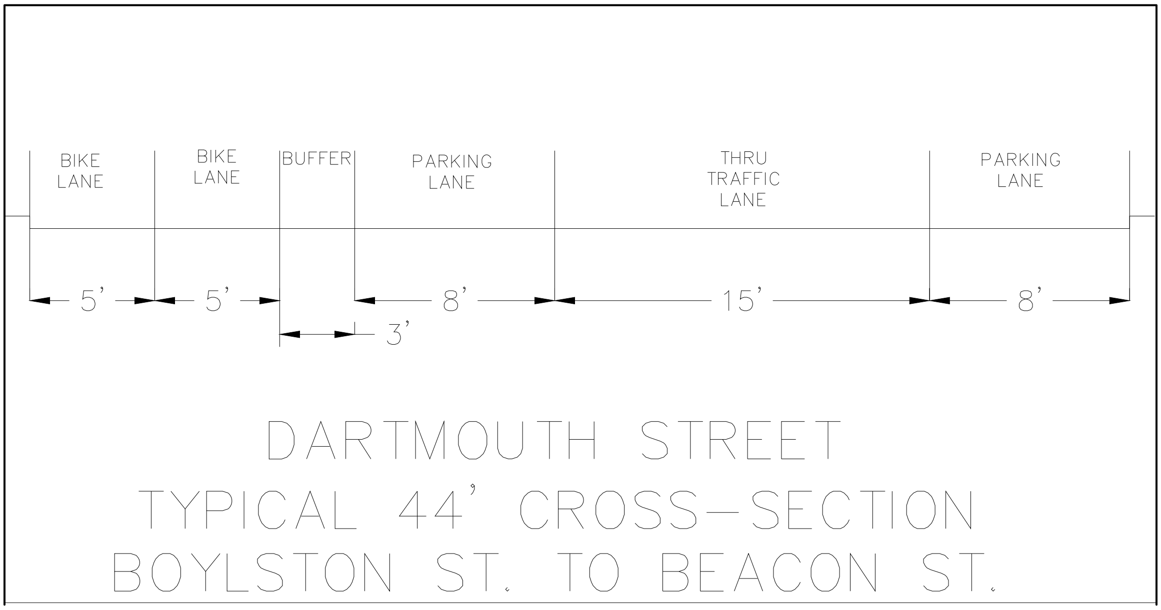
Table 6.3: Traffic Count on Dartmouth St. at Comm. Ave. WB

Comm. Ave. 5:00-5:15 pm			Comm. Ave. 5:15-5:30 pm			Dartmouth Street 5:00-5:15			Dartmouth Street 5:15-5:30 pm		
Cycle	WBR	WBT	Cycle	WBR	WBT	Cycle	NBT	NBL	Cycle	NBT	NBL
1	0	8	1	0	17	1	7	7	1	14	4
2	2	13	2	1	19	2	6	6	2	7	13
3	0	10	3	0	14	3	8	6	3	8	6
4	1	5	4	3	15	4	9	5	4	5	6
5	1	13	5	3	18	5	9	5	5	3	7
6	0	15	6	0	24	6	8	4	6	7	3
7	1	19	7	3	19	7	10	7	7	9	10
8	0	11	8	1	15	8	6	10	8	5	4
9	0	12	9	1	15	9	10	5	9	10	3
Total	5	106	**Total**	12	156	**Total**	73	55	**Total**	54	52
Comm. Ave. 5:30-5:45 pm			**Comm. Ave. 5:45-6:00 pm**			**Dartmouth Street 5:30-5:45 pm**			**Dartmouth Street 5:45-6:00 pm**		
Cycle	WBR	WBT	Cycle	WBR	WBT	Cycle	NBT	NBL	Cycle	NBT	NBL
1	2	13	1	1	25	1	5	5	1	10	6
2	2	15	2	3	16	2	12	11	2	8	8
3	2	16	3	1	17	3	9	5	3	11	6
4	0	20	4	0	12	4	16	7	4	8	6
5	1	13	5	0	13	5	12	3	5	14	5
6	0	17	6	0	12	6	9	9	6	7	7
7	1	9	7	1	15	7	10	9	7	6	7
8	1	21	8	1	9	8	9	6	8	8	3
9	0	13	9	3	19	9	11	3	9	9	6
Total	9	137	**Total**	10	138	**Total**	88	53	**Total**	81	54

This study shows that at the pm peak hour on April 3, 2008 an average of 10 vehicles entered the section of Dartmouth Street after the Commonwealth Avenue intersection. This was from both Commonwealth Avenue right turn traffic as well as through traffic from Dartmouth. The data also shows that the most cars entering this section during any one cycle was 16 vehicles. As long as vehicles have a green wave through Marlborough Street, a single lane of traffic can handle this volume.

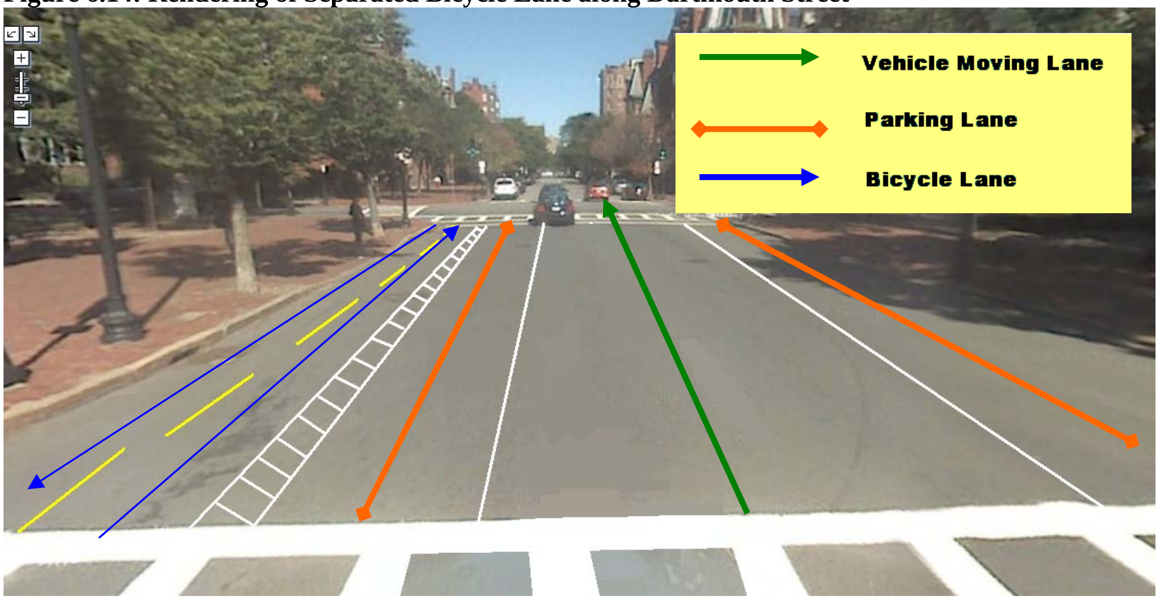
A single 15’ traffic lane yields enough space for a pair of 5’ bike lanes on the left side, a 3’ buffer, and two 8’ parking lanes. The figure below shows a typical cross section on this stretch of road.

Figure 6.13: Typical Cross Section between Comm. Ave WB and Beacon St.



Locating the parking between the travel lane and the bicycle lanes creates a separation between riders and vehicular traffic. New York City has had success in creating this type of facilities along 9th Avenue from 23rd to 16th street.

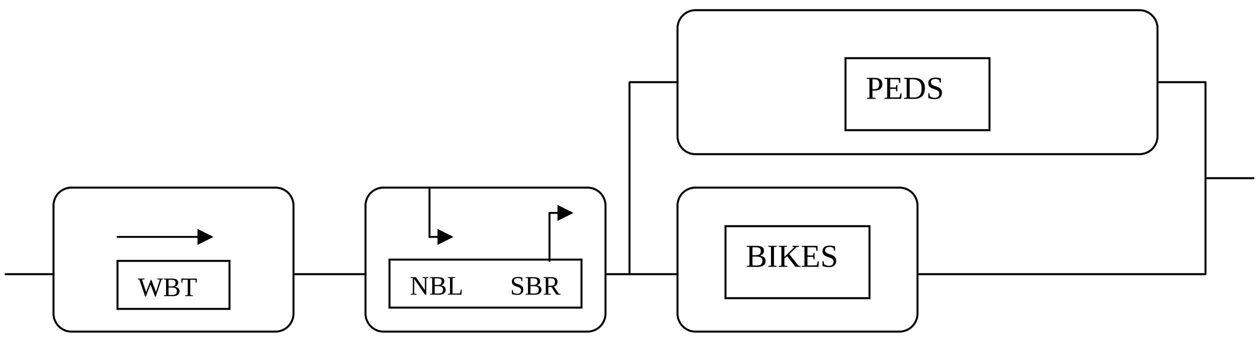
Figure 6.14: Rendering of Separated Bicycle Lane along Dartmouth Street



Intersection of Dartmouth Street at Beacon Street

Currently the intersection of Beacon Street at Dartmouth Street has a three phase cycle: Dartmouth Street left turn traffic and pedestrians crossing Beacon Street on the non conflicting side followed by Beacon Street thru traffic and pedestrians crossing Dartmouth Street. Currently pedestrians crossing Beacon Street conflicting with the left turn traffic from Dartmouth have a button operated signal that inserts a pedestrian phase between the two original phases. To avoid a conflict between left turning traffic and cyclists wishing to continue through the intersection, this report proposes to maintain the button actuated pedestrian phase but also add a fourth automatic 10 second bicycle phase with a bike light. This will provide cyclist with a phase to cross Beacon Street and continue on to Back Street without conflict with vehicular traffic.

