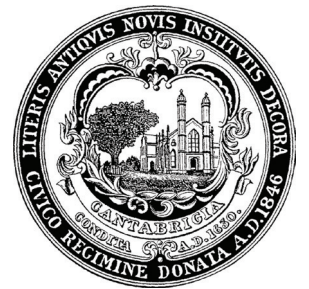


# POST CONSTRUCTION EVALUATION REPORT

## Western Avenue, Cambridge, Massachusetts



January 2019

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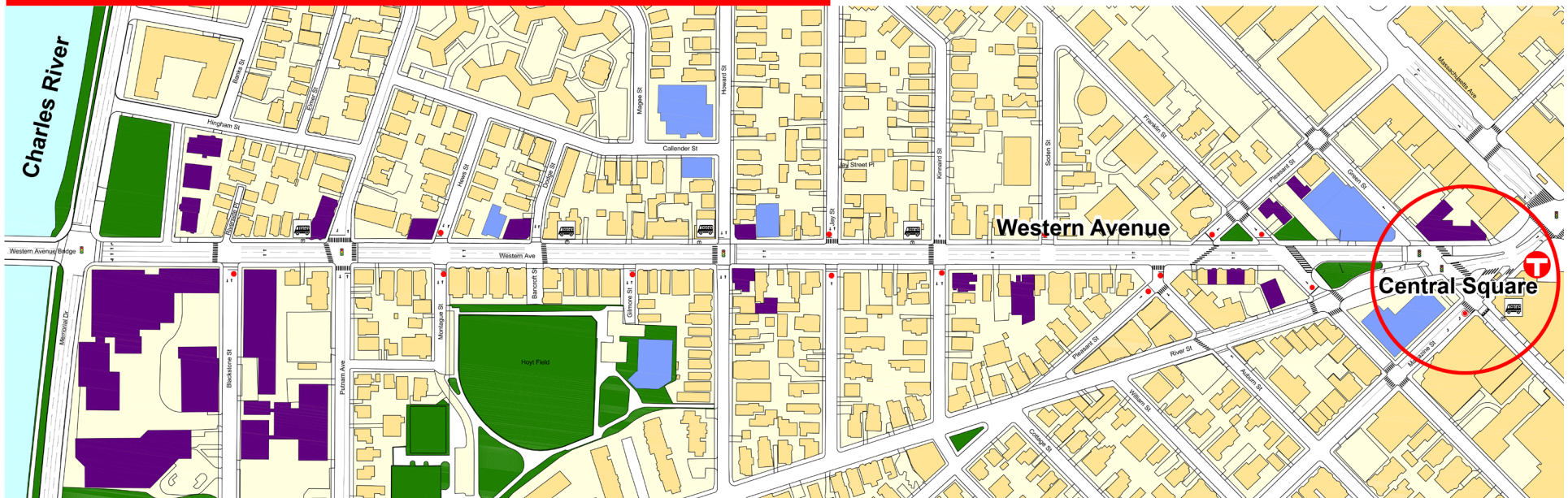


## A. INTRODUCTION

The Western Avenue project was a sewer separation and surface reconstruction project on a 1/2-mile section of roadway southwest of Central Square. The original motivation for the Western Avenue project was to upgrade aging utility infrastructure; but this also provided the opportunity to rethink the surface functionality and character of Western Avenue. Like many urban arterial corridors, Western Avenue had transformed over time from a neighborhood “main street” into a motor vehicle-dominated environment that did not necessarily meet the needs of its abutting residents and other roadway users, including pedestrians, cyclists, and transit riders.



