BOSTON REGION METROPOLITAN PLANNING ORGANIZATION

Stephanie Pollack, MassDOT Secretary and CEO and MPO Chair
Karl H. Quackenbush, Executive Director, MPO Staff

TECHNICAL MEMORANDUM

DATE: **January 18, 2018**

TO: **Cara Seiderman, Transportation Program Manager, Cambridge, MA**

FROM: **Casey-Marie Claude, MPO Staff**
Mark Abbott, MPO Staff

RE: **Bicycle Network Gap Feasibility Evaluation for Central Square**

1 BACKGROUND

2014 Bicycle Network Evaluation

In 2014, the Boston Region Metropolitan Planning Organization (MPO) staff conducted the Bicycle Network Evaluation, a regional study that resulted in a list of eleven locations designated as "high-priority" gaps based on how they scored against criteria used to assess their potential to improve bicycle connectivity.[1] The gaps identified as the highest priority were those where an improvement project would have the greatest potential to improve the Boston region's bicycle network goal of enhancing bicycle safety, continuity, and connectivity.

The purpose of this study is to build upon the original 2014 Bicycle Network Evaluation by assessing potential improvements to several high-priority gaps—such as the one found in Central Square—that could be considered for design and construction funding in future Transportation Improvement Program (TIP) cycles.

The outcomes of this study will include recommendations for appropriate types of bicycle facilities—for example, on-road bike lanes, protected bike lanes (cycle tracks), shared lanes, and shared-use paths—for each of the high-priority gaps selected for assessment. The findings and products of the study will support local, regional, and state planning efforts to provide a safe, convenient, continuous, and connected bicycle network in the metro Boston area.

2 Gap Selection

For this study, the Boston Region MPO selected three gaps from the list of eleven locations designated as "high-priority" gaps in the 2014 Bicycle Network

[1] Beth Isler, *Bicycle Network Evaluation* (Boston Region Metropolitan Planning Organization, May 2014). www.ctps.org/data/pdf/programs/livability/MPO_0515_Bicycle_Network.pdf.

Evaluation. MPO staff selected one gap from each category—small, medium, and long—based on criteria that included Massachusetts Department of Transportation (MassDOT) crash clusters, underserved/environmental justice communities, employment, town centers, central business districts, schools, universities, parks or open space, above-average numbers of future bicycle/pedestrian trips, and consistency with regional plans for bicycle transportation. The three locations approved by the MPO for study are:

- Central Square in Cambridge
- Sudbury Aqueduct Trail in Framingham
- Massachusetts Central Rail Trail in Waltham and Belmont

Staff selected the location in Cambridge because it was the highest-scoring bicycle network gap in the small category that had not already been studied.

2.1 Gap Location and Study Area

Figure 1 displays the location of the Central Square bicycle gap, as originally identified in the 2014 study. The study area (blue oval) ran from the northeastern ends of the bicycle facilities on Western Avenue across Massachusetts Avenue to the Harvard Street bike lane to the north. In the map, a dashed red line indicates where, within the gap, bicycle facilities are not installed—starting southwest of Massachusetts Avenue at the end of the separated bicycle lane on Western Avenue, continuing north along Prospect Street until north of Broadway where bike lanes are striped for both directions of travel; the bike lanes end near Gardner Road as Prospect Street approaches the Hampshire Street intersection.

Prospect Street was initially identified as a priority for bicycle improvements because this street is the most direct connection between the Hampshire Street bike lanes and the Western Avenue separated bicycle lane. As mentioned above, there are bike lanes on Prospect Street from north of Broadway to south of Hampshire Street, near Gardner Road. When MPO staff began studying this gap, they pursued the idea of adding bike lanes to the remaining segments of Prospect Street from Massachusetts Avenue to Hampshire Street because this would provide a continuous path of bicycle facilities between Central Square and Inman Square. However, plans to improve Inman Square to the north and River Street to the south make it impossible to accurately anticipate travel patterns in the near future. It would be imprudent to recommend adding bike lanes to Prospect Street before the analyses can be informed by observed changes in travel behavior once Cambridge improves Inman Square and River Street. To address these concerns, MPO staff used two different approaches to study the gap in the Boston region bicycle network at Central Square.

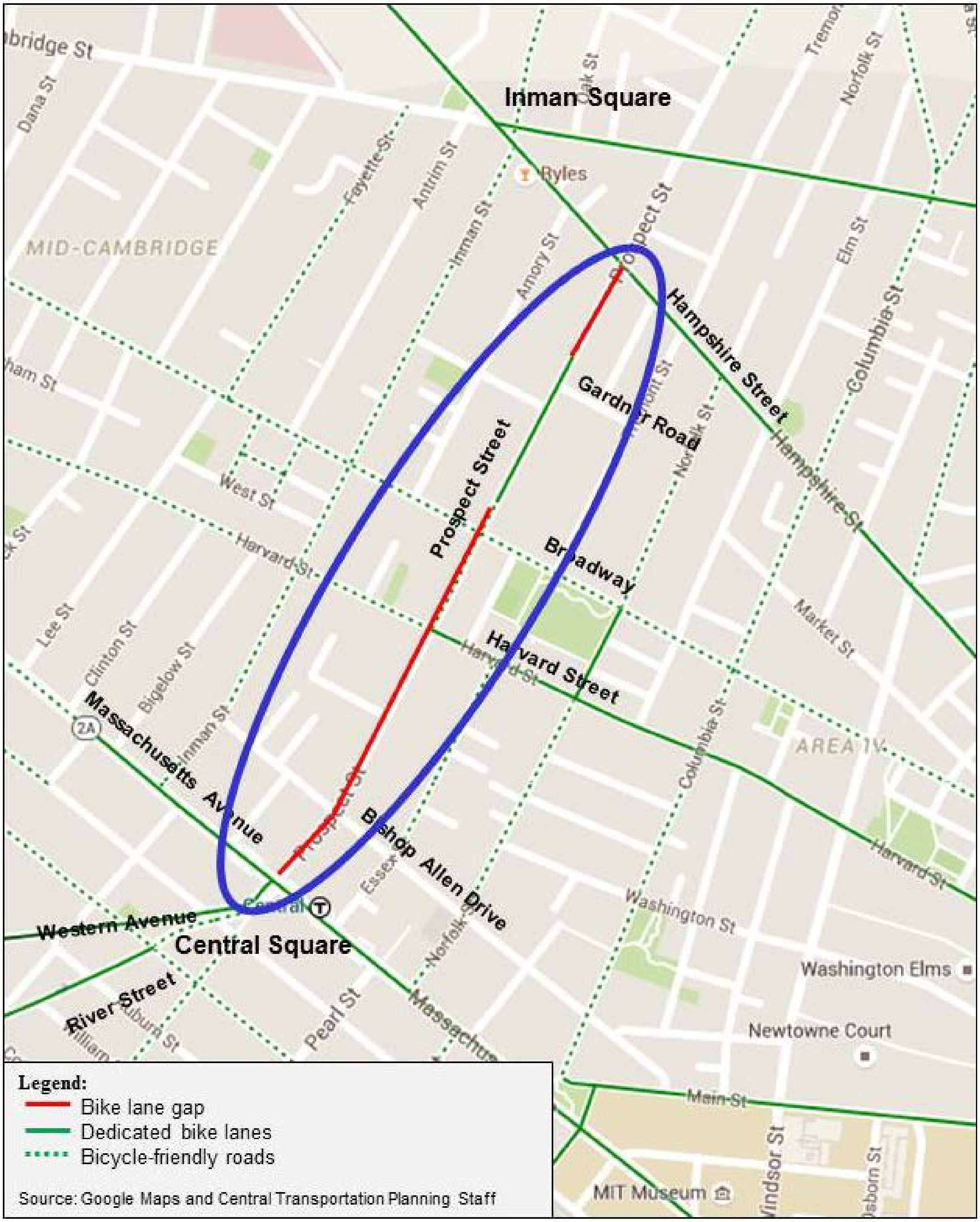

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FIGURE 1
Central Square Bicycle Network Gap

Central Square Gap
In Boston Region
Bike Network

3 Gap Evaluation

Staff evaluated the Central Square bicycle gap in two parts: 1) a walking tour and assessment of the existing signed bicycle route through Central Square from where it starts at Inman Square to where Western Avenue and River Street meet south of Massachusetts Avenue; and 2) a full analysis of the potential for closing the gap by way of adding bike lanes to Prospect Street. This second effort will need to be revisited once Cambridge improves Inman Square and River Street because the current findings likely will change after construction is complete. Closing this Boston region bicycle network gap could potentially benefit many people. Central Square and Inman Square are both commercial areas and major destinations in Cambridge. Both squares are also relatively well connected to the bicycle network—the main exception being a lack of north-south bicycle facilities between the two locations.

3.1 Improving the Existing Signed Bicycle Route

MPO staff joined City of Cambridge staff on November 14, 2017, for a walk audit of the signed bicycle route that travels through Central Square in Cambridge. The route connects Inman Square to the Boston University (BU) Bridge, which crosses the Charles River and connects to Boston. This signed route facilitates bicyclist travel through Central Square by directing bicycle traffic along streets identified by Cambridge as being comfortable for bicyclists. This route serves as an alternate north-south connection across Central Square with a less direct path to Inman Square than Prospect Street, but with many roadways that feature more space for cyclists, lower traffic speeds, and fewer conflicts with motor vehicles for bicyclists.