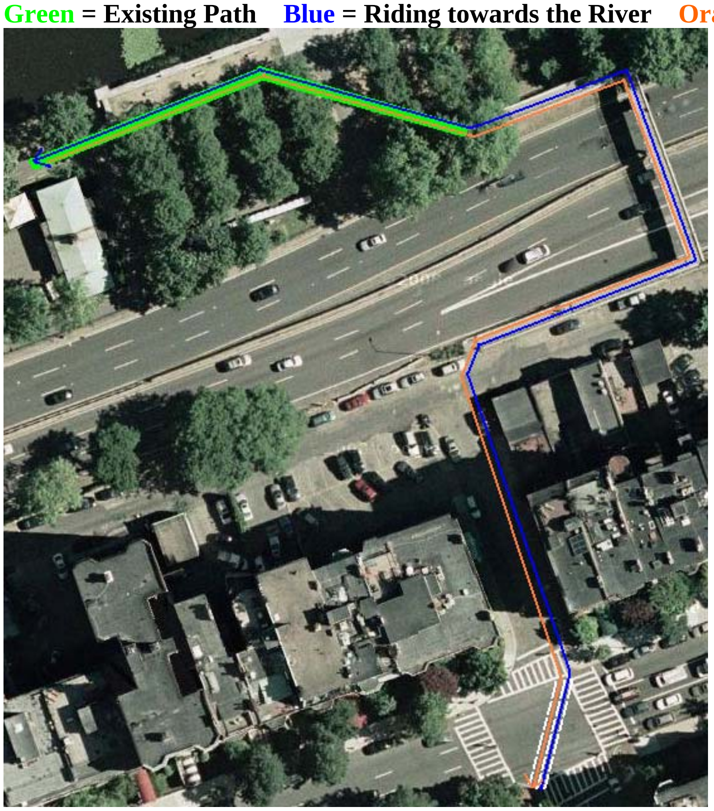
Figure 6.15: Timing Plan for Dartmouth Street at Beacon Street



Section 4: Entrance to Esplanade through Back Street

This stretch of road is crucial to the importance of the entire bicycle facility. It provides riders with access to the pedestrian bridge crossing Storrow Drive which in turn provides cyclist with access to the Charles River bike path, an already existing bicycle facility in Boston.

Figure 6.16: Entrance to Esplanade
Green = Existing Path Blue = Riding towards the River Orange = Riding away from river



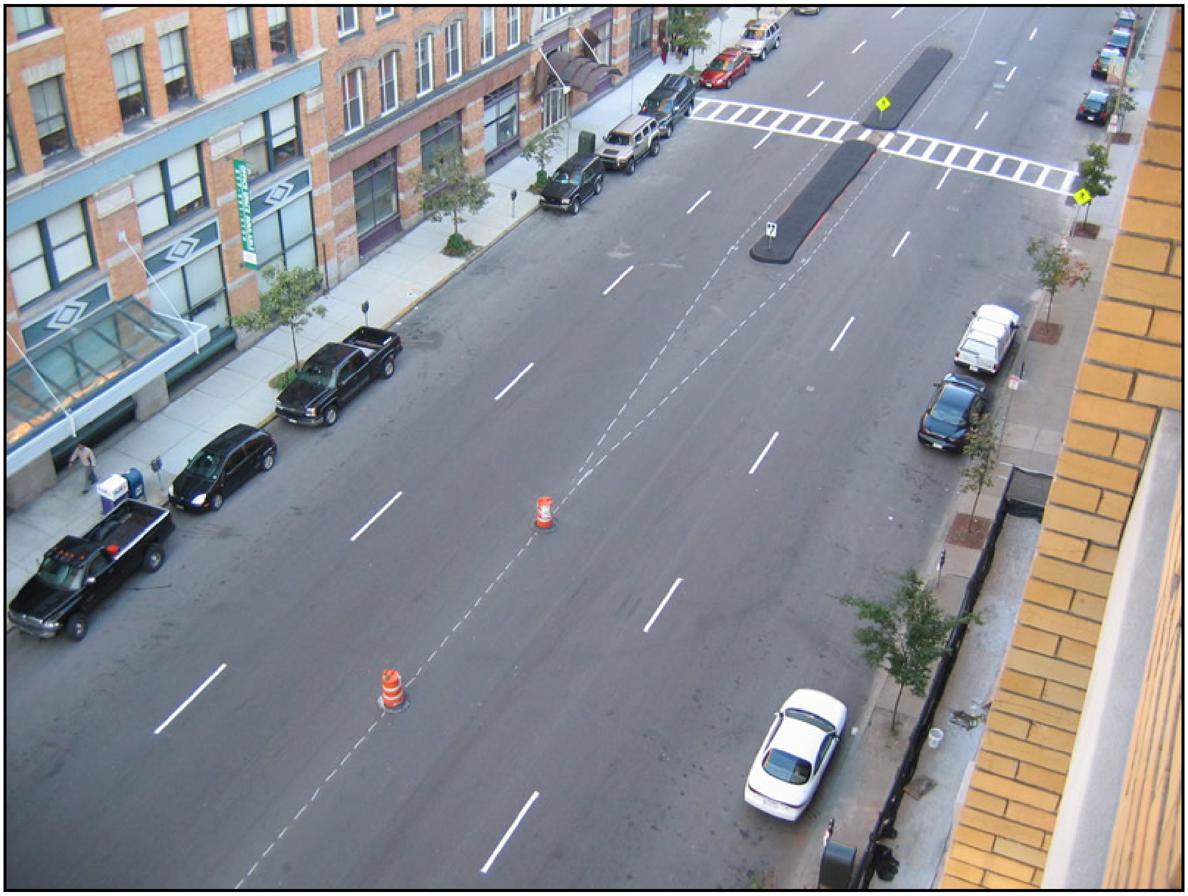
This report is proposing to mark the bike lane though the intersection of Beacon Street with dashed lines to show cyclists where to go and also provide vehicular traffic with a visual of the lanes and make them aware of bicycle presence.

Figure 6.17: Rendering of Beacon Street at Dartmouth Street – note the dashed markings

The entrance to Back Street across from Dartmouth Street is a one way street with traffic flowing away from the Charles River. The roadway is 26’ wide with a parking lane on either side leaving 10’ for one traffic lane. Rather than eliminating one lane of parking to accommodate a two way bicycle lane this report suggests the cross section be left as it is. This means cyclist will have to travel with traffic going away from the river, and contra flow going towards the river. Since this is such a short section, less than one city block, and traffic from Back Street onto Beacon Street is minimal, this report finds this street to fit the criteria established by the City of Brussels, Belgium regarding intermittently marked contra flow lanes.

Figure 6.18: Rendering of intermittently marked lane

VII. Summer St. and L St. - Dorchester Ave. to William J. Day Blvd.



Source: <http://www.livablestreets.info/files/28sep06_summerstreet.JPG>.

Introduction

South Boston is a densely populated area with many family oriented neighborhoods. It has limited parking, many lower income residents and is located close to Boston, but just out of walking distance, making the use of bicycles an ideal transportation alternative.

Unfortunately, South Boston only has one existing bicycle path, the Harbor Walk, along its southern shore. It is located off-street separate from traffic and can be seen in the figure below.

Figure 7.1: Proposed Bicycle Lane Site and Existing Bicycle Path

Summer and L Street's were chosen for several reasons. The first being they connect the center of the eastern half of South Boston with downtown, with connections at Fort Point Channel to the anticipated South Bay Harbor Trail. While the Harbor Walk Trail on the south shore is nice, it does not provide any connections of real interest, but the proposed bicycle lane site will connect with several major destinations. And finally, the combination of existing and proposed will create a good foundation for future bicycle facilities.

In this chapter of the report, the route along Summer and L Streets is presented and discussed.

Section A: Dorchester Ave. to Melcher St.

The first section of bicycle lanes is located on the Summer Street Bridge. The design here is straightforward. There is no parking on either side and in both directions the design calls for 11' travel lanes and 6' bicycle lanes. The reason for the wider 6' bicycle lanes is that east of the intersection at Melcher St. there is parking. Parking occupies 8' of space from the curb, and so to ease the transition from no parking to parking the bicycle lanes were simply widened. Also, the transition from no parking to parking is marked solid blue through the intersection. The design for this section can be seen below in Figure 7.2.

Figure 7.2: Dorchester Ave to Melcher Street

Section B: Melcher St. to West Side Dr.

Melcher St. to West Side Dr. poses several complications. There is parking on both sides, a median for protected pedestrian crossing, and then a dividing median for traffic towards the eastern end where parking ends on the south side.

From Melcher Street to the protected pedestrian median- After the Melcher Street intersection parking begins. Parking (8') and a bicycle lane (5') combine for a total width of 13'. The remainder of the road width is then equally given to the travel lanes. The travel lanes start at an approximate width of 12'6'', but then being to narrow 50' west of the median, to 10'6'' as the median steals away road width as shown in the figure below.