### Existing Conditions of Western Avenue



**Building Uses**  
Residential  
Public  
Commercial

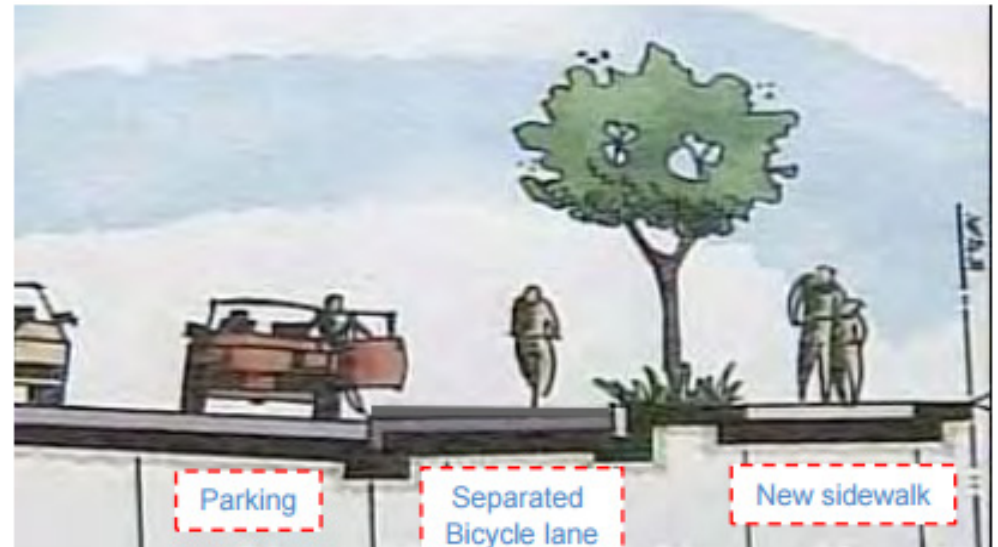
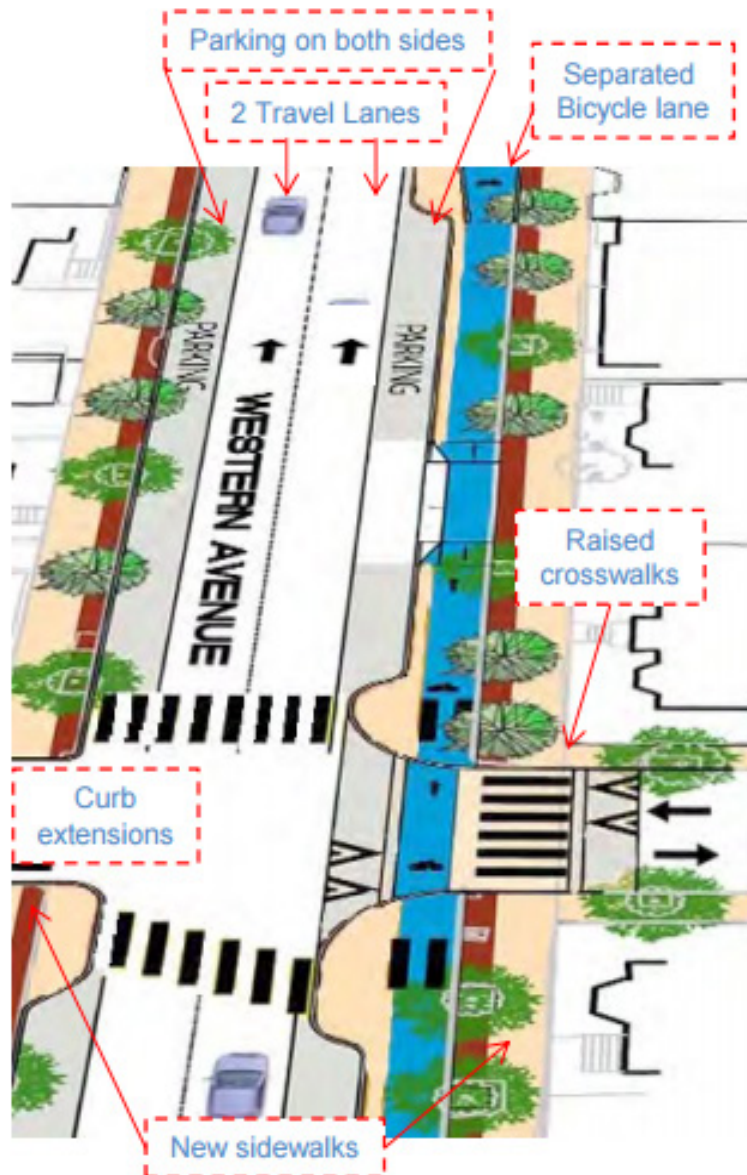


Figure 1: Image from the Western Ave Final Design and Construction Booklet, January 2012



The City of Cambridge began with a community process that launched in early 2010, completed final design during 2011-2012, and constructed the \$15 million project between 2012 and 2016.