In order to improve the comfort and safety of the signed bicycle route in Cambridge, city and MPO staff identified several changes that could be made to the physical environment:

- Include shared lane markings on signed bicycle route roadways without an allocated separate travel way for bicyclists (that is, bike lanes)
- Create an additional branch of the signed bicycle route along Western Avenue, with signage directing bicyclists to the Charles River instead of solely the BU Bridge
- Add wayfinding signage at identified locations
- Improve clarity for both bicyclists and motorists of turning maneuvers where the signed bicycle route changes from one street to another
- Improve crossings at busy, unsignalized intersections

Shared Lane Markings

Including shared lane markings along the signed bicycle route reinforces bicyclists' understanding that they are traveling along a route designated for bicycle travel. In this way, shared lane markings function as a second wayfinding resource, supporting the bicycle route signage. The shared lane markings also indicate to motorists that they should anticipate bicycle traffic along a specific roadway, reminding drivers to share the road. Norfolk Street north of Broadway is one street that could benefit from shared lane markings, while adding the markings at the start of both turning lanes where Inman Street meets Massachusetts Avenue could improve the intersection for road users. An exception to the shared lane marking suggestion is Bishop Allen Drive, of which only two blocks are included in the bicycle route. Adding shared lane markings for this short length could cause more confusion than clarity.

Alternately, the potential of adding shared lane markings on Inman Street southwest of Broadway should be explored. The roadway currently features what Cambridge staff referred to as “fog lines” to the left of the lane of parked cars, located on the right side of the street (Figure 2). This was added to encourage motorists to drive farther from parked cars. However, the striping causes confusion because it can be perceived as a bike lane, in spite of being too narrow and located directly within the path of opening car doors. Shared lane markings on this roadway could help all users understand that Inman Street does not include a separate travel way for bicyclists and that the roadway should be shared accordingly.

Figure 2
Inman Street “Fog Line”

Additional Signed Bicycle Route Branch

The purpose of the signed bicycle route is to help bicyclists who are less comfortable than others about riding, and/or who are not as familiar with

Cambridge and need help navigating their way through Central Square and the surrounding area. For this reason, there is support in the Cambridge community for directing bicyclists along bicycle-friendly Western Avenue, which includes a separated bike lane and bicycle signals at intersections. People perceive that Western Avenue is a more comfortable route than Magazine Street for cyclists traveling south from Central Square to the Charles River. To encourage using Western Avenue as a connection to the Charles River, Cambridge staff expressed interest in changing the signed bicycle route so that it travels along Western Avenue instead of Magazine Street. Although the route would change, the original signs along Magazine Street would not be removed because they may still be helpful wayfinding tools for people traveling in the area. New southbound route signage should read “Charles River” instead of “BU Bridge,” which the signage currently indicates (Figure 3). Once each branch of the bicycle route reaches the Charles River, additional signage should direct users to locations such as the BU Bridge. Figure 4 illustrates the alternate southbound bicycle route along Western Avenue.

Figure 3
Southbound Bicycle Route BU Bridge Signage

Replace Missing Wayfinding Signage

As MPO and Cambridge staff walked the signed bicycle route, there were a few locations where signage was not posted, but is needed. Wayfinding signs should be added to the following locations:

- Pleasant Street and Western Avenue
- Douglass Street and Bishop Allen Avenue
- At the beginning of the route in Inman Square

Improve Clarity of Turning Maneuvers

Heading north through Central Square, it is difficult for bicyclists to turn left onto Douglass Street from Massachusetts Avenue immediately after turning right onto Massachusetts Avenue from Brookline Street. Several ideas were proposed for remedying this concern:

- Add a bicycle route highlighted in green paint on Massachusetts Avenue to facilitate the left turn onto Douglass Street for bicyclists and to alert motorists that cyclists might want to make the turn
- Add a bicycle signal to the traffic signal where northbound traffic from Brookline Street meets Massachusetts Avenue
- Add a sign to the traffic signal facing Brookline Street that illustrates the turn (first, a right onto Massachusetts Avenue, then an immediate left onto Douglass Street)

Another improvement at Massachusetts Avenue and Douglass Street that was mentioned during the walk audit is the addition of a sign that would tell bicyclists traveling west along Massachusetts Avenue that they could turn right at Douglass Street to travel along the signed bicycle route to Inman Square.

A separate intersection along the route where bicycle and motorist conflicts could arise is the left turn from the Harvard Street bike lane to the contraflow bike lane on Norfolk Street. This road has a much lower traffic volume and slower travel speeds than Massachusetts Avenue, which means that collisions tend to be avoided. While this intersection might not require any changes, two ideas for improving the location are worth noting:

- Add a bike box to the southeastern corner of the intersection for a two-stage left turn
- Add a shared lane marking with a left turn arrow to the travel lane on Harvard Street

Improve Intersection Crossings

According to Cambridge staff, it is difficult for bicyclists to cross Broadway and Hampshire Street when traveling north up Norfolk Street. To remedy this, raised crossings, to increase driver awareness of the crossings, and slow vehicle speeds could be constructed, although it would be important to assess the impact of this traffic-calming strategy on vehicular traffic flow along both roadways.

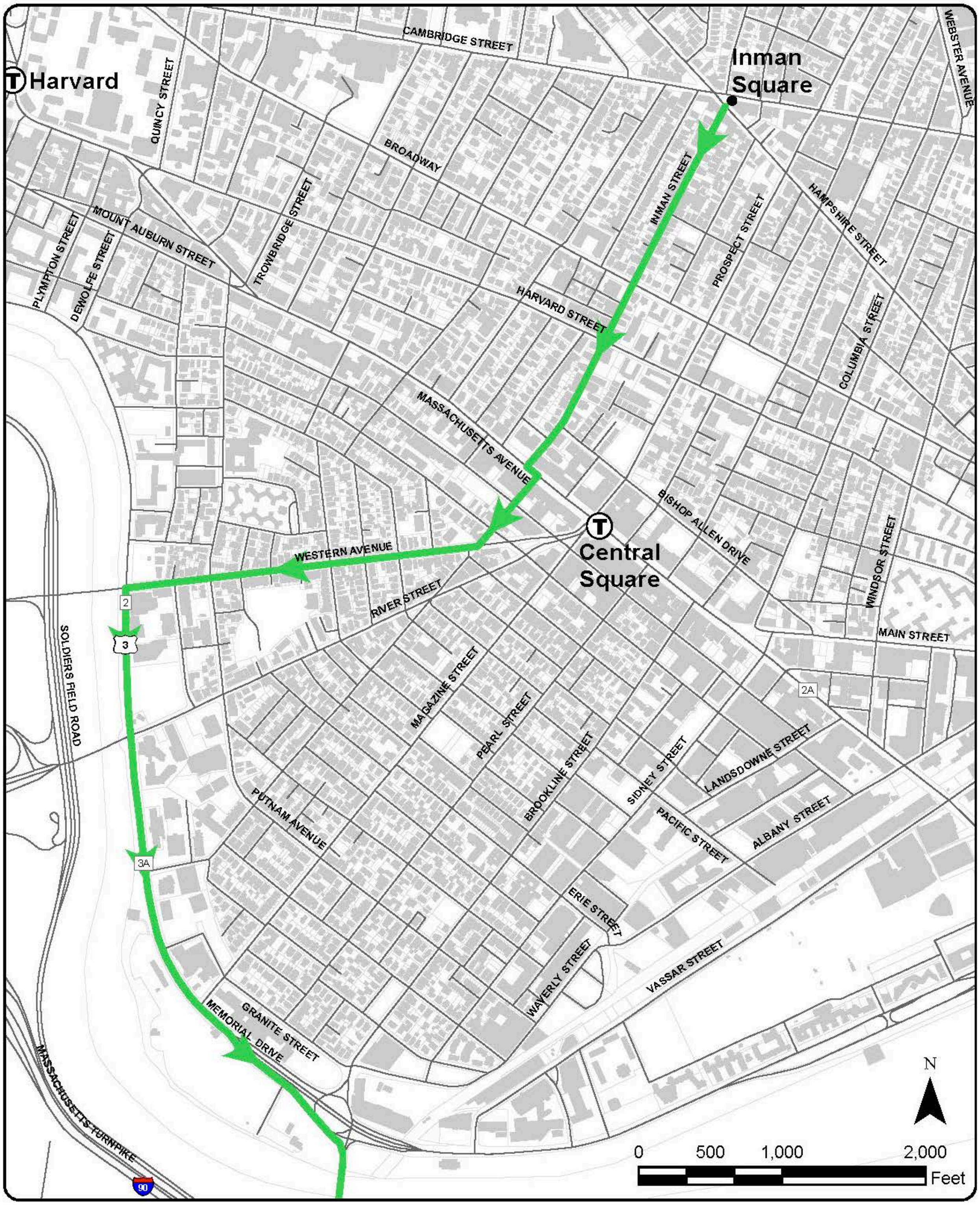

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FIGURE 4
Alternate Bike Route

Central Square
Bicycle Network
Gap Evaluation

3.2 Improving Prospect Street for Bicyclists

Constructing bicycle facilties on Prospect Street would directly close the Central Square bicycle network gap. To provide safe bicycling conditions along Prospect street, MPO staff assessed the feasibility of constructing bicycle lanes for both directions of travel. The current right-of-way on Prospect Street is too narrow to accommodate continuous bicycle lanes, so the left-turn lanes on Prospect Street at the signalized intersections would need to be removed. These left-turn lanes were originally added to Prospect Street to reduce the number of crashes on the roadway and, according to City of Cambridge staff, this approach has proven successful. The potential safety implications of removing left-turn lanes to add bike lanes to Prospect Street, coupled with the unknown travel impacts of the Inman Square and River Street reconstruction projects, has led MPO staff to recommend that Cambridge should not provide additional bicycle accommodations on Prospect Street until the reconstruction projects are complete and the idea can be studied once more with updated travel information. To inform this future study, MPO staff offer the following summary[2] of their evaluation of removing the Prospect Street left-turn lanes:

Prospect Street

Prospect Street is a locally controlled, two-lane, two-way arterial roadway that connects Central Square to Inman Square. It intersects Massachusetts Avenue at Western Avenue and River Street in Central Square, and intersects Hampshire Street near Inman Square. Massachusetts Avenue and Hampshire Street currently have conventional bike lanes in place. Both of these intersections are signalized. Between Massachusetts Avenue and Hampshire Street, Prospect Street crosses three more signalized intersections at Bishop Allen Drive, Harvard Street, and Broadway. Exclusive left-turn lanes are present on Prospect Street at Bishop Allen Drive, Harvard Street, Broadway, and on the northbound leg of the Hampshire Street intersection.