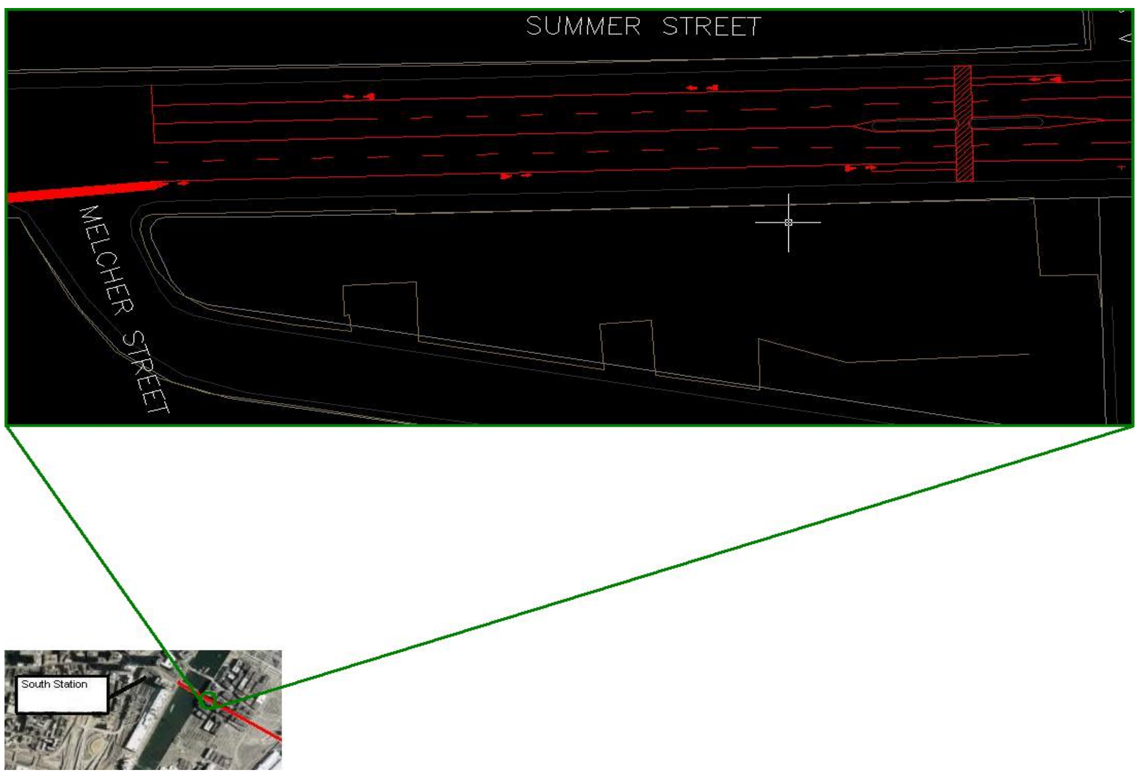


Figure 7.3: Melcher Street to pedestrian median

Also at the median, there is an existing section of no parking on either side as to allow a safety buffer for motorists to see crossing pedestrians. The proposed bicycle lane will continue on its alignment as parking is again continued shortly after.

Pedestrian median to introduction of divided vehicular median- Again, the combined width of parking and bicycle lane will be 13'. For the ease of striping between these medians, the lanes closest to the bicycle lanes will be marked as 11'. The lanes closest to the center line will widen, but then all lanes meet at the beginning of the vehicular median and have uniform widths of 11' as shown in the figure on the following page.

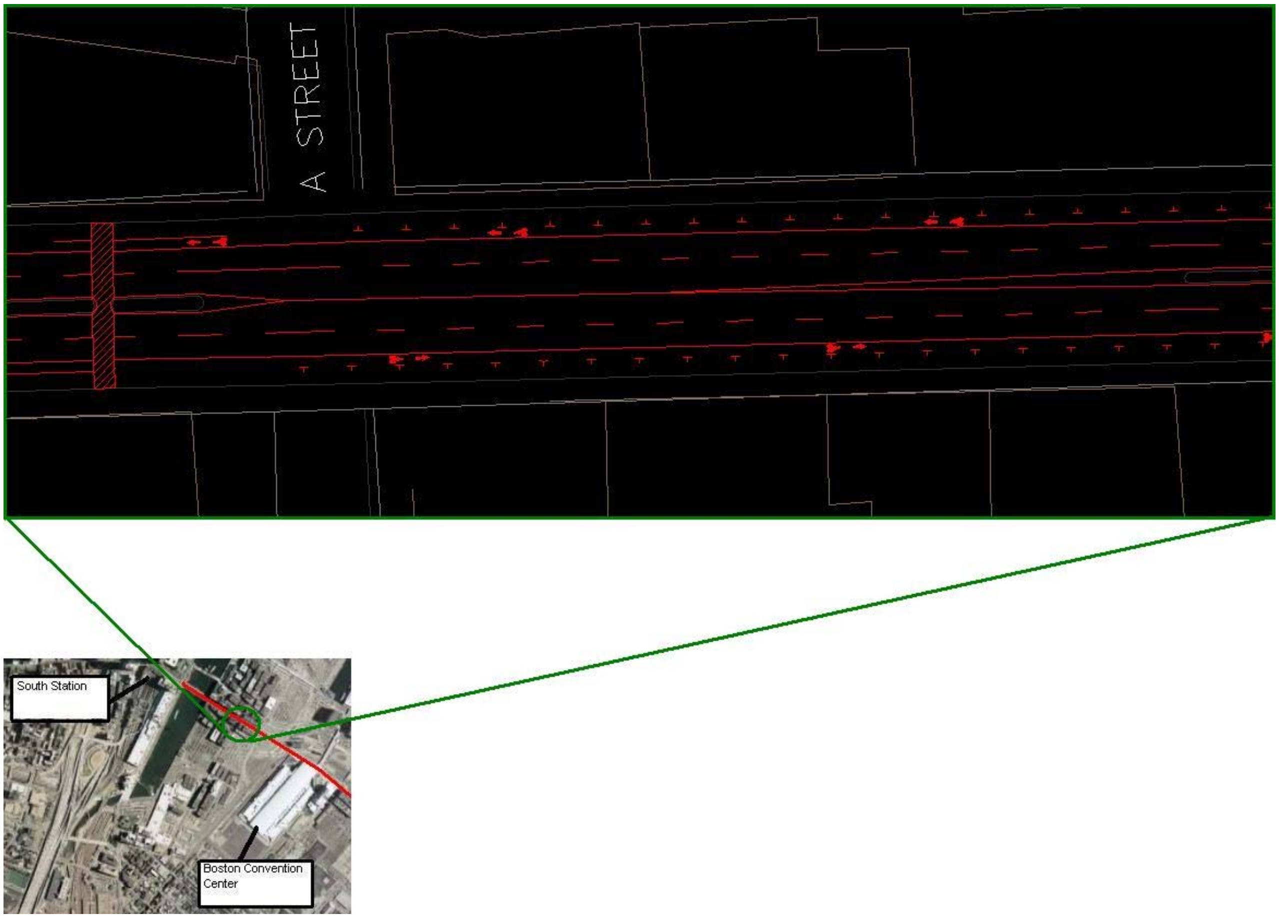


Figure 7.4: Pedestrian median to vehicular median

Beginning of divided median to West Side Dr- The figure for this section can be found on the following page in Figure 7.5. Westbound lanes will have uniform widths of 11' and a combined width of parking and bicycle lane at 13'. On the eastbound side the lane widths will continue at 11' from the beginning of the vehicular median and widen to 12' at the dividing line separating the two lanes before the intersection. They will remain 12' to the intersection of West Side Dr.

On the eastbound side, the parking lane becomes a cabstand area that serves as a storage buffer for the Boston Convention center. The bicycle lane alignment will require the cabstand parking lane to be marked solid white as apposed to the existing parking T's. The cabstand area extents approximately 200' eastward from the final "T" and will not be impacted by the proposed bicycle lane. However, at then end of the cabstand lane, the width has been reduced to 6'4'', which is acceptable because cabbies here rarely open their doors. The bicycle lane, through the intersection, will be striped dotted white. It will not be solid blue as there are rarely right turns onto West Side Drive.

Figure 7.5: Vehicular median to West Side Dr.

Section C: West Side Dr. to World Trade Center Ave.

West Side Dr. to World Trade Center Ave. is the section that houses the Boston Convention Center. Westbound has limited width. In order to fit two travel lanes, a bicycle lane and parking, widths of 10’, 5’ and 7’ 6’’ were given respectively. It should be acceptable to reduce the parking lane by ½’ because the combined 12’6’’ for parking and bicycle lane still provides adequate protection against dooring. The smaller travel lane width of 10’ next to a bicycle lane should be acceptable as it provides adequate operational space, as explained in Chapter 3.

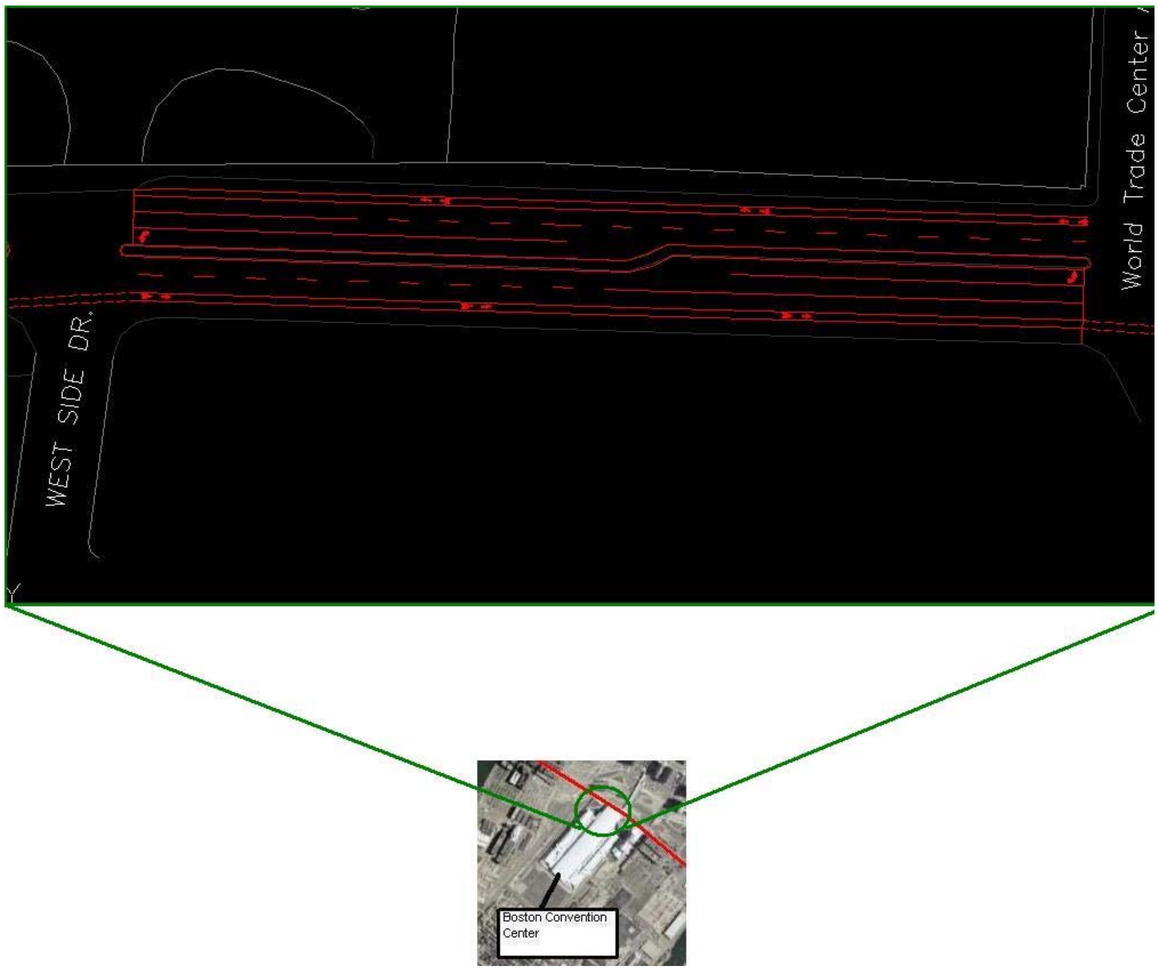


Figure 7.6: West Side Dr. to World Trade Center Ave.