The community process for the Western Ave project was intended to be broad-reaching and detailed; it included an appointed advisory committee, public meetings and open houses, and other local outreach events. During the community process, the discussion of issues and potential solutions with stakeholders were placed within the framework of the City's overall policies of increasing safety for all users; promoting sustainability; facilitating bicycle, pedestrian and transit use; and improving residential quality of life. Stakeholders provided the design team with feedback on existing conditions and issues, as well as potential solutions.

A set of community goals for the project developed by the advisory committee served as guiding principles for the potential solutions that were considered in the community and design process. The most notable features of the final project and their related goals are shown for the next several pages with additional details provided throughout the report.

## Community Goals

- A. Ensure corridor is safe for all users
- B. Ensure appropriate traffic speed
- C. Improve conditions for walking, bicycling, and transit riders
- D. Maintain adequate traffic flow
- E. Provide disability access
- F. Improve access to businesses
- G. Provide adequate parking
- H. Improve stormwater management goals through green design
- I. Promote environmental sustainability
- J. Improve landscaping
- K. Reinforce residential character

## Project Elements and Relevant Goals

A “cycle track” (the name in use at the time), now called a grade-separated bicycle facility, provides a key link between the local bike network and the regional Charles River pathway system that connects to Boston and Watertown. People for Bikes chose this project as the 2015 Best New Bike Lane. The separated bicycle facility is pervious asphalt and includes enhanced features like green surfacing at conflict areas, bike signals, and left turn boxes.

**See Goals: A, C, H, F**

Six additional pedestrian crossings across Western Avenue, a more direct pedestrian crossing at Green Street, and improved crossings, including raised crossings on side streets and curb extensions.

In addition, crossings were shortened by the narrowing of lanes from 13' to 10.5'.

**See Goals: A, B, D, E, F**

Expanded linear planting areas, as well as enlarging and upgrading of three key parks and plazas (including Cronin Park), have made Western Avenue a more pleasant community “front yard.”

**See Goals: H, I, J, K**



## Project Elements and Relevant Goals (Continued)

Public art installations, developed with detailed community input, tell and celebrate the rich history of the Riverside Neighborhood, also known as “The Coast.” This included plaques with historical vignettes installed throughout the corridor and a vertical sculpture entitled “Celebrate the Coast” at Cronin Park.

**See Goal: K**



Innovative stormwater infrastructure, including pervious pavement, bio-filtration planters, and hydroslide deflection systems reduce pollutant loading on the Charles River and resolve chronic flooding issues.

**See Goals: H, I**



Bus stop islands with amenities (shelters, benches) so that riders have space to wait outside of the cycle track and sidewalk area, and so that the bus does not have to pull out and back into traffic to pick up passengers.

**See Goals: C, I**





## B. CORRIDOR HISTORY

Western Avenue was first laid in 1824 as Watertown Turnpike, a connection between the heart of Cambridge and its then-rural neighbors. Later, the renamed Western Avenue became a neighborhood main street in its own right for the area now known as Riverside, while still retaining its function as a connector to the west.

The construction of parkways along the Charles River—Memorial Drive and Soldiers Field Road—and more significantly the Massachusetts Turnpike Extension, resulted in a new role and dramatic change in character for Western Avenue. The roadway was changed from two-way to one-way westbound; together with the approximately parallel one-way eastbound River Street, this street became a significant connection between Cambridge, Somerville, and other cities to the regional roadway network. With this new role, Western Avenue lost much of its atmosphere as a neighborhood street. Traffic speed and throughput became a priority, and many of the human-scaled aspects of the corridor were downgraded or lost.