Pedestrian and Bicycle Comfort

An evaluation of the current conditions of Prospect Street, as it relates to pedestrian levels of traffic stress (LTS) and bicycle levels of comfort (BLC), scores the roadway at an LTS 3 (LTS scale 1 to 4) and BLC 4[3] (BLC scale 1 to 5). This indicates that it presents a moderate-to-great amount of traffic stress and may be uncomfortable for many, or most, bicyclists. Prospect Street contains constant motor vehicle traffic, with no bike lane, and steady bus traffic—9.5 buses per hour, (4.75 buses per hour in each direction)—that makes frequent stops near the Bishop Allen Drive, Harvard Street, and Broadway intersections.

[2] For the full evaluation, see “Improving Prospect Street” in Appendix A.
[3] For a full description of LTS and BLC relative to Prospect Street, see Appendix A2.1.

Safety

Staff examined crash records from the MassDOT Registry of Motor Vehicles from 2011 to 2013. There were 108 crashes reported in the segment of Prospect Street between Massachusetts Avenue and Hampshire Street. Of the total reported crashes, 16 involved bicycle crashes, with injuries resulting from 63 percent of the bicycle crashes. Of the 12 pedestrian crashes, 42 percent resulted in injuries, as did 19 percent of the 80 reported vehicle-only crashes. Half of the total number of injury crashes between 2011 and 2013 were bicycle- and pedestrian-related crashes.

The intersections along Prospect Street have crash rates somewhat higher than the state/district average of 0.70 crashes per million entering vehicles (MEV).[4] The intersection crash rates per MEV for locations along Prospect Street are as follows.

- Massachusetts Avenue: 0.64
- Bishop Allen Drive: 0.83
- Harvard Street: 1.02
- Broadway: 0.92
- Hampshire Street: 1.02

Further, Cambridge staff noted that prior to installing the left-turn lanes at the signalized intersections along Prospect Street, there were a large number of crashes at this location because of turning vehicles. This led to installation of the present left-turn lanes on Prospect Street.

Existing Traffic Operations Conditions

To determine the effect of installing bike lanes in place of left-turn lanes, MPO staff built a traffic analysis network for the AM and PM peak periods with Synchro 9.[5] The five signalized intersections along Prospect Street operate satisfactorily overall during the AM peak period (Level of Service [LOS] D or better), although some individual movements operate at LOS E or F. During the PM peak period, the northbound movements on Prospect Street operate at capacity (LOS E) at the intersections of Prospect Street at Massachusetts Avenue and at Bishop Allen Drive; these intersections as a whole operate at LOS E. The other three intersections operate satisfactorily during the PM peak period.

[4] Massachusetts Department of Transportation, 2016, Intersection Crash Rates, www.massdot.state.ma.us/highway/Departments/TrafficandSafetyEngineering/CrashData/CrashRates/Intersection.aspx.

[5] Trafficware Inc., Synchro Studio 9, Synchro plus SimTraffic, Sugar Land, Texas.

Proposed Improvement Alternatives and Evaluation

MPO staff developed and analyzed the impact of removing left-turn lanes and adding bicycle lanes on vehicular traffic operations for two alternative traffic signal optimization scenarios. The following are the two alternatives that were evaluated.

- **Alternative 1**: This alternative adds bike lanes in both directions from Massachusetts Avenue through the intersections at Bishop Allen Drive, Harvard Street, and Broadway to connect to the existing bike lane segment on Prospect Street north of Broadway. Figure 5 shows that Alternative 1 closes the majority of the bicycle network gap, but does not address the portion of the gap on River Street or the portion on Prospect Street near Hampshire Street. It also optimizes traffic signal timing to reflect removal of the left-turn lanes.

  The results of traffic operations analysis for the five Prospect Street intersections indicate that the intersections operated at LOS C or better. The 50th percentile queues do not exceed lane storage lengths. Queue lengths are expected to be equal to or less than the 50th percentile queues half of the time—95th percentile queues may exceed storage length; 95th percentile queues are met or exceeded 5 percent of the time.

- **Alternative 2**: This alternative extends the bike lanes proposed in Alternative 1 on Prospect Street all the way to Hampshire Street, removing the current northbound left-turn lane at Hampshire Street. Figure 6 shows that Alternative 2 provides continuous bicycle facilities between Central Square and Inman Square, but it does not address the portion of the bicycle network gap on River Street. It also optimizes traffic signal timing to reflect removal of the left-turn lanes.

  As with Alternative 1, the results of traffic operations analysis for the six Prospect Street intersections indicates that the intersections operated at LOS C or better. The 50th percentile queues do not exceed lane storage lengths. Queue lengths are expected to be equal to or less than the 50th percentile queues half of the time—95th percentile queues may exceed storage length; 95th percentile queues are met or exceeded 5 percent of the time.

Examples of the existing and proposed cross-sections at the Prospect Street intersections are shown in Figures 7 and 8.

Summary of Prospect Street Bicycle Lanes

Based solely on the above analysis of existing traffic operations and development, Prospect Street could be a good candidate for bike lanes. The two alternatives would ameliorate the Central Square bicycle network gap while accommodating people that drive, walk, bicycle, and take the bus. Alternative 1 proposes bike lanes between Massachusetts Avenue and the existing bike lane on Prospect Street north of Broadway. Adding this bike lane would provide 1,800 feet of roadway with bicycle facilities, contributing to 2,300 feet of continuous bike lane on Prospect Street. In addition to the fixes in Alternative 1, Alternative 2 also proposes a bike lane in place of the northbound left-turn lane at Hampshire Street. Alternative 2 would add an additional 300 feet of bike lane for 2,600 feet of continuous bike lane on Prospect Street. LTS for people biking would improve, thus increasing the number of people who would feel comfortable biking on Prospect Street.

However, since this study was undertaken, conditions and priorities in Cambridge have changed. Inman Square reconstruction is set to begin in 2018, and there are planning efforts underway for River Street and Central Square. These efforts could have significant impacts on the operations of Prospect Street. In addition, based on Cambridge's feedback on safety regarding the conditions prior to installing the left-turn lanes and the numerous bus routes that travel the length of Prospect Street, staff recommended not removing the left-turn lanes at this time. Cambridge values the safety improvements for all Prospect Street users achieved by adding left-turn lanes and considers them to be necessary for providing acceptable operations to all road users. In contrast, designating a route for bicyclists along Prospect Street would only address conditions for one travel mode, and the City already offers a safer and more comfortable alternative for cyclists along its signed bicycle route through Central Square. Although operationally the intersections could function acceptably for motor vehicle traffic, removing the turn lanes could potentially impact pedestrian and bicycle LOS at the intersections. New analysis of traffic and travel behavior along Prospect Street should occur once the planning efforts at Inman Square, River Street, and Central Square are complete.