At the intersection of West Side Dr. on the westbound side the bicycle lane is narrowed to 4’ where the sidewalk bulbs out and there is no parking, as shown in Figure 7.6. With no gutter pan and no risk of “dooring” from parked cars, 4’ is an adequate bicycle lane width. On the following page in Figure 7.7, a diagram of the gutter pan is shown.

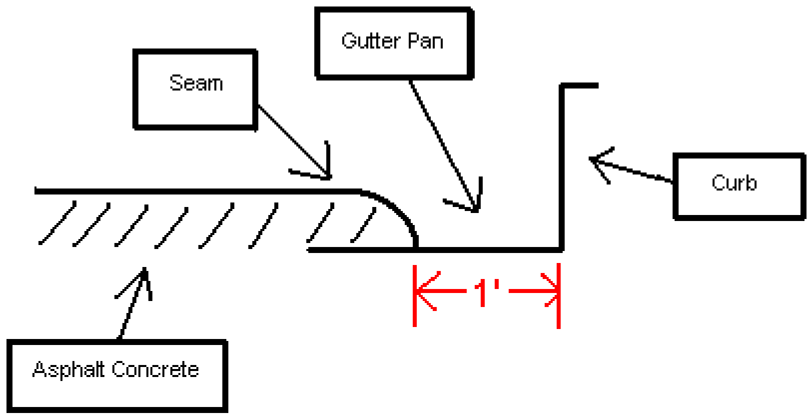


Figure 7.7: Gutter Pan

The eastbound side has travel lanes of width 11', a bicycle lane of width 5' and cab stand lane of 10'. The left turn lane will be of width 10'. The bicycle lane will again be striped dotted white, through the intersection, as it transitions back to the curb following the World Trade Center Ave. intersection.

Section D: World Trade Center Ave. to D. St.

World Trade Center Ave to D. St is straightforward. Lane widths will start out as 11' on both sides at and then narrow to 10'6'' at the approaching intersections. There is only parking on the westbound side, but both sides remain symmetrical. The left turn lanes will vary in width on the westbound and eastbound sides at 10'6'' and 10', respectively.

The eastbound side does not have parking for security reasons; however, the bicycle lane will not hug the curb, but it will continue along side the travel lane in order to avoid upstream and downstream transitions.

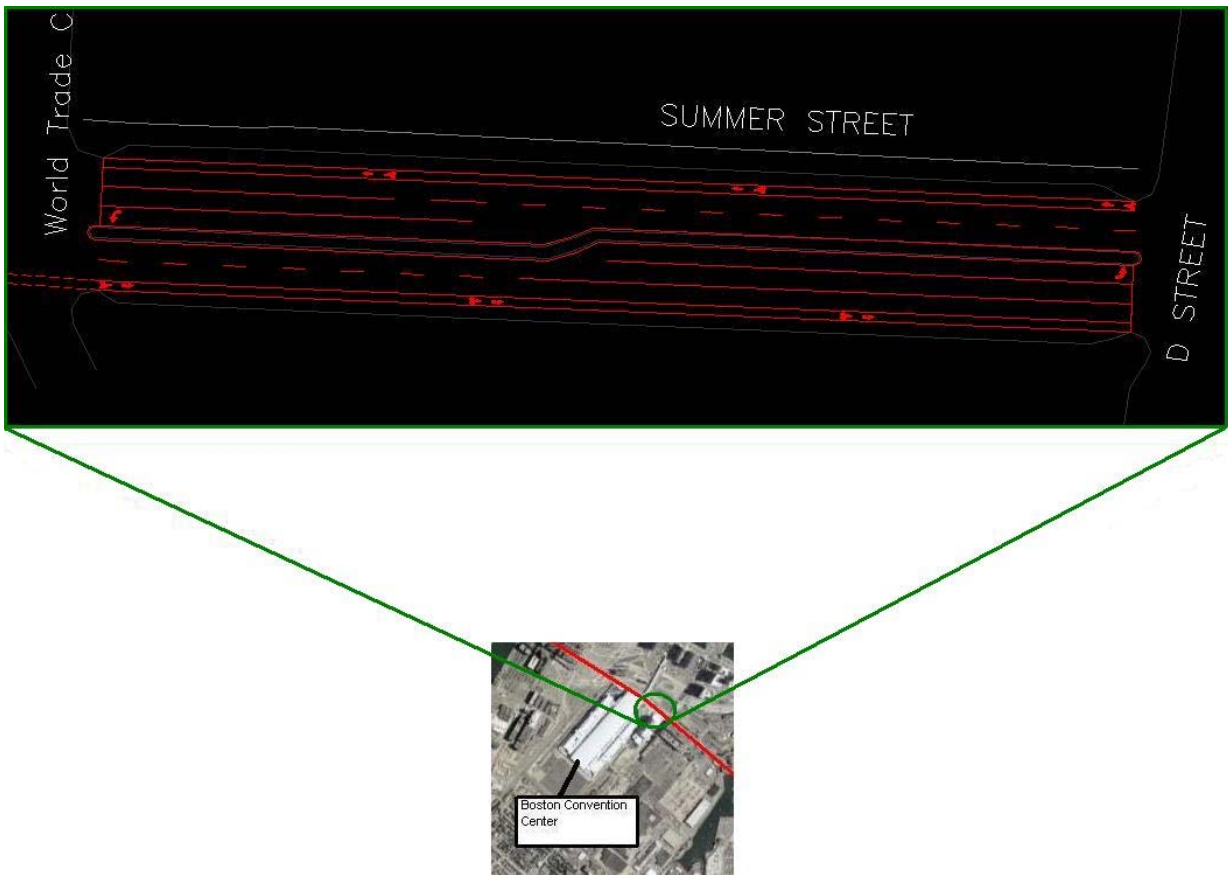


Figure 7.8: World Trade Center Ave to D St.

Section E: D St. to Pumphouse Rd.

D St. to Pumphouse Rd. poses one of the two most difficult design aspects of Summer St, a right turn lane on the westbound side.

Westbound

The westbound side approaching D St. has an existing third lane that turns into a designated right turn lane. Right turn lanes have the utmost importance in designing bicycle lanes because ambiguity exists between motorists making right turns and cyclists going straight. In this section, cyclists going thru have to move left and pass through between two medians, one designed for the right turn lane. Existing conditions provide three lanes, one that becomes a right turn lane. There are many design solutions for this type of conflict, but by eliminating the right turn lane and moving the conflict upstream, the right turn lane becomes an added lane, thus the right of way is unambiguous. Right turn cars must merge across the bicycle lane, yielding to bicycles, to get into the added right turn lane, but where lanes simply became right turn lanes, bicycles would be forced to merge across. This stressful situation should be avoided wherever possible. Also, long right turn lanes should be avoided because during lower traffic periods because they put the bicycle lane between two fast moving lanes of traffic. The design, in Figure 7.9 shown below, addresses all of these issues.

Figure 7.9: D St. to Pumphouse Rd.

A turn count was conducted to see whether a right turn lane is needed. The data is show below in Table 7.1.

Table 7.1: World Trade Center Ave. Turn Count 8:30-8:45am 4/14/08			
	Right Turn Lane	Thru Lane	Thru Lane
Total Vehs	63	39	33
Hourly Vehs	252	156	132

This data shows that the proposed two lanes will be sufficient to containing the volume of vehicles observed. Of the 540 vehicle in the westbound lanes, approximately 47% of the vehicles are turning right. This means, on average, that a car will make a right hand turn every 14.3 seconds. The percentage may seem deceiving, but the total volume is low, leading to the conclusion, that in fact, a right turn lane is not needed, and the proposed design is adequate.

The westbound travel lanes approaching D St. will have a uniform width of 10'4''. The bicycle lane is well off the curb in this design for the approaching intersection at D St. It is general knowledge that turning traffic, whether bicycle or motorist, must yield to traffic going straight. In this case, the cyclist is going straight, which let motorists know they must yield.

The bicycle lane will be positioned approximately 8' off the curb with a hatched out section of no-travel for motorists, with the exception of a bus stop. An 80' transition section is provided for motorists to make an "S" maneuver into the right hand turn lane, which is an alternating hatched, no hatch section, of the bicycle lane. An S maneuver ensures that a vehicle will travel at 25mph or less as it enters the turn lane. Following the transition section, the bicycle lane is marked solid blue beginning 200' from the intersection.

Instituting parking or a cab stand to take up this marked out no-travel space may be an option; however, there is a government building across the street that might make this impossible due to security issues.

A proposed 5' bicycle lane will be next to the marked out no-travel out area and will begin reducing to 4' at the beginning of the motorists' S maneuver transition. The reduction will coincide with the vehicular transition of 80'. The left edge of the bicycle lane will remain straight so motorists do not think cyclists are turning. The reason for the bicycle lane width reduction is because of the curb to curb distance of 25' at the D. St. intersection between the medians.

The transition point also takes into account the right turn signal, allowing space for eight cars to queue up and wait for the light without blocking the bicycle lane transiting point. The data shows that during a typical cycle of 90 seconds, if the average car arrives at 14.3 second intervals, that 7 cars will be queued, and if each car takes up 25', then the necessary distance to prevent blockage of the bicycle lane is 175'. The design calls for a storage buffer of approximately 191', adequate for needed queue.