In addition, Western Avenue has functioned as an important public transportation route hosting the former Boston Elevated Railway streetcar surface line connecting Central Square with Watertown Square. Later, the Metropolitan Transit Authority, precursor to the MBTA, ran electric trolleybus services on the same route until March 1961 when the MBTA converted this route's operations to motor bus service. In 1972, the MBTA began to operate through service from Central Square to Waltham. In addition, Western Avenue has hosted other MBTA bus routes

connecting at times Brighton, Boston and Cleveland Circle, Brookline with Central Square.

A survey conducted early in the outreach process for the reconstruction project confirmed the public's increasingly negative perceptions of Western Avenue. The survey responses underscored the neighborhood's feeling that the Avenue once was, and could be again, a major community asset. Many comments specifically noted high vehicle speeds, difficulties in safely crossing the street, concerns about safety while biking, and a general deterioration in the physical roadway, sidewalk and streetscape infrastructure. Survey respondents believed this had contributed to a lack of investment in, and deterioration of, many abutting structures and properties.

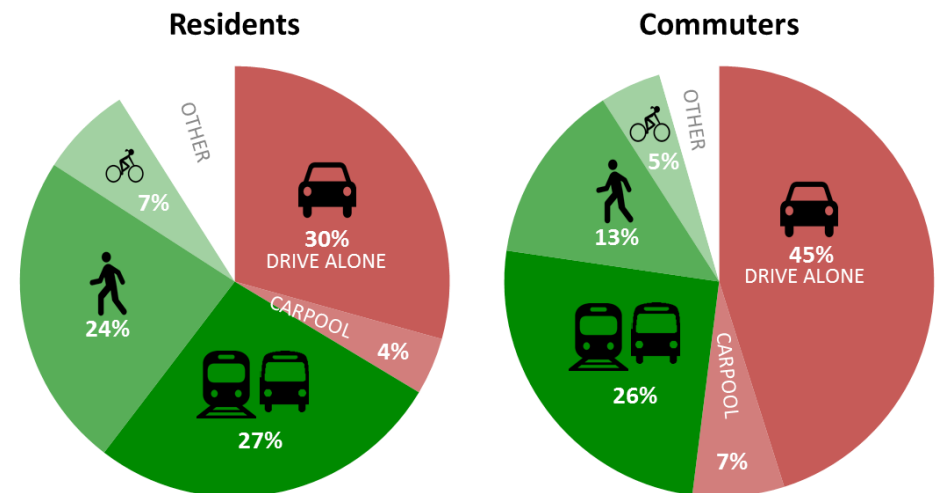


Figure 2: How People Commute to and from Cambridge.

There was also a sense of disconnect between a roadway which had come to function largely as a route for through vehicles, (many of them from outside of Cambridge), and a local populace which increasingly relied on non-auto travel modes such as

walking, biking, and transit. Currently, Cambridge has one of the highest proportions of walk/bike/transit commuting trips in the US – 58% for residents and 44% for non-residents commuting to Cambridge.<sup>1</sup>