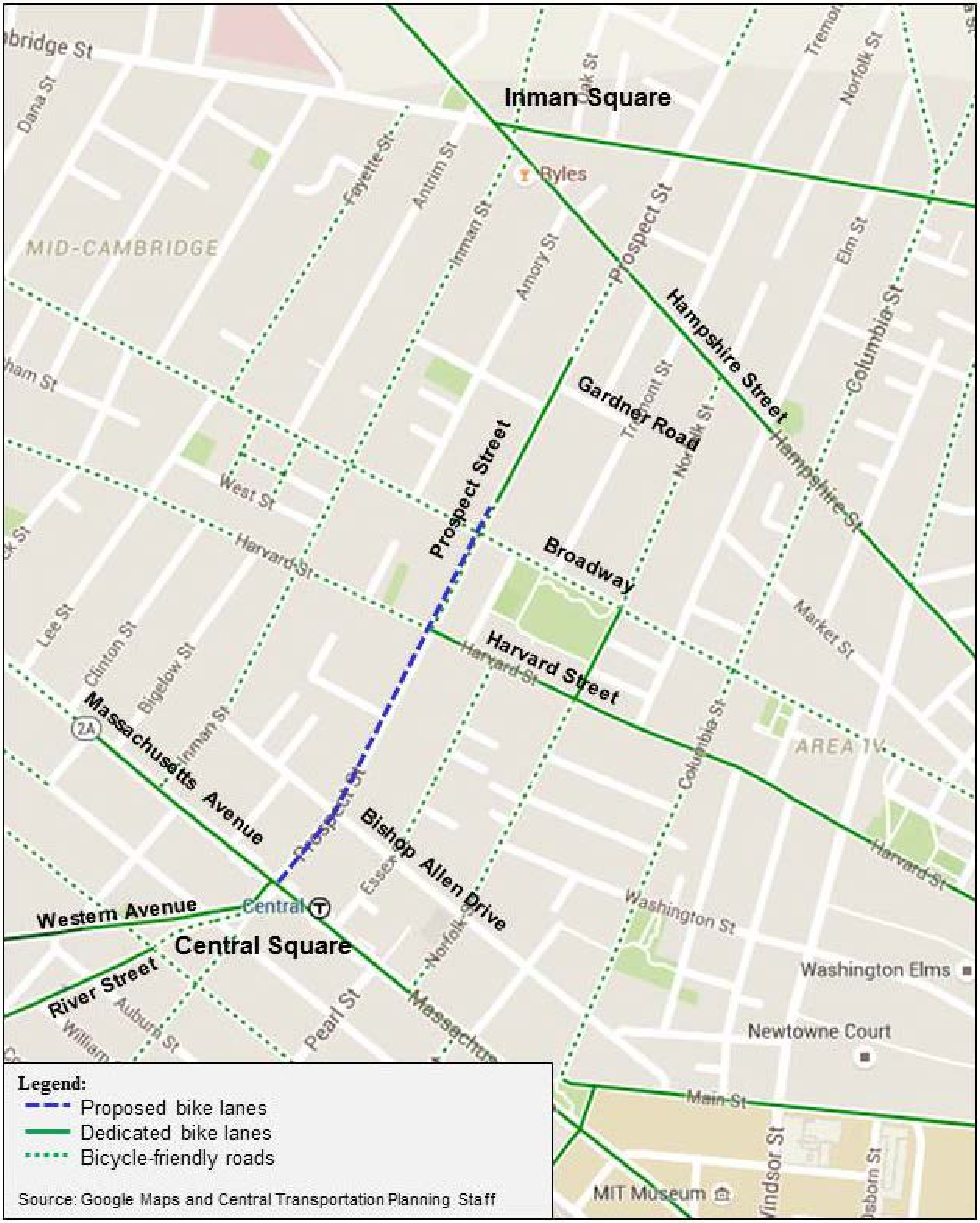

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FIGURE 5
Alternative 1: Bike Lane – Massachusetts Avenue to Broadway

Central Square Gap In Boston Region Bike Network

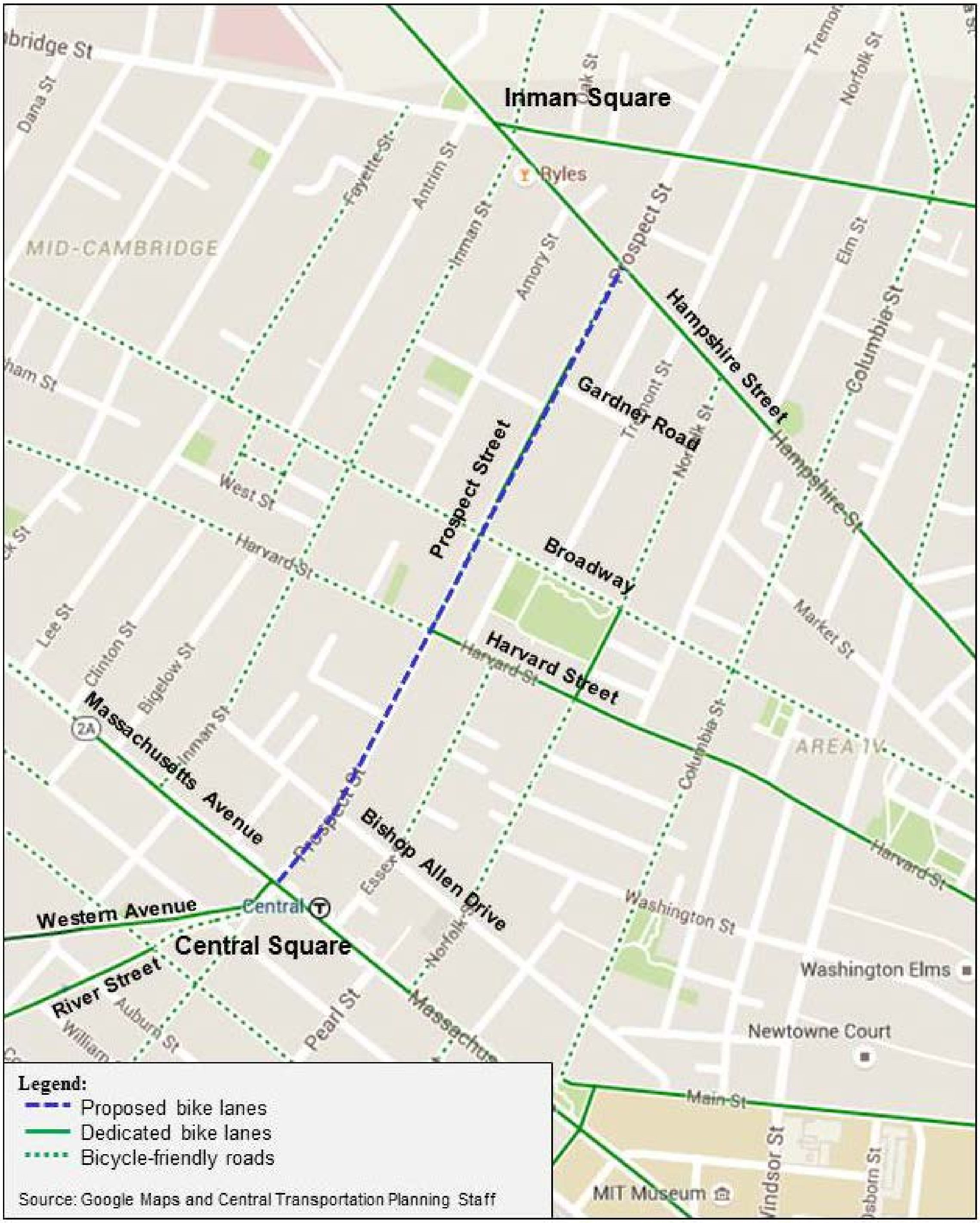

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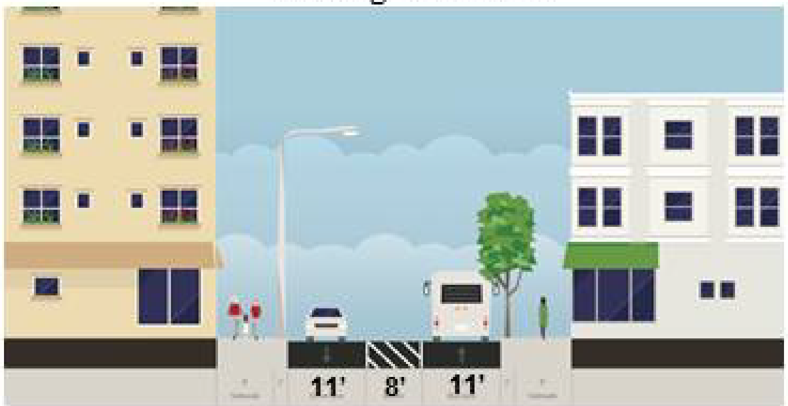
FIGURE 6
Alternative 2: Bike Lane –
Massachusetts Avenue to Hampshire Street

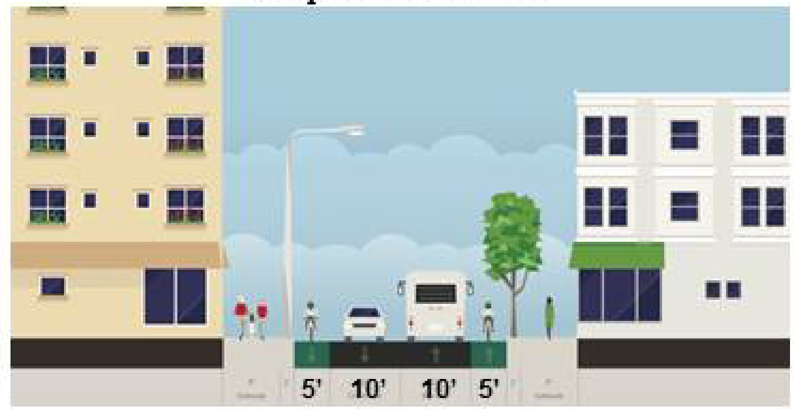
Central Square Gap
In Boston Region
Bike Network