Eastbound

The eastbound side is straightforward with a 6' bicycle lane next to the curb and providing 14' travel lanes in the beginning, narrowing to 13' travel lanes and a 5' bicycle lane approaching Pumphouse Rd.

Section F: Pumphouse Rd. to Drydock Ave.

This section also has a right turn lanes that required extra investigation. Eastbound and Westbound will be discussed separately. Below in Figure 7.10 is the proposed design for this section.

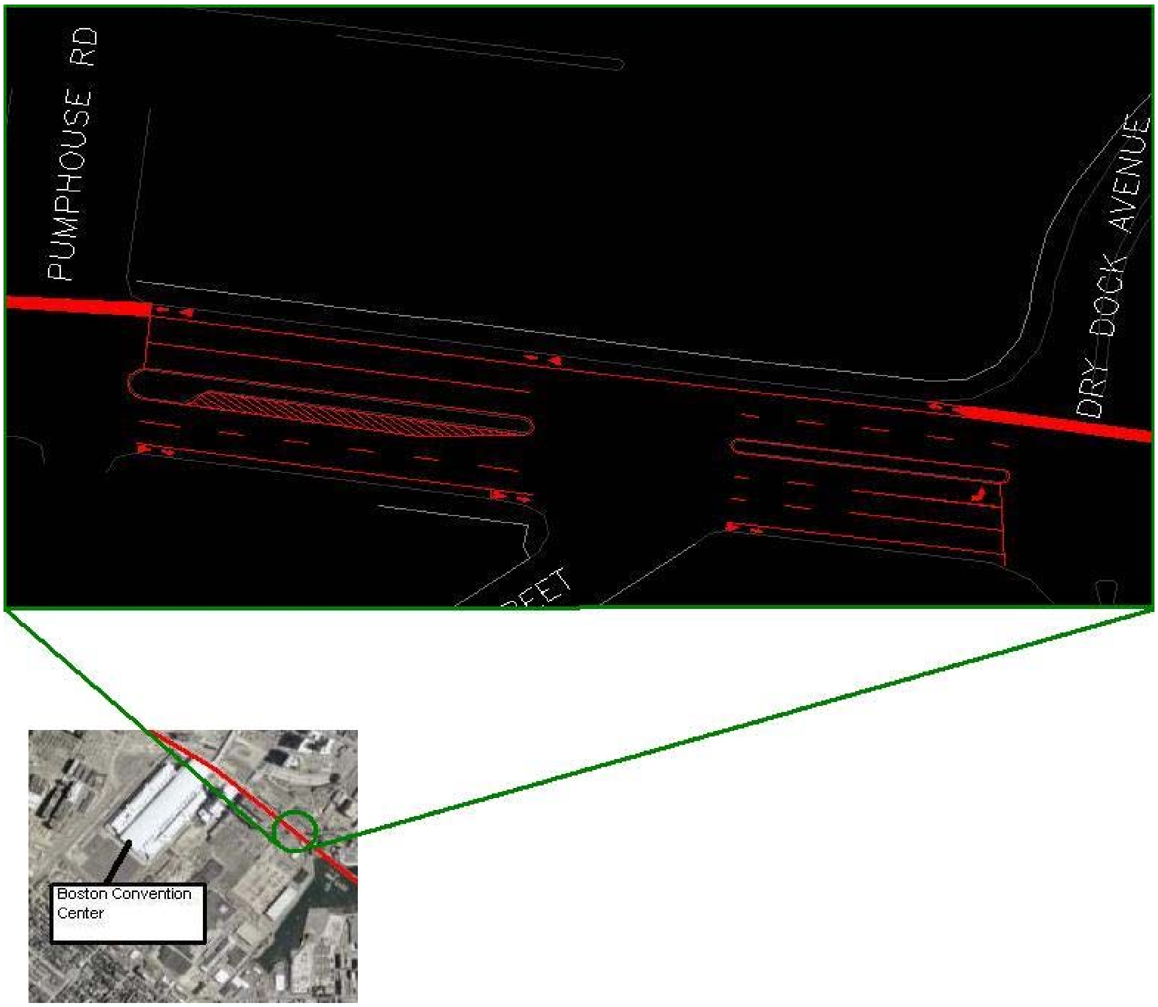


Figure 7.10: Pumphouse Rd. to Drydock Ave.

Eastbound

The proposed eastbound side begins with two uniform travel lanes at 11’5’’ and a bicycle lane at 5’, at Pumphouse Rd. An existing third lane will be hatched out as no-travel to keep the two travel lanes uniform. It was observed that the left turn lane marked at the intersection of Drydock Ave. will not experience any capacity loss as only a few cars were seen making left hand turns onto Drydock Ave. At the intersection of Drydock Ave. the lane widths will all be 12’. The unnecessary right hand turn/through signage will be removed in the right lane. A turn count was not performed for right turns eastbound as very few cars were observed during other data collection.

Westbound

Westbound starts out as a two lane section, but then switched to three lanes (two thru and a thru/ right lane). To remain congruent with the upstream section where the turn lane was reduced, the design calls for a lane drop. A turning movement count was performed at this intersection to analyze two things; right hand turns onto Pumphouse Rd, and queue building towards Drydock Ave. The data collected is shown in Table 7.2 below.

Table 7.2: Pumphouse Rd and Summer St Turning Movements 7:25-8:25am 3/27/08										
	WBR	WBT	WBT	WBT	EBT	EBT	EBL	SBR	SBL	SBL
7:25-7:40	51	36	83	28	48	41	6	4	4	12
7:40:-7:55	60	39	91	26	50	65	5	5	7	17
7:55-8:10	56	46	74	41	50	62	3	4	6	4
8:10-8:25	55	34	97	34	51	57	1	6	3	5
TOTALS	**222**	155	345	129	199	225	**15**	**19**	20	38
			629		**424**				**58**	

The highlighted data shows the data used to determine if a right hand turn lane was needed. The data shows only 27% of the total volume is turning right and that a car, on average, turns right ever 16.3 seconds. Though this justifies that a right turn lane is not needed, it does not, however, justify the lane drop. The use of Synchro 5 was required for further analysis of this issue for the proposed conditions.

Synchro 5 was used to analyze estimated volume/capacity ratio, delay, queue length, and level of service for each approach, assuming a cycle length of 120 seconds. The data for each approach is shown below in Table 7.3.

Table 7.3: Pumphouse Road Synchro 5 Analysis			
	EBT	WBT	SBL
v/c	0.21	0.57	0.12
Delay	7.3	20.9	26.4
LOS	A	C	C
95% queue	84	310	35

The data highlighted in Table 7.3 shows the necessary estimated calculations to determine if the lane drop is suitable. The queue length, 95% of the time, was 310' and since the section length is approximately 400', blocking Drydock Ave with backed up traffic will not occur. The level of service C is also acceptable.

The bicycle lane will be marked solid blue through the intersection as there is a considerable transition from the curb to the next section of lane going towards D St.

Section G: Drydock Ave. to East Broadway St.

This is the longest section and is broken into three subsections; Drydock Ave. intersection, the bridge, and the parking area to East Broadway. The first two subsections will be discussed in this section; however, the final section (the beginning of parking to East Broadway St.) will be discussed later for a reason that will be explained.

Drydock Ave. intersection- On the westbound approach, existing conditions were observed to be confusing and dangerous. There are two thru lanes that suddenly become one thru lane and one right turn lane. Many cars get trapped in the right turn lane and illegally go thru or dangerously dart back into the left thru lane. Eliminating the existing right turn only lane and proposing a right/thru lane needed to be investigated. A turn count was performed and the data is below in Table 7.4.

Table 7.4: Drydock Ave. Turn Count 7:50-8:05am 4/14/08			
	Right Turn Lane	Thru Lane	Left Turn Lane
Total Vehs	76	213	N/A
Thru in RT lane	14	N/A	N/A
Hourly Vehs	304	852	N/A

This data supports the observation that the current existing conditions are dangerous. Of the total volume, only 27% are making right hand turns. That means a car makes a right every 11.9 seconds. While this number is high, it does not warrant a designated right turn lane.

Regarding the illegal thru movements in the right turn lane, the volume for the thru movements is so high that having a single thru lane causes bottlenecking. This was observed during the turn count and further supports the proposed right/thru lane.

On the following page, Figure 7.11 shows the intersection and beginning of the bridge section.