<sup>1</sup> Source: 2009-2013 American Community Survey

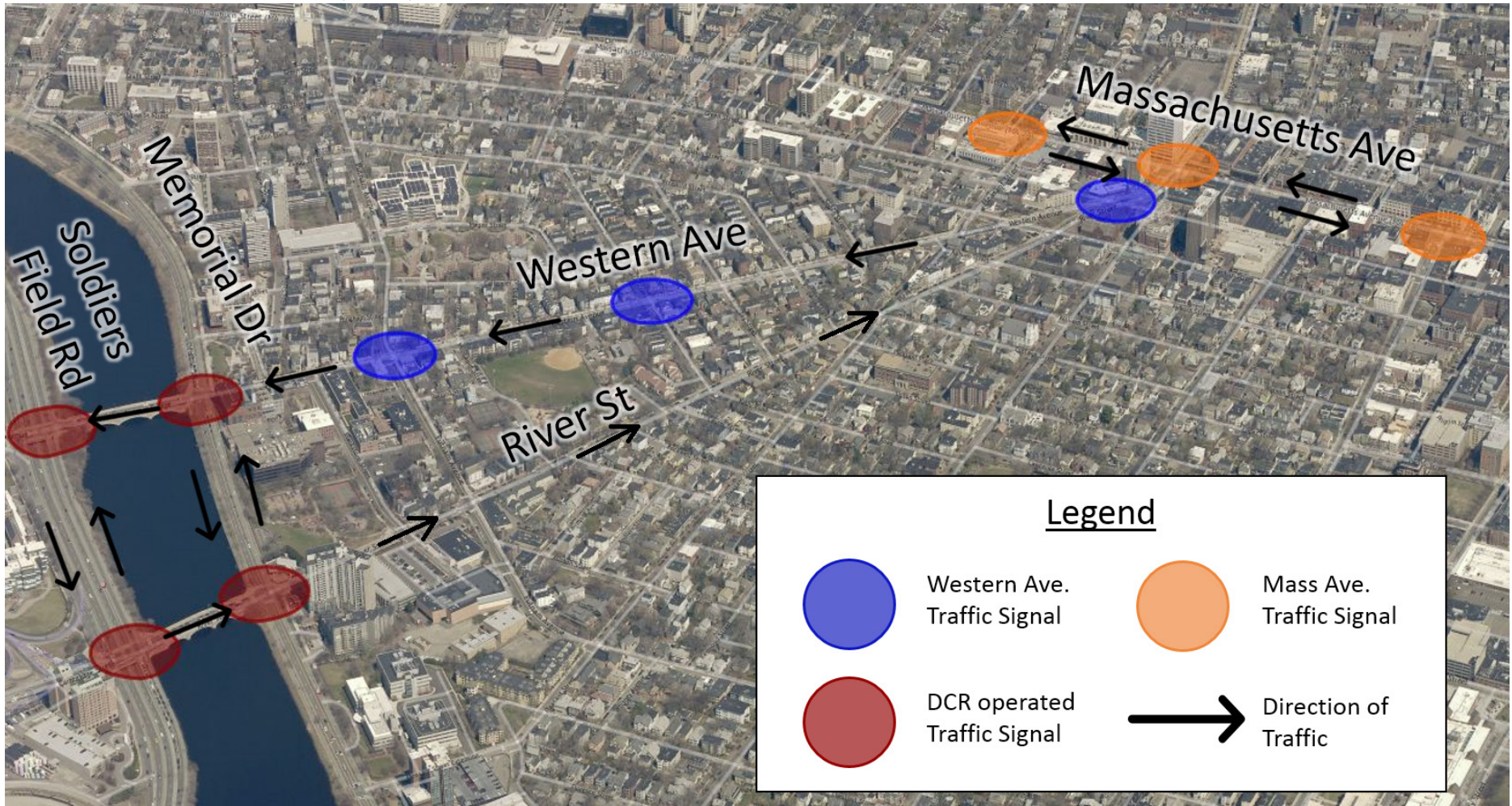


Figure 3: Transportation context of Western Avenue corridor

\*DCR = Massachusetts Department of Conservation and Recreation



## C. PRE-CONSTRUCTION CONDITIONS

The project was a corridor approximately 3,000 linear feet long, that is, just over a half mile—the street segment between the signalized intersection of Western Avenue with River and Green Streets on the east and with Memorial Drive on the west. There were an additional two signalized intersections within the project limits at Howard Street and Putnam Avenue.

Western Avenue lies between Massachusetts Avenue and Memorial Drive and is a one-way pair with River Street. The signals on both Massachusetts Avenue and Memorial Drive are coordinated in a north/south direction disfavoring traffic on Western Avenue. Additionally, the signals at Memorial Drive and Soldier's Field Road are operated by Massachusetts Department of Conservation and Recreation (DCR). Transportation conditions on these regional roadways serve as “bookends” to Western Avenue and influence traffic patterns along the corridor. For example, signal operations along Western Avenue may not be able to compensate for westbound traffic congestion experienced on the corridor due to congestion occurring on the arterial roadways of Memorial Drive or Massachusetts Avenue. Likewise, bus travel times on Western Avenue are impacted by conditions to the east and west of the Western Avenue corridor. Finally, the way that people use bicycles on Western Avenue are influenced by the neighboring streets and the perceived comfort of their bicycling facilities. See pages 25-28 for information on Bicycle Level of Comfort in the corridor.