Prospect Street at Massachusetts Avenue

Existing Conditions

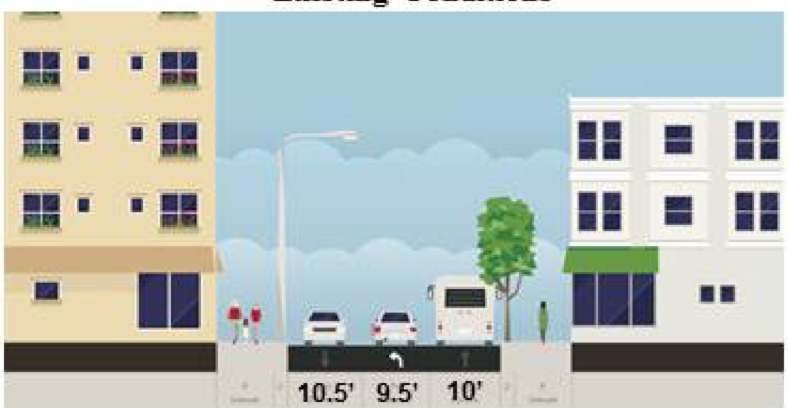


Proposed Conditions



Prospect Street at Bishop Allen Drive

Existing Conditions



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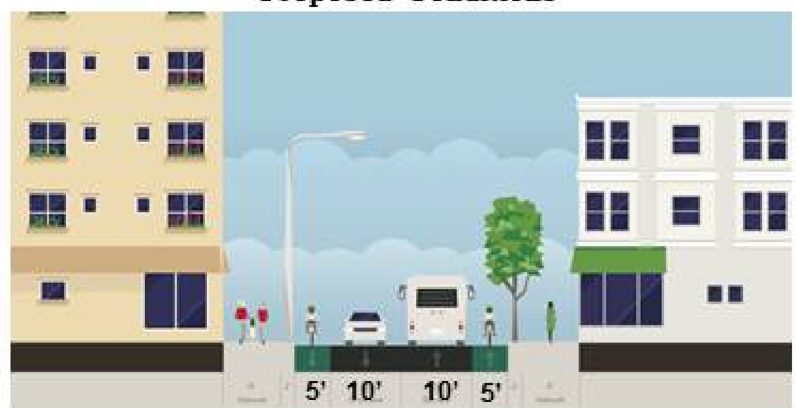

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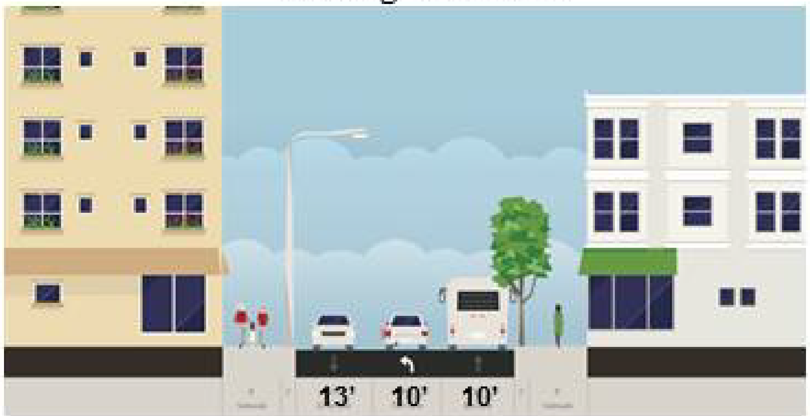
FIGURE 7
Proposed Cross Sections for Alternatives 1 and 2

Central Square Gap In Boston Region Bike Network

Prospect Street at Harvard Street

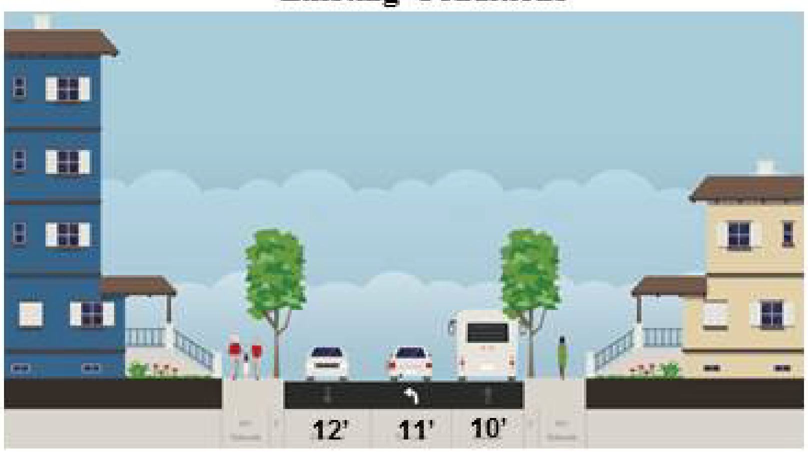
Existing Conditions



Proposed Conditions

Prospect Street at Broadway

Existing Conditions



Proposed Conditions

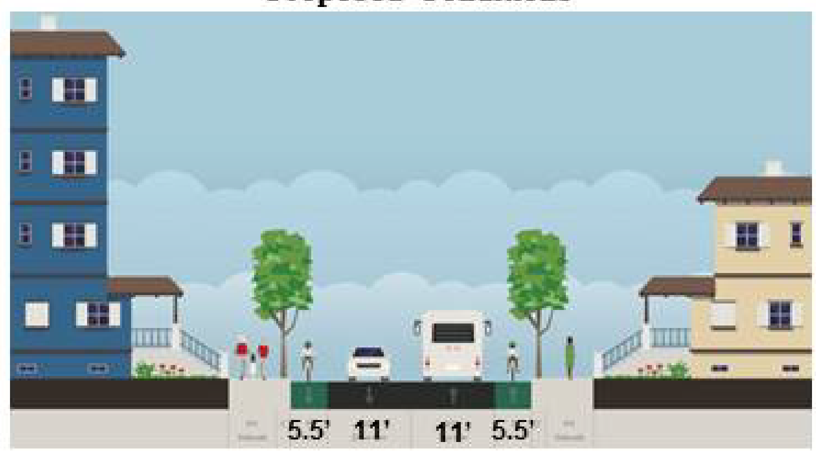


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FIGURE 8
Proposed Cross Sections for Alternatives 1 and 2

*Central Square Gap
In Boston Region
Bike Network*

4 Conclusion and Next Steps

This study offers the City of Cambridge a fresh perspective on Prospect Street—a thoroughfare that is well used by drivers, pedestrians, bus riders, and bicyclists—and proposes alternatives for improvement. This study examined the potential to close the Central Square bicycle network gap. However, based on this evaluation, staff recommends that neither improvement alternative—add a bicycle lane, and remove left-turns lanes along Prospect Street—be implemented at this time. Staff recommends re-examining these improvement alternatives once Cambridge has completed its planning efforts at Inman Square, River Street, and Central Square.

In the meantime, staff recommends that improvements be made to the existing signed bicycle route that directs travel through Central Square to Inman Square. These improvements include adding shared lane markings to roadways along the route without allocated separate travel ways for bicyclists, such as bike lanes; creating an additional southbound branch of the signed bicycle route along Western Avenue, in addition to the Magazine Street route; adding wayfinding signage at identified locations; improving clarity for both bicyclists and motorists of turning maneuvers where the signed bicycle route changes from one street to another; and improving crossings at busy, unsignalized intersections.

MSA/cmc

Appendix A—Improving Prospect Street

A1 Prospect Street

Constructing bicycle facilties on Prospect Street would directly close the Central Square bicycle network gap, so analysis of the gap began there. Prospect Street is a locally controlled, two-lane, two-way arterial roadway that connects Central Square to Inman Square.

Prospect Street intersects Massachusetts Avenue at Western Avenue and River Street in Central Square, and intersects Hampshire Street near Inman Square. Massachusetts Avenue and Hampshire Street currently have conventional bike lanes in place. Both of these intersections are signalized. Between Massachusetts Avenue and Hampshire Street, Prospect Street crosses three more signalized intersections at Bishop Allen Drive, Harvard Street, and Broadway. Exclusive left-turn lanes are present on Prospect Street at Bishop Allen Drive, Harvard Street, Broadway, and for the northbound leg of the Hampshire Street intersection. Because of the narrow right-of-way, in order for bicycle lanes to be added, the left-turn lanes on Prospect Street at the signalized intersections would need to be removed.

The roadway, functionally classified as a principal arterial, is part of the National Highway System (NHS), and thus is eligible for federal funds provided for the program. Prospect Street features two 10-to-13-foot-wide travel lanes in each direction and 8-to-10-foot continuous and connected sidewalks on both sides of the street. Bicycle lanes are present for roughly half of the distance between Broadway and Hampshire Street. Bus stops are present at multiple intersections, serving Routes 64, 68, 83, and 91. No on-street parking is present on this stretch of Prospect Street. The right-of-way is generally 50 feet. The posted speed limit is generally 30 miles per hour in both directions and it is not affected by school zones.

Level of Traffic Stress

The Level of Traffic Stress (LTS) methodology[6] from the Mineta Transportation Institute is used to understand how stressful a street is for biking and to suggest how many people would be comfortable biking on a given road. The lower the LTS on a four-point scale, the more suitable the street for people interested in biking. LTS considers the following criteria:

[6] M. C. Mekuria, P. G. Furth, H. Nixon, 2012, Low-Stress Bicycling and Network Connectivity, Mineta Transportation Institute, MTI Report 11-19.