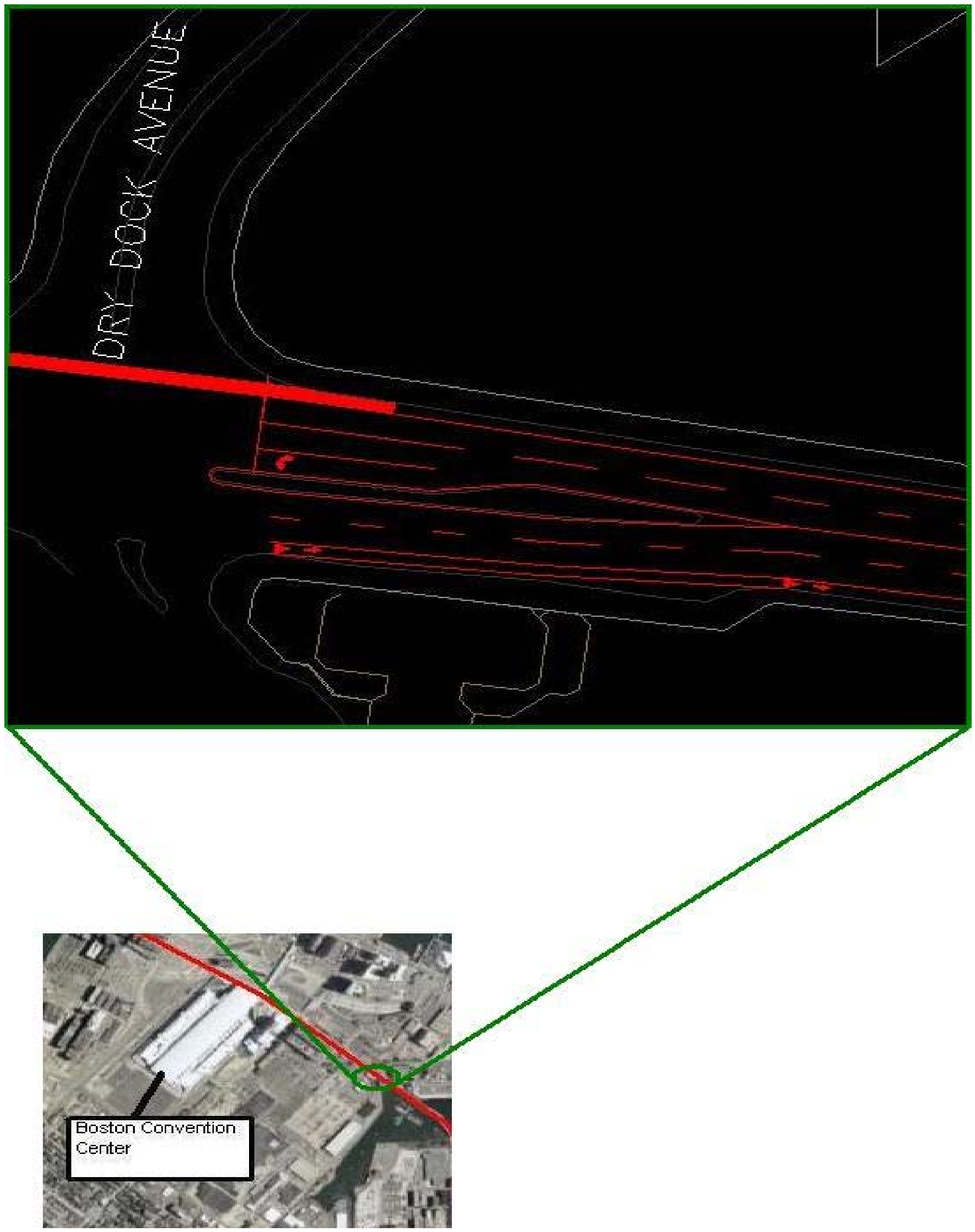


Figure 7.11: Drydock Ave. intersection

Westbound

The proposed thru lane widths for the intersection start at 12’6’’, narrow to 11’6’’, and then return to 12’6’’ at the intersection. The left hand turn lane will be 11’. The bicycle lane will be 5’ with solid blue marking beginning 50’ before the intersection because of the high turn volume. The solid blue will continue through the intersection.

Eastbound

On the eastbound side a 5' bicycle lane will eliminate informal parking in front of the UPS building. It is estimated that 8 parking spots will be removed; however, it was observed that the facility has ample parking in the rear. The lane widths will be begin as 12' and taper to 11' in the narrower part right before the beginning of the bridge, briefly widen to 12'' and then narrow again to 11'6'' on the bridge section. The bicycle lane will hug the travel lane instead of the curb due to the curbs winding geometry before the bridge.

The bridge- It has adequate space for 4 travel lanes at 11'6'' and two bicycle lanes varying from 4'6'' to 5'7''. The reason for the varying width in the bicycle lane is so the travel lanes are uniform throughout. Lanes can be measured from the existing centerline. No figure is shown for there are no design issues.

Section H: Parking Section to East 4th St.

The last subsection in Section G was not discussed because it has a unique characteristic that requires lengthy explanation. The unique characteristic is Floating Bicycle Lanes.

Floating Bicycle Lane Explanation

These are bicycle lanes that are curbside in the peak direction with no parking and two travel lanes. In the off-peak direction, there will be parking, a bicycle lane, and one travel lane. In Figure 7.12, there are the dimensions for the peak and off peak hours for one side.

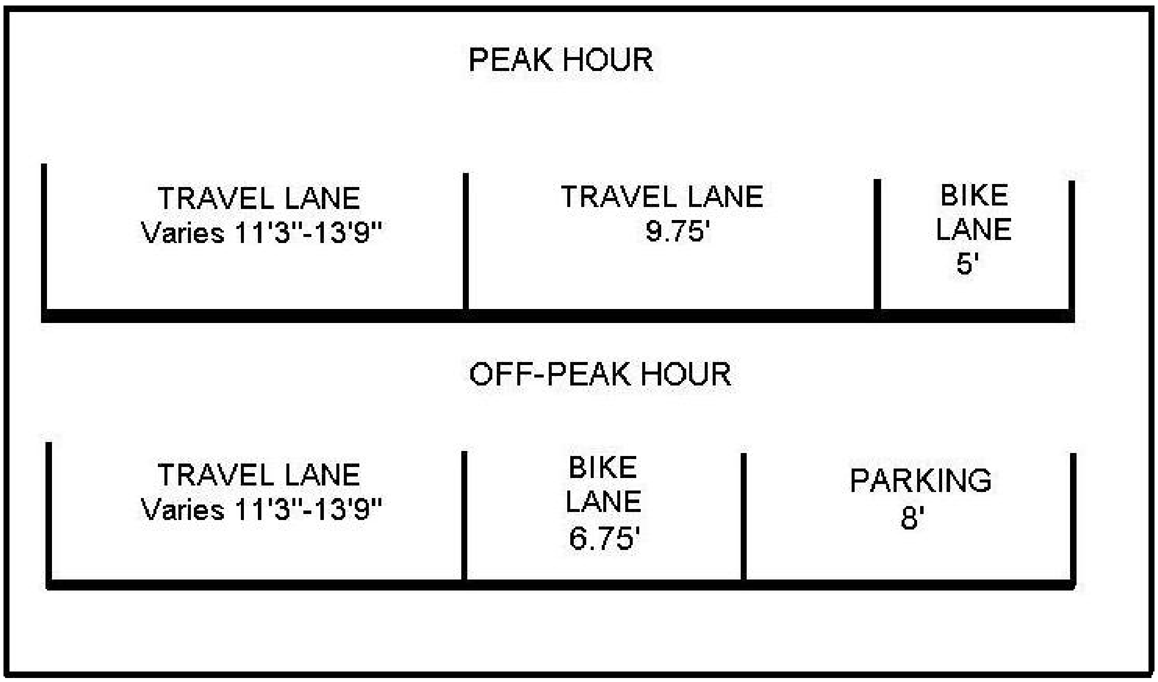


Figure 7.12: Floating Bicycle Lane Cross Sections

Floating Bicycle Lane Markings and Function

The above cross sections for both the peak and off-peak hours are both striped on the road. Figure 7.13, on the following page, shows a typical striped cross section and has labels to help envision the function. In addition to the bicycle, travel, and parking lane delineations, there are times marked on the pavement in combination with the bicycle lane markings. For example, the A.M. peak direction was found to be northbound. In that direction, the time will be marked as 7-9:30A.M., located in between the bicycle and the arrow marking as shown in Figure 7.13. For the off peak hours, a sharrow without its chevrons are used in combination with the words "All Other Times", to show where cyclists are to ride when parking is implemented.

The same goes for the P.M. peak direction, which was found to be southbound. Everything remains the same except the time changes to 4:30-6 P.M. The thing to understand here is that while the peak direction does not have parking during the peak hour, the opposite direction does. During non peak hours, both sides will have parking.

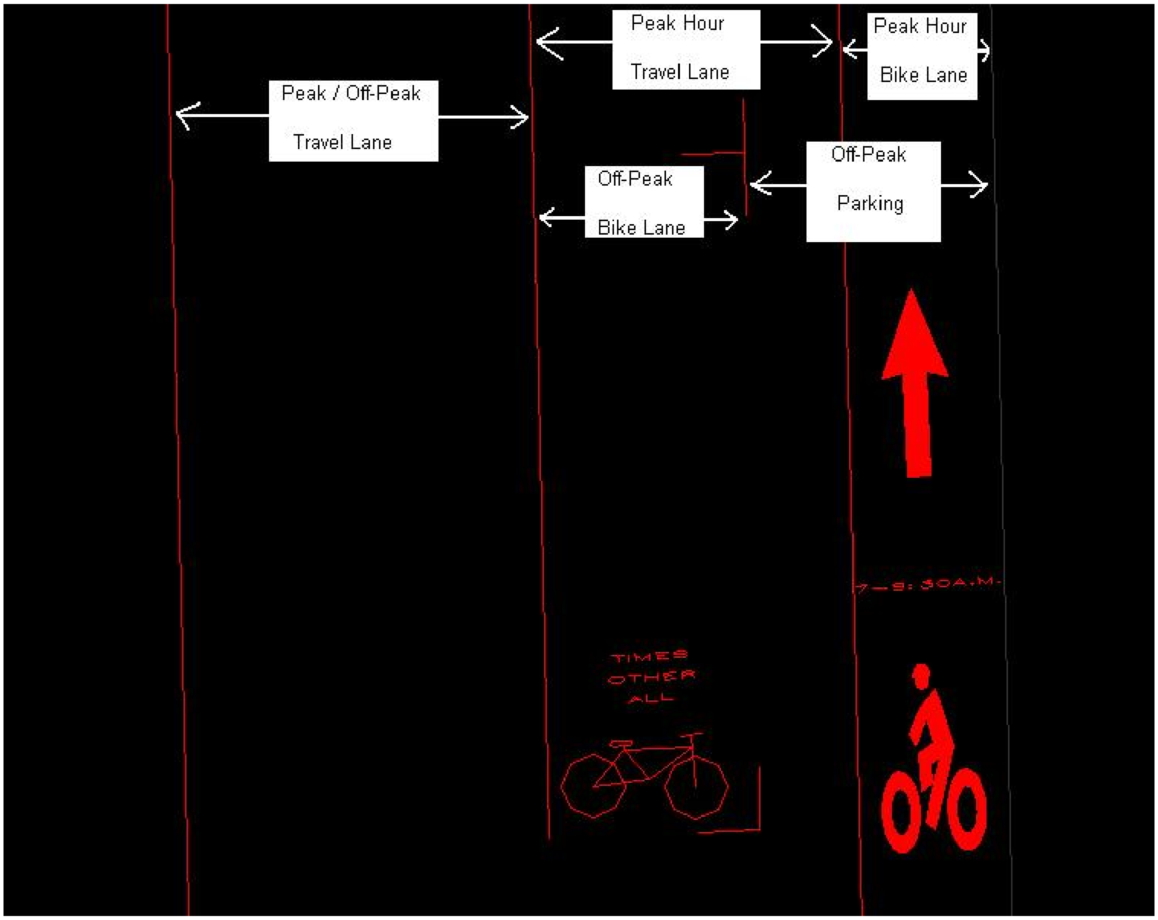


Figure 7.13: Striped Floating Bicycle Lane Cross Section

Support for Floating Bicycle Lanes
The most notable case of floating bicycle lanes happens in San Francisco along the Embarcadero, between Harrison and Howard Streets. It was implicated and it received relatively good feedback. A report concerning floating bicycle lanes and further figures concerning dimensions and function can be found at the following website.
http://takethetooker.ca/?p=50