## (1) Multimodal Accommodation

Western Avenue is a multimodal environment, with pedestrians, cyclists, transit riders, and drivers. Previous to construction, for most of the corridor, the curb-to-curb width was approximately forty-five (45) feet. This was generally allocated, from south to north, as a 7-foot parking lane, two 13-foot vehicle lanes (WB), a 5-foot bicycle lane, and a 7-foot parking lane. See Figure 4 below.

<sup>2</sup> In this area, there is a large landscaped area (Memorial Park) which functions as a median between Western Avenue and River Street. This area does not accommodate pedestrians along its north and south edges.

## Pedestrian Accommodation

### Sidewalks

People walking had sidewalks on both sides of Western Avenue from Green Street to Memorial Drive, except for the south side of Western Avenue between Green and Franklin Streets.<sup>2</sup> Each sidewalk zone was approximately 10 feet wide, consisting of a 6-foot sidewalk and a 4-foot planting/furniture zone.

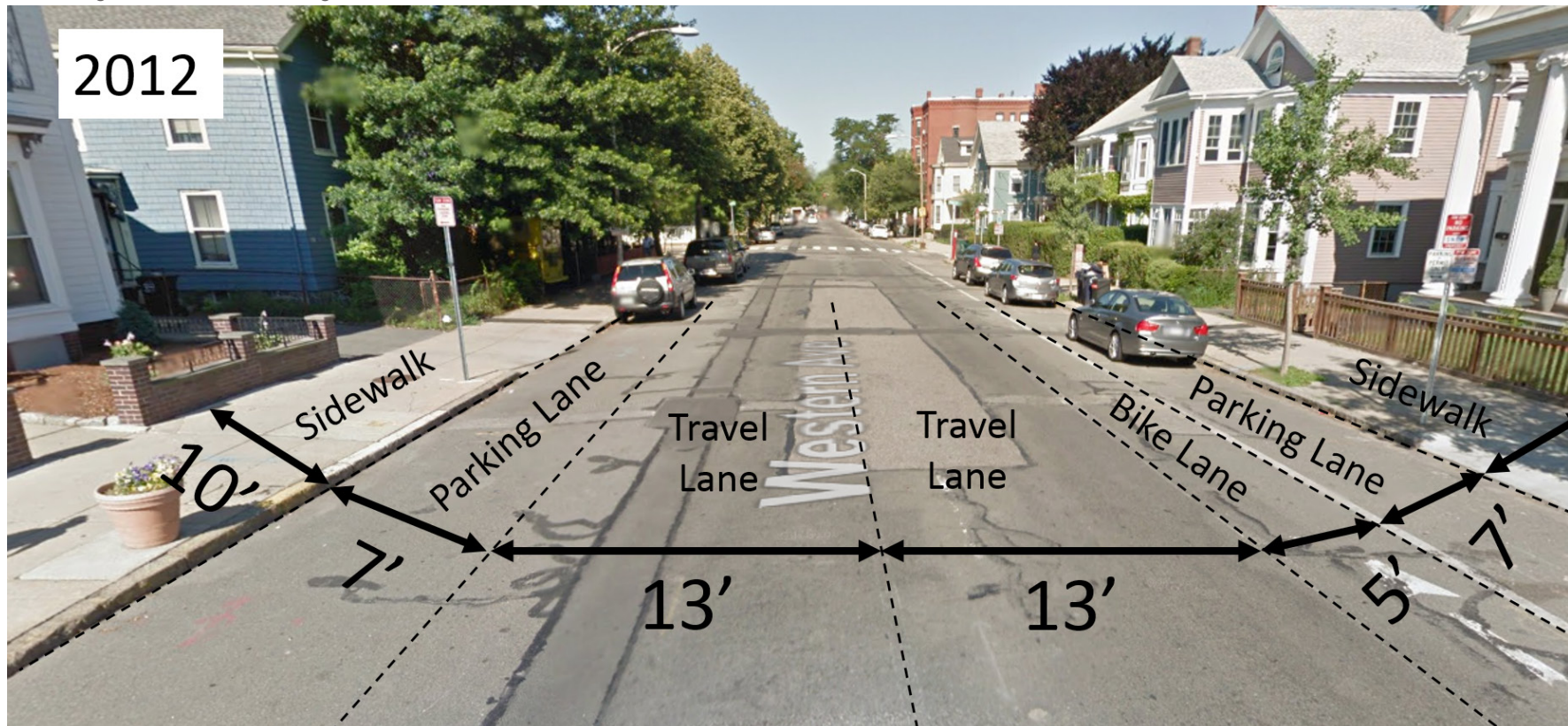


Figure 4: Existing Condition Cross Section in 2012

## Crosswalks

People on foot could cross at all side streets with marked crosswalks within the study area, with two exceptions, the crossings from the:

- Southeast to southwest corners of Franklin Street and Western Avenue
- Southeast to the southwest corners of Memorial Drive and Western Avenue

People on foot could cross Western Avenue on both sides each of the signalized intersection, at Green Street, Howard Street, Putnam Avenue and Memorial Drive. At the Green Street intersection, people on foot could cross with auto traffic. At the signalized intersections at Howard Street and Putnam Avenue, people on foot could cross only during an exclusive pedestrian phase. At the Memorial Drive intersection, people on foot could cross either with the Western Avenue westbound traffic or during a brief exclusive pedestrian phase.

At four-way non-signalized intersections, people on foot could cross Western Avenue only on one side of the intersection. However, at Jay Street and at Hews/Montague Street people on foot could not cross at all.

At the T intersections at Soden and Gilmore Streets, people on foot could not cross Western Avenue. However, at Bancroft and (northern) Pleasant Streets, people on foot could to cross Western Avenue on only one side of the intersection.