- Presence of bike lanes
- Number of through lanes
- Presence of parking lanes
- Sum of bike lane width and parking lane width
- Speed limit or prevailing speed
- Bike lane blockage
- Residential classification or presence of center lines

Roadways scoring LTS 1 are most comfortable for biking and suitable for almost all cyclists, including children, who can safety cross intersections. Low-speed residential streets with minimal vehicular traffic may score LTS 1, as will street with greater vehicular speeds or traffic volumes, but which provide physically protected bike lanes. Roadways scoring LTS 4 present the highest levels of stress for bicyclists. Streets with no bike lanes and a 35 mph or higher speed limit would score LTS 4, as would streets with bike lanes and 40 mph or higher speed limits. (See Table A-1)

Bicycle Level of Comfort

The City of Cambridge has developed a similar methodology to assess how comfortable a street is for biking, the five-point scale Bicycle Level of Comfort (BLC) [7], which is based on LTS. BLC uses streets' average daily traffic (ADT) to determine scores on streets without bike lanes, where bicyclists must share travel lanes with motor vehicles. It considers the effect of ADT upon "operating space stress" on one-way streets with parking on both sides and no bike lanes; and "bus frequency stress" is also considered. (See Table A-2 below for descriptions of roadways for each BLC level.)[8]

Currently, Prospect Street scores LTS 3 and BLC 4, which indicates that it presents a moderate-to-great amount of traffic stress and may be uncomfortable for many, or most, bicyclists. Prospect Street contains constant motor vehicle traffic, with no bike lane; and steady bus traffic—9.5 buses per hour, 4.75 buses per hour in each direction—makes frequent stops near the Bishop Allen Drive, Harvard Street, and Broadway intersections.

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[7] Toole Design Group, 2015, Cambridge Bicycle Network Plan, Appendices, City of Cambridge.
[8] Toole Design Group, 2015, Cambridge Bicycle Network Plan, Chapter 5: Creating a Bicycle Network Vision, City of Cambridge.

TABLE A-1
Levels of Traffic Stress (LTS)

LTS 1	Presenting little traffic stress and demanding little attention from cyclists, and attractive enough for a relaxing bicycle ride. Suitable for almost all cyclists, including children trained to cross intersections safely. On links, cyclists are either physically separated from traffic, or are in an exclusive bicycling zone next to a slow traffic stream with no more than one lane per direction, or are on a shared road where they interact with only occasional motor vehicles (as opposed to a stream of traffic) with a low speed differential. Where cyclists ride alongside a parking lane, they have ample operating space outside the zone into which car doors are opened. Intersections are easy to approach and cross.
LTS 2	Presenting little traffic stress and therefore suitable to most adult cyclists but demanding more attention than might be expected from children. On links, cyclists are either physically separated from traffic, or are in an exclusive bicycling zone next to a well-confined traffic stream with adequate clearance from a parking lane, or are on a shared road where they interact with only occasional motor vehicles (as opposed to a stream of traffic) with a low speed differential. Where a bike lane lies between a through lane and a right-turn lane, it is configured to give cyclists unambiguous priority where cars cross the bike lane and to keep car speed in the right-turn lane comparable to bicycling speeds. Crossings are not difficult for most adults.
LTS 3	More traffic stress than LTS 2, yet markedly less than the stress of integrating with multilane traffic, and therefore welcome to many people currently riding bicycles in American cities. Offering cyclists either an exclusive riding zone (lane) next to moderate-speed traffic or shared lanes on streets that are not multilane and have moderately low speed. Crossings may be longer or across higher-speed roads than allowed by LTS 2, but are still considered acceptably safe to most adult[s].
LTS 4	A level of stress beyond LTS 3.

Source: Mineta Transportation Institute.

Table A-2
Bicycle Level of Comfort (BLC)

BLC 1	Places where only people on bicycles or foot are allowed, like off-street paths or separated bicycle facilities; quiet neighborhood streets with only occasional vehicular traffic travelling at low speeds.
BLC 2	Neighborhood streets with some traffic, not travelling too fast; bike lanes against the curb; wide bike lanes on streets without much traffic that make travel predictable for people in cars and on bicycles.
BLC 3	Roads with frequent car traffic that may travel fast at times; bicycle lanes that are often blocked by vehicles – whether trucks making deliveries, cars pulling in an out of parking spaces, or car doors opening into the adjacent bicycle lane; narrow, often one-way, single-lane streets with frequent car traffic that can't pass bicyclists due to parking on either side.
BLC 4	Roads that have fast and/or constant motor vehicle traffic and no bicycle lane; streets with steady bus traffic making frequent stops; bicycle lanes that are often blocked by illegal parking.
BLC 5	Roads designed as highways, meant to carry extremely high volumes of very fast moving motor vehicle traffic travelling between cities.

Source: City of Cambridge,

A2 River Street

A portion of the Central Square gap includes River Street between Franklin Street and Massachusetts Avenue. This 470-foot segment of River Street includes intersections at Franklin Street, Green Street, Magazine Street, and Massachusetts Avenue. River Street is generally a two-lane one-way roadway that carries heavy traffic from Boston to Central Square. ADT is 10,900 between Memorial Drive and Massachusetts Avenue according to the MassDOT Roadway Inventory. An exclusive left-turn lane is added between Franklin Street and Green Street. After the Green Street intersection the two lanes become a through lane and an exclusive right-turn lane. This section of River Street, which has no bike lanes, scores LTS 3-to-4 and BLC 3-to-4; the street presents a moderate to great amount of traffic stress and may be uncomfortable for many, or most, bicyclists.

Adding a bike lane on this portion of River Street would be challenging because of the constrained roadway between the existing curb, median, and traffic islands. Adding a five-foot bike lane would narrow the width of general-traffic or turn lanes to less than 10 feet at some points. The heavy volume of right-turning traffic from River Street onto Massachusetts also poses challenges for the placement of a bike lane. Large turning radii at the intersection of River Street, Western Avenue, Massachusetts Avenue, and Prospect Street could enable northbound and eastbound vehicles to turn right at speeds that could be hazardous for pedestrians or bicyclists.

Taken together, these challenges suggest that accommodating a bike lane on River Street is not a simple task and might require reconstruction, including potential tree removal. A cursory analysis of the local network of one-way streets between the existing River Street bike lane and Massachusetts Avenue does not yield short-term alternative routes that could close this section of the Central Square gap. Alternative routes potentially could be created via contraflow bike lanes and bicycle traffic signals, but also could require removal of parking spaces. Based on the challenges of addressing the lack of bicycle facilities between the end of the River Street bike lane and Massachusetts Avenue, staff decided to focus its limited resources on the portion of the Central Square gap north of Massachusetts Avenue.

A3 SAFETY CONDITIONS

The previous section demonstrated that, from an operations perspective, exclusive left-turn lanes may not be necessary at multiple intersections along Prospect Street, and accordingly, installation of bicycle lanes might be possible. Examining the safety conditions will also inform tradeoffs between the existing left-turn lanes and proposed bicycle lanes. The City of Cambridge would need to balance the potential safety advantages of bicycle lanes and exclusive left-turn lanes when evaluating proposed alternatives for Prospect Street.

A3.1 Crash Summary

Staff obtained and examined crash records from the MassDOT Registry of Motor Vehicles from 2011 to 2013. Between 2011 and 2013, 108 crashes were reported in the segment of Prospect Street between Massachusetts Avenue and Hampshire Street. Table A3 summarizes these crashes.

Table A3
Analysis of Injuries and Total Crashes on Prospect Street

Location Type	Location	Pedestrian Crashes[a]	Cyclist Crashes[a]	Vehicle-Only Crashes[a]	Number of Total Crashes[a]
Intersection	Massachusetts Ave.	2/2	0/2	1/11	3/15
Segment	Mass. Ave. to Bishop Allen Dr.	0/0	0/0	0/1	0/1
Intersection	Bishop Allen Dr.	0/5	1/1	1/9	2/15
Segment	Bishop Allen Dr. to Harvard St.	0/0	0/0	3/7	3/7
Intersection	Harvard St. [b]	0/0	1/2	4/15	5/17
Segment	Harvard St. to Broadway	0/0	0/0	2/2	2/2
Intersection	Broadway	0/1	2/2	2/19	3/22
Segment	Broadway to Hampshire St.[c]	0/1	2/3	1/4	3/8
Intersection	At Hampshire St.[d]	3/3	4/6	1/12	8/21
Intersection	**Total Intersection Crashes**	**5/11**	**8/13**	**9/66**	**21/90**
Intersection	**Intersection Injury Rate**	**45%**	**62%**	**14%**	**23%**
Segment	**Total Segment Crashes**	**0/1**	**2/3**	**6/14**	**8/18**
Segment	**Segment Injury Rate**	**0%**	**67%**	**43%**	**44%**
All	**Total – All Crashes**	**5/12**	**10/16**	**15/80**	**29/108**
All	**Overall Injury Rate**	**42%**	**63%**	**19%**	**27%**

[a] Crash numbers reported in injury crashes/total crashes. [b] Bike lanes are present on the one-way leg of Harvard Street exiting the intersection. [c] Bike lanes are present on part of the Prospect Street segment between Broadway and Hampshire Street. [d] Bike lanes are present on Hampshire Street.

Data available from reported crashes suggests that people biking, walking, or using a wheelchair or mobility device are more vulnerable to injuries in a crash than are people in motor vehicles. Of these three modes, the greatest prevalence of injuries is among bicyclists. Of the 16 reported cyclist crashes, 63 percent involved injuries. Forty-two percent of the 12 pedestrian crashes resulted in injuries, as did 19 percent of the 80 reported vehicle-only crashes. Half of the total number of injury crashes between 2011 and 2013 are vehicle-only crashes, and the other half are bicycle and pedestrian crashes.

Bicycle, pedestrian, and motor vehicle crash clusters eligible for the Highway Safety Improvement Program (HSIP) intersect the bicycle network gap. The intersections of Prospect Street at Massachusetts Avenue, Broadway, and Hampshire Street are each included in large HSIP-eligible bicycle crash clusters located along each of those respective streets. These clusters most likely indicate greater volumes of cyclists rather than greater rates of cyclist crashes. Large HSIP-eligible pedestrian crash clusters include Prospect Street from Gardner Road to Hampshire Street and the intersection of Prospect Street and Massachusetts Avenue. These crash clusters may also be more indicative of greater pedestrian volumes than of greater pedestrian crash rates. A HSIP-eligible motor vehicle crash cluster is located at the intersection of Prospect Street and Harvard Street.