Beginning of parking to East 4st St. The Bridge has no parking, but once parking begins, the proposal is to have floating bicycle lanes. There is not enough space available for two lanes, a bicycle lane and parking. So to preserve parking during off peak hours and in the off peak direction, floating bicycle lanes is the best option. However, when parking is discontinued at the intersection, the bicycle lane will be along the curb. On the following page, in Figure 7.14, the intersection of Summer St and East 1st St is shown to illustrate the section of no parking. This is the only section with no parking for the remainder of the design.

Figure 7.14: Summer and East 1st Streets

As shown in the figure above, there is enough room without parking to place a bicycle lane curbside with two travel lanes. This section of bicycle lane will not change at any time of the day and there will be no times posted in either of the two bicycle lane markings. However, the southbound right travel lane will become an exclusive right turn lane for the A.M. only. The reason for this will be identified in the following justification section.

Floating Bicycle Lane Justifications

The Justification for the floating bicycle lanes will be split into two sections; Summer and East 1st Streets, and East Broadway and L Streets. These two intersections will determine whether or not floating bicycle lanes can be implemented. The critical sums method was used to determine the level of service for each intersection assuming 4 phase intersections. Level of service was defined by boundaries given in Table 7.5 below.

Table 7.5: Maximum Critical Sum by LOS	
LOS	4 PHASES
A	825
B	965
C	1100
D	1225
E	1375
F	>1375

Summer and East 1st Streets Intersection

Due to the flip flop nature of the bicycle lanes during AM and PM, critical sums were taken for both situations and modified to accommodate the loss of a travel lane in the off-peak direction.

AM

Unfortunately, an AM turning count for this intersection was not obtained; however, one was created by using the PM turn count percentages and the northbound thru volume for the East Broadway and L Streets intersection. The numbers were tweaked to fit a basic volume count obtained for the Summer and East 1st Streets intersection. Volumes were measured at the southbound stop line and the total number of vehicles going northbound counted. The volumes are shown in Table 7.6 below.

Table 7.6: Summer St Volume Count Tuesday, February 19, 2008

	8:30-8:45am	8:45-9:00am	9:00-9:15am	9:15-9:30am	
Northbound	219	262	183	152	**816**
Southbound	76	83	88	76	**323**

The created AM turning movements is shown in Table 7.7 and represented in Figure 7.15.

Table 7.7: Created A.M. Turning Movements

SBR	SBT	SBL	WBR	WBT	WBL	NBR	NBT	NBL	EBR	EBT	EBL
29	228	66	161	84	32	60	615	70	15	34	40

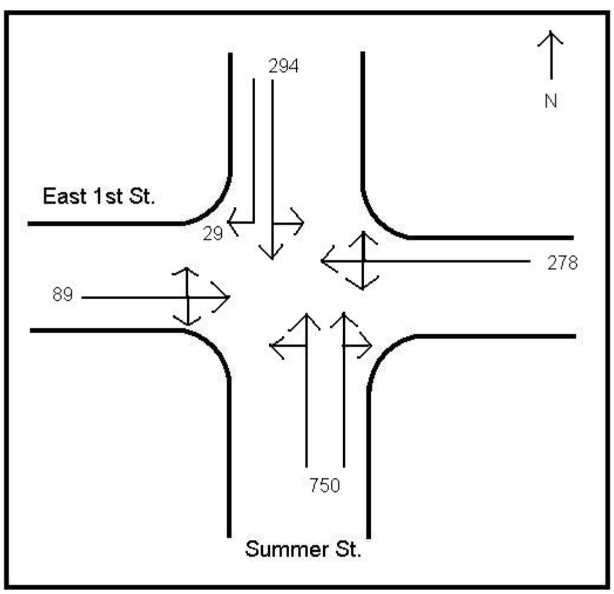


Figure 7.15: Summer and East 1st Streets AM

The explanation for having a right turn only lane southbound heading towards the intersection is because it is not the peak direction just after the intersection; the floating bicycle lane design reduces two lanes to one. There cannot be two thru lanes with only one receiving, so the left lane was made a left/thru lane. This was taken into consideration during the critical sums calculation to see if the proposed design would work. Table 7.8, below, shows the critical sum calculation and the corresponding level of service for the intersection.

Table 7.8: AM-Critical Sums

	EBT	WBT	SBT	NBT
LABEL	1	2	4	3
V	89	278	294	750
Lanes	1	1	1	2
v/l	89	278	294	375
Sum v/l	367		669	
Critical Sum	1036			
LOS	B			

Table 7.8 shows that the proposed design will work for the AM. Now, the PM must be checked.

PM

A PM count was obtained for this intersection. The data for the count is shown below in Table 7.9and represented in Figure 7.16.

Table 7.9 Summer St and East 1st Street Turning Movements 5:00-6:00pm 3/11/08

	SBR	SBT	SBL	WBR	WBT	WBL	NBR	NBT	NBL	EBR	EBT	EBL
TOTALS	87	756	229	76	39	15	22	236	29	14	30	36

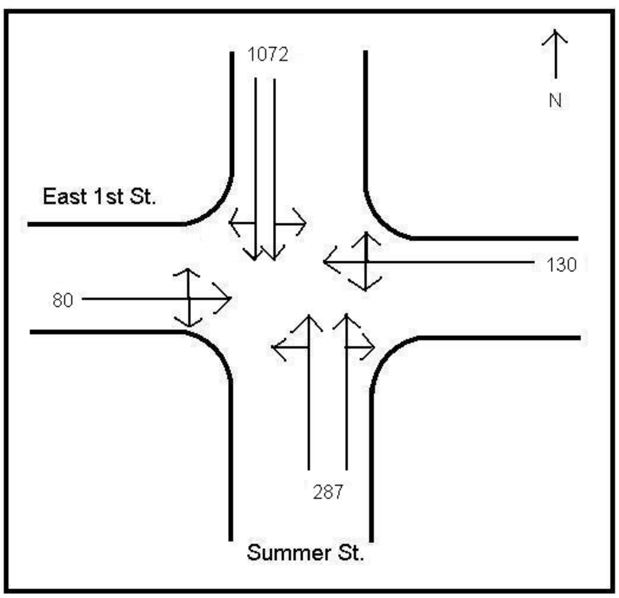


Figure 7.16: Summer and East 1st Streets PM

The calculations for the critical sum are shown on the next page in Table 7.10.

Table 7.10: PM-Critical Sums

	EBT	WBT	SBT	NBT	SBT
V	80	130	1072	287	1072
Lanes	1	1	2	1	1
v/l	80	130	536	287	1072
Sum v/l	210	823	1359		
Critical Sum	1033		1569		
LOS	B				E

The highlighted column in Table 7.10 was the initial calculation with the right turn only lane. This would have forced the entire thru lane volume into one lane, thus giving the intersection a level of service E. However, changing the right turn only lane to AM only, it gives the southbound thru 2 lanes instead of 1.

East Broadway and L Streets Intersection

AM

Table 7.11 below shows the AM turning movements for the intersection and is represented in Figure 7.17.

Table 7.11: L St. and East Broadway Turning Movements 4/3/08 7:30-8:30am

	SBR	SBT	SBT	SBL	WBR	WBT	WBL	NBR	NBT	NBT	NBL	EBR	EBT	EBT	EBL
TOTALS	86	33	116	20	88	142	10	21	122	532	121	36	54	45	102

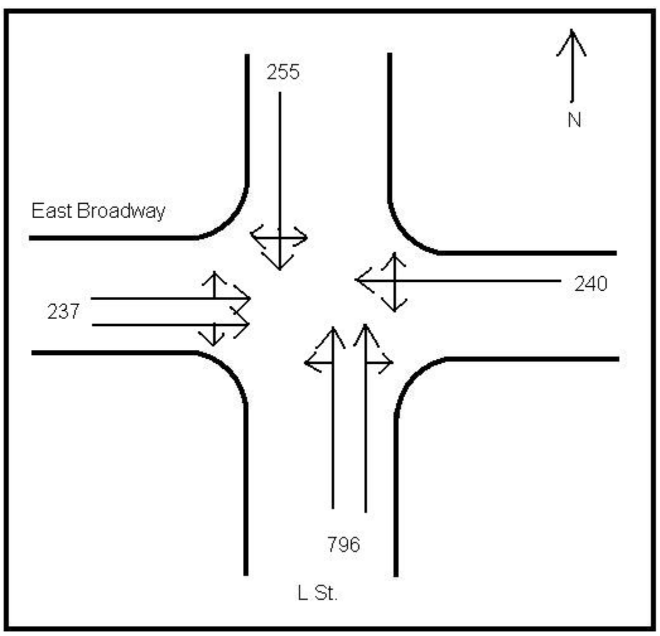


Figure 7.17: East Broadway and L Street AM

The calculations for the critical sum are shown on the next page in Table 7.12.

Table: 7.12 AM- Critical Sums

	EBT	WBT	SBT	NBT
V	237	240	255	796
Lanes	2	1	1	2
v/l	118.5	240	255	398
Sum v/l	358.5		653	
Critical Sum	1011.5			
LOS	B			

A level of service B means that the AM design will work at the intersection. Now the PM.