## Bicycle Accommodation

On Western Avenue, people on bikes had a striped, westbound bicycle lane between Pleasant Street and Blackstone Street. This bicycle lane was approximately five-feet wide between the right-hand travel lane and seven-foot wide parking lane.

On Western Avenue, east of Pleasant Street and west of Blackstone Street, people on bikes shared the travel lanes with motor vehicles. However, there were no indications, like sharrows or “share the road” signage, to indicate this.

## Public Transit Accommodation

### Central Square Hub

Central Square, which is located at the eastern end of the Western Avenue corridor, is a hub for public transportation routes. The Massachusetts Bay Transportation Authority (MBTA) provides numerous bus routes to Central Square and a station on the rapid transit Red Line.

A number of bus routes converge at Central Square, as a result, buses travel in the area on various routings. These routes use portions of Western Avenue, River, Magazine, Green, and Franklin Streets. Given the complex routings, at the same time as the Western Avenue project, Cambridge commissioned a detailed analysis of bus operations through Central Square, which led to preliminary recommendations for improvements to bus operations in Central Square.<sup>3</sup>

<sup>3</sup> The report for this analysis can be found at: <https://www.cambridgema.gov/~media/Files/CDD/Transportation/transitcommittee/2014/CentrSqBusAccCircStudy.pdf?la=en>



## Western Avenue

Of the seven bus routes traversing Central Square, Western Avenue hosts two MBTA bus routes: route 64 connecting Brighton with University Park or Kendall Square and route 70/70A connecting Waltham with University Park. In addition to the bus stops in Central Square, people board buses at the following stops on Western Avenue:

- West of Green Street
- West of Kinnaird Street
- West of Howard Street
- East of Dodge Street
- West of Putnam Avenue

Prior to construction, neither the City nor the MBTA had installed bus shelters at the bus stops outside of Central Square.

## (2) Vehicular Accommodation

Within the project limits, people in automobiles had two travel lanes in the westbound direction. People could park their vehicles at parallel parking spots on both sides of the street from Franklin to Blackstone Streets.<sup>4</sup> Between Blackstone Street and Memorial Drive, there was no parking available; people driving had four lanes—two through-travel lanes, a shared left-through lane, and a short right-turn only lane.

<sup>4</sup> Between Green Street and Franklin Street, parking was provided on the north side only.