According to MassDOT, signalized intersections in MassDOT District 6, where Cambridge is located, have an average crash rate of 0.70 crashes per MEV.[9] The intersections along Prospect Street appear to have crash rates somewhat higher than the state/district average. The intersection crash rates per MEV for locations along Prospect Street are as follows.

- Massachusetts Avenue: 0.64
- Bishop Allen Drive: 0.83
- Harvard Street: 1.02
- Broadway: 0.92
- Hampshire Street: 1.02

A3.2 Safety Impacts of Bicycle Lanes

Bicycle lanes can reduce crash rates along roadway segments. National Cooperative Highway Research Program Report 766[10] states that bike lanes have a positive impact on safety when compared with unmarked roadways, posting crash reduction rates of 36 and 50 percent.

> Bahar et al. (2008) found that the presence of a bike lane reduces bicycle crashes by 36 percent. This finding is supported by other research. Reynolds et al. (2009) examined the relationship between bicycle infrastructure and cyclist safety through a review of 23 papers from 1975 through 2009. When examining the studies related to roadway segments (rather than intersections), marked bike lanes and bicycle routes were found to reduce crash rates and injuries by about half when compared to unmodified roadways. The safety effectiveness of specific bicycle facility designs was not described by Reynolds et al.

On providing dedicated bicycle lanes on urban arterials, the Highway Safety Manual 2010 discusses the following trends that indicate benefits of bike lanes.[11] The manual does not provide crash modification factors because of a lack of data. Crash modification factors are empirically based measures that quantify the impact of roadway modifications upon crash rates.

[9] Massachusetts Department of Transportation, 2016, Intersection Crash Rates, https://www.massdot.state.ma.us/highway/Departments/TrafficandSafetyEngineering/CrashData/CrashRates/Intersection.aspx.

[10] National Cooperative Highway Research Program Report 766: Recommended Bicycle Lane Widths for Various Roadway Characteristics, 2014, Transportation Research Board, http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_766.pdf.

[11] Highway Safety Manual, 2010, pp. 13-74.

- Providing dedicated bicycle lanes in urban areas appears to reduce bicycle-vehicle crashes and total crashes on roadway segments. However, the magnitude of the crash effects is uncertain at this time.
- Installing pavement markings at the side of the road to delineate a dedicated bicycle lane appears to reduce erratic maneuvers by drivers and bicyclists. Compared with a wide curb lane, the dedicated bicycle lane may also lead to increased comfort for both bicyclists and motorists.

There are not sufficient data to determine how provision of dedicated bike lanes would affect the cyclist crash rate at intersections.

A3.3 Safety Impacts of Exclusive Left-Turn Lanes

Exclusive left-turn lanes can potentially reduce crashes at intersections. The Federal Highway Administration (FHWA) and Highway Capacity Manual (HCM) recommend a crash-modification factor of 0.90 for installing left-turn lanes on one major road approach to a signalized four-leg, urban intersection, which would reduce crashes by 10 percent. The FHWA and HCM recommend a crash modification factor of 0.81 for installing left-turn lanes on both major road approaches to a signalized four-leg, urban intersection, which would reduce crashes by 19 percent. The crash-modification factors for crashes resulting in injuries are 0.91 (a 9 percent crash reduction) for installing left-turn lanes on one major road approach to a signalized four-leg, urban intersection and 0.83 (a 17 percent crash reduction) for installing left-turn lanes on both major-road approaches to a signalized four-leg, urban intersection.

These crash-modification factors apply at intersections where the major road experiences ADT of 7,200-to-55,100 vehicles, and the minor road experiences ADT of 550-to-2,600 vehicles. Massachusetts Avenue, Harvard Street, Broadway, and Hampshire Street exceed the ADT for minor roads, so we do not know how well the crash-modification factors apply to these intersections. Where left-turn lanes are added on only one approach, the HCM notes that “observed variability suggests that this treatment could result in an increase, decrease, or no change in amount of crashes.”[12][13]

Depending on the specific intersection geometry, increased pedestrian exposure to crashes is a potential disadvantage of roadways with exclusive left-turn lanes.[14] We do not know how the presence of exclusive left-turn lanes would

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[12] Highway Safety Manual, 2010, pp. 14-22.

[13] U.S. Department of Transportation (DOT), Federal Highway Administration, 2002, Safety Effectiveness of Left- and Right- Turn Lanes, p. 141.

[14] U.S. DOT, Federal Highway Administration, 2004 Signalized Intersections: Informational Guide, Chapter 12 – Individual Movement Treatments, https://www.fhwa.dot.gov/publications/

affect bicyclists. Nor do we know how removing exclusive left-turn lanes would affect crash-modification factors. However, adding exclusive left-turn lanes could have a proportionate inverse effect on crashes. Because we don't know how the number of crashes is expected to change when exclusive left-turn lanes are removed, adding exclusive left-turn lanes could have the exact opposite effect. Thus, if left-turn lanes were removed at one major road approach to a signalized four-leg, urban intersection, the crash-modification factor might increase to 1.10 (10 percent). Similarly, if left-turn lanes were removed at both major road approaches, the crash-modification factor could increase to 1.19 (19 percent).

A4 EXISTING TRAFFIC OPERATIONS CONDITIONS

In order to determine the impact of installing bike lanes in place of left-turn lanes, MPO staff built a traffic analysis network for the AM and PM peak periods with Synchro 9.[15] The analyses were conducted in a manner consistent with HCM methodology, which describes driving conditions in terms of congestion at signalized and unsignalized intersections with levels of service (LOS) ratings A through F. LOS A represents the best operating conditions (little to no delay), while LOS F represents the worst operating conditions (very long delay). LOS E represents operating conditions at capacity (limit of acceptable delay). (Table B-1 in Appendix B presents results of the existing analyses associated with each LOS for signalized intersections.)

Table A4
Levels of Service and Control Delays at Signalized Intersections

Level of Service	Signalized Intersections Control Delay (seconds per vehicle)
A	≤ 10
B	> 10-20
C	> 20-35
D	> 35-55
E	> 55-80
F	> 80

In addition to the three intersections where left-turn lane removal is proposed, staff analyzed the two intersections to the north and south. (Table B1, in Appendix B presents results of the LOS analysis for existing conditions in terms of delay and queues for each intersection approach and each intersection overall. The five signalized intersections along Prospect Street operate

research/safety/04091/12.cfm#c121 (accessed March 28, 2016).
[15] Trafficware Inc., Synchro Studio 9, Synchro plus SimTraffic, Sugar Land, Texas.

satisfactorily overall during the AM peak period (LOS D or better), although some individual movements operate at LOS E or F. During the PM peak period, the northbound movements on Prospect Street operate at capacity (LOS E) at the intersections of Prospect Street at Massachusetts Avenue and at Bishop Allen Drive; and these intersections as a whole operate at LOS E. The other three intersections operate satisfactorily during the PM peak period.

A5 PROPOSED IMPROVEMENT ALTERNATIVES

MPO staff developed and analyzed the impact of removing left-turn lanes and adding bicycle lanes on vehicular traffic operations for two alternative traffic signal optimization scenarios.

- **Alternative 1**: This alternative adds bike lanes from Massachusetts Avenue through the intersections at Bishop Allen Drive, Harvard Street, and Broadway to connect to the existing bike lane segment on Prospect Street north of Broadway. Alternative 1 closes the majority of the bicycle network gap, but does not address the portion of the gap on River Street or the portion on Prospect Street near Hampshire Street. It also optimizes traffic signal timing to reflect removal of the left-turn lanes.

- **Alternative 2**: This alternative extends the bike lane proposed in Alternative 1 on Prospect Street all the way to Hampshire Street, removing the current northbound left-turn lane at Hampshire Street. Alternative 2 provides continuous bicycle facilities between Central Square and Inman Square, but it does not address the portion of the bicycle network gap on River Street. It also optimizes traffic signal timing to reflect removal of the left-turn lanes.

5.1 Evaluation of Proposed Alternatives

The proposed alternatives were evaluated to verify that they would not only remove the bicycle gap between Central Square and Inman Square, but to ensure that conditions for bicyclists would improve and traffic conditions would operate at acceptable levels.

Level of Traffic Stress

Adding bike lanes would improve the Level of Traffic Stress for bicyclists along Prospect Street to at least LTS 2, with LTS 1 possible in some sections, depending on the width of the bike lane. This score indicates that the street would become suitable for most adult cyclists. Adding bike lanes would improve the Bicycle Level of Comfort score to BLC 3 on most sections of Prospect Street, accounting for bus frequency greater than the citywide average. A few segments of Prospect Street within 100 feet of a bus stop would continue to experience BLC 4 even after bike lanes are installed.

Adding bike lanes on Prospect Street would allow cyclists heading to the Western Avenue Bridge or the River Street Bridge from north of Massachusetts Avenue to avoid biking on Massachusetts Avenue—which has a LTS of 3 despite the bike lane because of the presence of parking spaces, the narrow width of the bike lane and parking combined, and frequent bike lane blockage. Similarly, the City of Cambridge rates Massachusetts Avenue a 4 (out of 5) on its BLC scale, indicating that the roadway is not comfortable for biking for most people.