PM

Table 7.13 below shows the PM turning movements for the intersection and is represented in Figure 7.18.

Table 7.13: L St. and East Broadway Turning Movements 4/1/08 4:30-5:30pm

	SBR	SBT	SBT	SBL	WBR	WBT	WBL	NBR	NBT	NBL	EBR	EBT	EBT	EBL
TOTALS	181	112	380	76	20	167	4	22	162	80	47	66	55	50

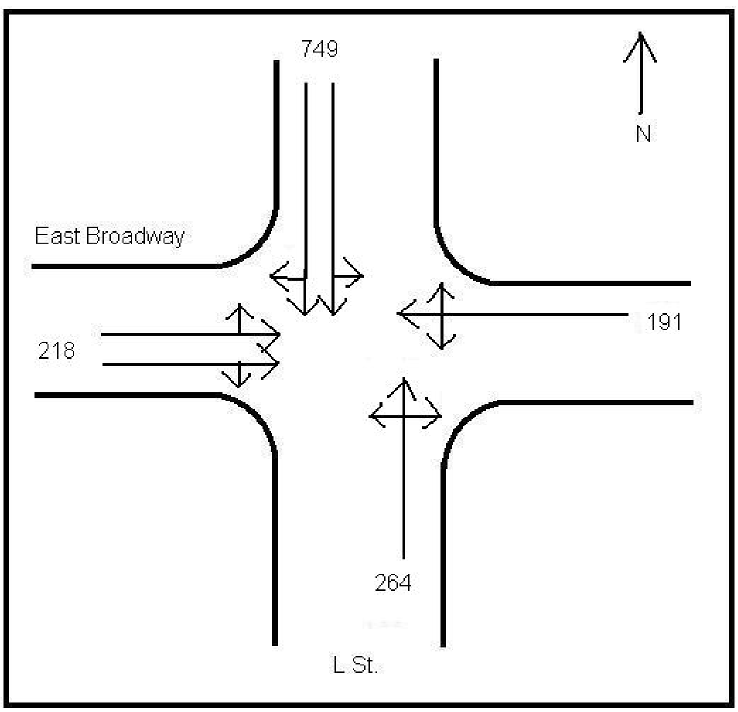


Figure 7.18: East Broadway and L Street PM

The calculations for the critical sum are shown on the next page in Table 7.14.

Table 7.14: PM-Critical Sums

	EBT	WBT	NBT	SBT
V	218	191	264	749
Lanes	2	1	1	2
v/l	109	191	264	374.5
Sum v/l	300	638.5		
Critical Sum	938.5			
LOS	A			

A level of service A completes the analysis and tells that floating bicycle lanes can be placed on both sides from the beginning of parking after the bridge on Summer St going southbound to East 4th St on L St. Below, in the final figure, Figure 7.19, the area where the floating bicycle lanes will be striped is circled.

Figure 7.19: Floating Bike Lane Overview

Section I: East 4th St. to William J Day Blvd.

At approximately 1,900', this section is too narrow to institute any striped bicycle lanes. Rather than simple end the bicycle lane, the proposal is to use sharrows to provide connectivity to the Harbor Walk and bicycle path along the southern shore. Sharrows are shared lane arrows that emphasize that cyclists will be riding in the travel lane with vehicles and guides cyclists away from parked cars. This section has narrow width and its short blocks reduce vehicular speeds and increase safety for cyclists.

And so the connector from downtown Boston to the existing path has been designed. Now, let's build it!

Pavement Marking Specifications

Dashed pavement marking lines are to be 10’ in length and have 20’ in between. Solid lines separating lanes at intersections will as noted on the plans. The bicycle lane pavement marking shall be placed at the beginning of each bicycle lane at the intersection and approximately every 200’ afterward. Where noted bicycle lanes will be painted across intersections for visibility. Bicycle lanes painted across intersections will be painted with dashed blue lines as noted on the plans. Bicycle lane transitions will be painted solid blue where indicated on the drawings. The color scheme on the drawings is only for visibility. The actual bicycle lanes will be white.

Cost Estimation

The following pages include the cost estimates for each of the streets included in this report. Unit prices were determined by examining average bid prices from the City of Boston Public Works Department Engineering Division and from recommendations from Cara Seiderman, Bicycle Coordinator from the City of Cambridge. The unit prices used are included in Table 8.1.

Table 8.1: Cost Estimate Table

Pavement Marking Costs		
Description	Units	Cost
Pavement Marking Removed (Paint)	LF	$4.00
Pavement Marking Removed (Thermoplastic)	SF	$3.50
4" Solid White Line (Paint)	LF	$1.50
Pavement Arrow/ Legends (Thermoplastic)	SF	$11.00
Stop Line/Crosswalk (Thermoplastic)	SF	$2.50
4" Solid Yellow Line (Thermoplastic)	LF	$1.50
Solid Blue Paint	SF	$11.00
Arrow, Straight	EA	$129.80
Arrow, Left or Right	EA	$173.80
Arrow, Combination	EA	$309.10
"ONLY" Legend	EA	$247.50
Bike Symbol w/ arrow	EA	$127.60
Bike Symbol w/ sharrow	EA	$102.30
Bike Symbol Alone	EA	$70.40

Estimate for Commonwealth Avenue – Kenmore Square to Arlington Street

Commonwealth Avenue - Kenmore Square to Arlington Street Cost Estimate				
Item	Amount	Unit	Unit Price	Cost
Pavement Marking Removed (Paint)	4,533	LF	$4.00	$18,132.00
4" Solid White Line (Paint)	19,333	LF	$1.50	$28,999.50
4" Solid Yellow Line (Thermoplastic)	2,471	LF	$1.50	$3,706.50
Stop Line/Crosswalk (Thermoplastic)	2,835	SF	$2.50	$7,087.50
Bike Symbol w/ Arrow	68	EA	$127.60	$8,676.80
Pavement Marking Removed (Thermoplastic)	298	SF	$3.50	$1,043.00
Bike Symbol Alone	10	EA	$70.40	$704.00
Solid Blue Paint	9,000	SF	$11.00	$99,000.00
"ONLY" Legend	14	EA	$247.50	$3,465.00
Arrow, Straight	4	EA	$129.80	$519.20
Bike Symbol w/ Sharrow	4	EA	$102.30	$409.20
Arrow, Left or Right	14	EA	$173.80	$2,433.20
			Total Cost	$174,175.90

Estimate for Commonwealth Avenue – B.U. Bridge to Warren Street

Commonwealth Avenue - Packard's Corner to BU Bridge Cost Estimate				
Item	Amount	Unit	Unit Price	Cost
Paint Removed	14,390	LF	$4.00	$57,558.08
4" White Line	17,868	LF	$1.50	$26,802.38
4" Yellow Line	4,709	LF	$1.50	$7,063.38
Lane Hatching (2' Spacing)	9,095	SF	$0.32	$2,926.41
Bike Symbol w/ Arrow	53	EA	$127.60	$6,762.80
Thermoplastic Removed	375	SF	$3.50	$1,312.50
Blue Paint	2,833	SF	$11.00	$31,162.24
"ONLY" Legend	20	EA	$247.50	$4,950.00
Straight Arrow	9	EA	$129.80	$1,168.20
Left/Right Arrow	17	EA	$173.80	$2,954.60
			Total Cost	$142,660.59

Commonwealth Avenue - Warren St. to Packard's Corner Cost Estimate				
Item	Amount	Unit	Unit Price	Cost
4" White Line	7,241	LF	$1.50	$10,861.50
Bike Symbol w/ Arrow	37	EA	$127.60	$4,721.20
Bike Symbol w/ Sharrow	11	EA	$102.30	$1,125.30
			Total Cost	$16,708.00

<u>Estimate for Dartmouth Street – Stuart Street to Esplanade</u>

Dartmouth Street - Esplanade to Stuart Street				
Description	Amount	Units	Cost	Price
Pavement Marking Removed (Paint)	865.0	LF	$4.00	$3,460.00
Pavement Marking Removed (Thermoplastic)	314.5	SF	$3.50	$1,100.75
4" Solid White Line (Paint)	8657.0	LF	$1.50	$12,985.50
Pavement Arrow/ Legends (Thermoplastic)	470.9	SF	$11.00	$5,179.90
Stop Line/Crosswalk (Thermoplastic)	201.0	SF	$2.50	$502.50
4" Solid Yellow Line (Thermoplastic)	1142.0	LF	$1.50	$1,713.00
Solid Blue Paint	593.0	SF	$11.00	$6,523.00
			Total Cost	$31,464.65

Estimate for Summer Street – Dorchester Avenue to William J. Day Boulevard

Summer Street and L Street - Dorchester Avenue to William J Day Bouvelard				
Item	**Amount**	**Unit**	**Unit Price**	**Cost**
"ONLY"	1	EA	$247.50	$247.50
Bike Symbol w/ arrow	89	EA	$127.60	$11,356.40
Bike Symbol w/ sharrow	27	EA	$102.30	$2,762.10
Bike Symbol Alone	22	EA	$70.40	$1,548.80
Arrow, Left, or Right	1	EA	$173.80	$173.80
4" Solid White Line (Paint)	32208.5	LF	$1.50	$48,312.75
Solid Blue Paint	2843	SF	$11.00	$31,273.00
Pavement Marking Removed (Thermoplastic)	79	SF	$3.50	$276.50
Pavement Marking Removed (Paint)	12276	LF	$4.00	$49,104.00
			Total Cost	**$145,054.85**

Acknowledgements

Spokes Engineering would like to thank all those who helped make our report and designs possible.

Professor Peter Furth, our capstone advisor, met with the group on a regular basis to review our ideas and give constant feedback and recommendations based on his vast transportation expertise and personal bicycling experience.

Nicole Freedman, Boston's Bicycle Coordinator, also helped us greatly in establishing bicycle routes and priorities for the city.

Cara Seiderman, Bicycle Coordinator for the City of Cambridge, provided figures for cost estimating.

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