Within the two alternatives, a range of bike- and travel-lane widths could be considered on Prospect Street near the Harvard Street, Broadway, and Hampshire Street intersections. On the roadway segments near Harvard Street and Broadway, bike lane and buffer widths of 5-to-6.5 feet are possible, with corresponding travel lane widths of 11.5-to-10 feet. Near the Hampshire Street intersection, bike lane and buffer widths of 5-to-7 feet are also possible, with corresponding travel lane widths of 12-to-10 feet. A 5- to 5.5-foot wide bike lane achieves LTS 2 on these sections of Prospect Street. A 6-foot or wider bike lane, or 5-foot wide bike lane with a 1- to 2-foot buffer attains LTS 1. Because of the constrained roadway surface near Massachusetts Avenue and Bishop Allen Drive, a maximum bike lane width of five feet is proposed, along with travel lane widths of 10 feet. A 5-foot bike lane equates to LTS 2 on these sections of Prospect Street.

Traffic Operations

Results of the traffic signal analysis are shown in Table C-1 in Appendix C.

Alternative 1

The results of traffic operations analysis for the five Prospect Street intersections indicate that the intersections operated at LOS C or better (see Table C-1 in Appendix C).The 50th percentile queues do not exceed lane storage lengths. Queue lengths are expected to be equal to or less than the 50th percentile queues half of the time—95th percentile queues may exceed storage length; 95th percentile queues are met or exceeded 5 percent of the time.

Alternative 2

As with Alternative 1, the results of traffic operations analysis for the five Prospect Street intersections indicates that the intersections operated at LOS C or better (see Table C-1 in Appendix C). The 50th percentile queues do not exceed lane storage lengths. Queue lengths are expected to be equal to or less than the 50th percentile queues half of the time—95th percentile queues may exceed storage length; 95th percentile queues are met or exceeded 5 percent of the time.

Appendix B—Existing Traffic Analysis

Table B-1
Peak-Hour LOS, Delay, and Queue for Existing Conditions

Intersection / Approach	Movement	AM LOS	AM Delay	AM 50th Queue	AM 95th Queue	PM LOS	PM Delay	PM 50th Queue	PM 95th Queue	Lane Length
Prospect St. at Massachusetts Ave. River St.:										
Mass Ave EB	T	C	29.9	160	251	C	34.4	133	216	469
Mass Ave EB	R	C	23.9	14	38	C	31.9	20	52	50
Mass Ave WB	T	C	25.6	105	172	D	35.3	141	226	174
Mass Ave WB	R	E	71.6	42	#125	F	190.6	79	#185	100
River St NB	T	C	28.8	207	320	E	77.0	230	355	146
River St NB	R	C	26.5	57	119	C	24.8	72	150	146
Prospect St SB	T+R	E	78.4	287	403	F	87.9	296	m401	276
Total Intersection	**All**	**D**	**44.2**			**E**	**68.8**			
Prospect St. at Bishop Allen Dr.:										
Bishop Allen Dr WB	L+T+R	F	112.4	80	#187	F	116.1	158	#325	544
Prospect St NB	L	B	11.6	8	m10	B	11.1	13	m15	100
Prospect St NB	T+R	D	49.5	287	394	E	78.0	354	m446	276
Prospect St SB	L	B	11.3	26	m35	C	25.6	44	m90	105
Prospect St SB	T+R	B	19.4	278	375	C	26.7	268	370	741
Total Intersection	**All**	**D**	**44.7**			**E**	**66.1**			
Prospect St. at Harvard St.:										
Harvard St EB	L+T+R	C	32.8	150	242	F	113.5	119	#230	474
Prospect St NB	L	B	17.5	17	m30	A	8.1	23	m25	115
Prospect St NB	T+R	C	34.0	337	451	B	17.8	335	m444	741
Prospect St SB	L	B	19.5	14	m26	A	9.6	8	m14	110
Prospect St SB	T+R	C	34.3	295	m407	B	17.0	226	307	347
Total Intersection	**All**	**C**	**33.2**			**C**	**31.7**			
Prospect St. at Broadway:										
Broadway EB	L	B	19.1	11	30	B	19.6	15	39	50
Broadway EB	T+R	D	46.2	231	#405	C	24.1	127	211	472
Broadway WB	L	C	23.7	28	65	C	22.5	37	79	50
Broadway WB	T+R	C	26.0	139	226	D	38.1	256	#442	996

Intersection / Approach	Movement	AM LOS	AM Delay	AM 50th Queue	AM 95th Queue	PM LOS	PM Delay	PM 50th Queue	PM 95th Queue	Lane Length
Prospect St NB	L	C	25.0	40	m56	C	30.3	34	m55	100
Prospect St NB	T+R	D	41.4	292	398	E	68.1	326	#463	347
Prospect St SB	L	A	8.8	3	m4	C	20.2	7	m17	105
Prospect St SB	T+R	B	16.4	254	m353	C	25.4	195	m296	1107
Total Intersection	**All**	**C**	**31.9**			**D**	**40.1**			
Prospect St. at Hampshire St.:										
Hampshire EB	L+T+R	C	26.0	263	408	C	34.4	187	#306	504
Hampshire WB	L+T+R	B	18.0	129	207	D	39.9	225	#385	1012
Prospect St NB	L	C	31.1	65	m94	A	5.8	19	m23	185
Prospect St NB	T+R	C	26.5	218	m304	A	9.4	150	m186	1107
Prospect St SB	L+T+R	D	42.6	243	#411	B	17.1	116	185	358
Total Intersection	**All**	**C**	**28.9**			**C**	**23.9**			

Notes: Delay in seconds per vehicle. Total Intersection Delay is signal delay, rather than the sum of control delay and queue delay. 50th and 95th percentile queue length in feet. # 95th percentile volume exceeds capacity, queue may be longer. m = Volume for 95th percentile queue is metered by upstream signal.

Appendix C—Traffic Analysis for Alternatives 1 and 2

Table C-1
Peak-Hour LOS, Delay, and Queue for Alternatives 1 and 2

Intersection / Approach	Movement	AM LOS	AM Delay	AM 50th Queue	AM 95th Queue	PM LOS	PM Delay	PM 50th Queue	PM 95th Queue	Lane Length
Prospect St. at Massachusetts Ave. and River St.:										
Mass Ave EB	T	C	29.9	160	251	C	34.4	133	216	469
Mass Ave EB	R	C	23.9	14	38	C	31.9	20	52	50
Mass Ave WB	T	C	25.6	105	172	D	35.3	141	226	174
Mass Ave WB	R	E	63.1	42	#125	F	190.6	79	#185	100
River St NB	T	C	26.6	207	320	C	23.3	230	355	146
River St NB	R	C	26.5	57	119	C	24.8	72	150	146
Prospect St SB	T+R	B	17.0	64	145	B	11.5	69	m170	276
Total Intersection	**All**	**C**	**26.0**			**C**	**33.0**			
Prospect St.: at Bishop Allen Dr.:										
Bishop Allen Dr WB	L+T+R	C	28.6	68	137	D	47.1	148	#303	544
Prospect St NB	L+T+R	A	7.9	57	74	B	17.1	117	m#166	276
Prospect St SB	L+T+R	C	28.2	298	406	C	32.6	329	441	741
Total Intersection	**All**	**B**	**19.2**			**C**	**28.5**			
Prospect St. at Harvard St.:										
Harvard St EB	L+T+R	D	38.7	162	#271	D	46.3	117	#220	474
Prospect St NB	L+T+R	C	20.1	334	473	B	19.5	382	m463	741
Prospect St SB	L+T+R	B	10.1	91	m147	A	7.5	102	129	347
Total Intersection	**All**	**C**	**20.2**			**B**	**19.2**			
Prospect St. at Broadway:										
Broadway EB	L	C	21.4	11	32	C	22.4	16	44	50
Broadway EB	T+R	D	51.7	245	#435	C	29.0	137	229	472
Broadway WB	L	C	28.0	30	71	C	27.0	40	86	50
Broadway WB	T+R	C	29.9	148	240	E	55.7	278	#483	996
Prospect St NB	L+T+R	C	22.8	41	#133	C	26.9	84	#518	347
Prospect St SB	L+T+R	B	14.7	265	m358	C	22.7	190	m294	1107
Total Intersection	**All**	**C**	**28.8**			**C**	**33.7**			
Prospect St. at Hampshire St.:										

Intersection / Approach	Movement	AM LOS	AM Delay	AM 50th Queue	AM 95th Queue	PM LOS	PM Delay	PM 50th Queue	PM 95th Queue	Lane Length
Hampshire EB	L+T+R	C	26.0	263	408	C	34.4	187	#306	504
Hampshire WB	L+T+R	B	18.0	129	207	D	39.9	225	#385	1012
Prospect St NB	L	C	26.7	65	m78	A	6.2	18	m21	185
Prospect St NB	T+R	C	23.0	220	m258	A	8.4	110	m133	1107
Prospect St SB	L+T+R	D	42.6	243	#411	B	17.1	116	185	358
Total Intersection	**All**	**C**	**28.0**			**C**	**23.7**			

Delay in seconds per vehicle. Total Intersection Delay is signal delay, rather than the sum of control delay and queue delay. 50th and 95th percentile queue length in feet. # 95th percentile volume exceeds capacity, queue may be longer. m = Volume for 95th percentile queue is metered by upstream signal. Source: Central Transportation Planning Staff.