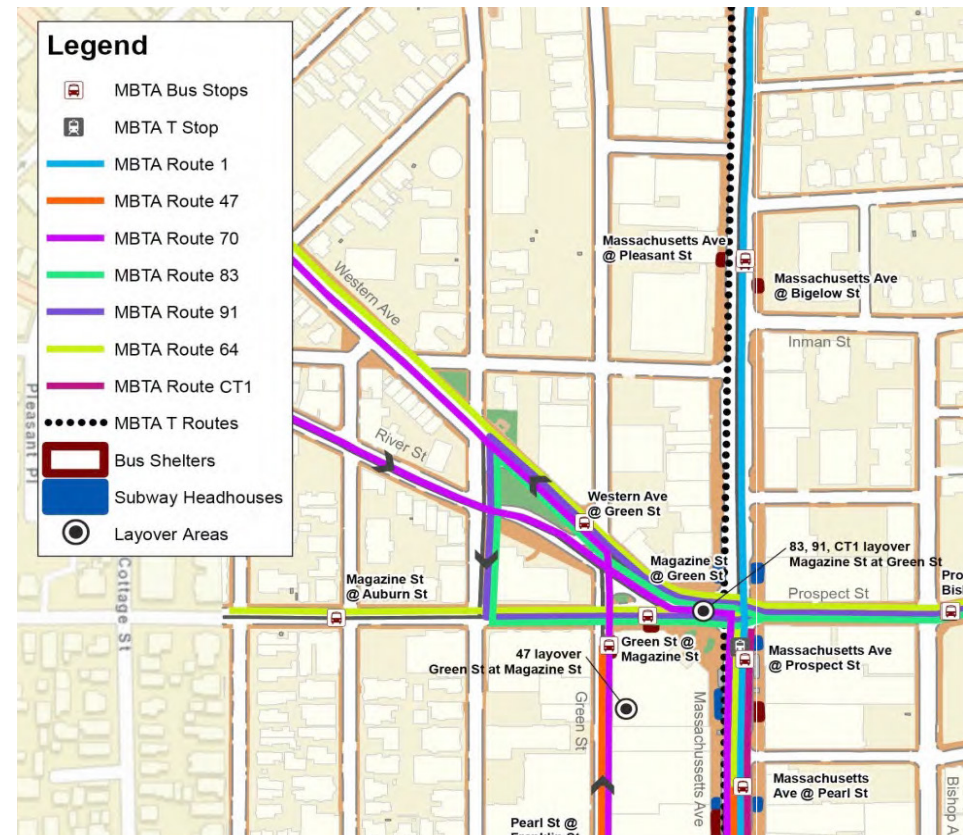


Figure 5: Partial Central Square Bus Route Map

People driving on cross streets had a combination of one- and two-way roadways; all of the cross streets had one travel lane in the allowed direction(s) of travel.

The City and the DCR, respectively, installed traffic control signals at four intersections: Green Street, Howard Street, Putnam Street, and Memorial Drive. Cambridge did not synchronize or otherwise

coordinate these signals along Western Avenue; however at Memorial Drive, the DCR coordinated signals along the Memorial Drive corridor. Cambridge programmed the signal at Green Street with a complex three-phase operation, including concurrent pedestrian crossings. While, at Howard and Putnam Streets, Cambridge programed the traffic signals to have a two-phase vehicular operation and an actuated pedestrian phase.

## D. PUBLIC INVOLVEMENT and PLANNING/DESIGN PROCESS

### (1) Public and Stakeholder Involvement

The Western Avenue project included an detailed public and stakeholder involvement process, collaboratively managed by the City's Community Development and Public Works Departments. The Community Development Department took the lead on the surface design, while the Public Works Department took the lead on subsurface infrastructure design.

Key elements of the public process included the following:

- An **advisory committee** that the city formed with a cross-section of resident and business interests in the project area. This 19-person committee met with city and design team staff eight times between January 2010 and June 2011. The meetings progressed from discussions of existing concerns; establishment of project goals; description of relevant city



policies; presentation of the design *toolbox*; explanation of technical data and analyses; presentation and discussion of alternative conceptual designs; discussions of landscape, urban design, green Infrastructure and public art options; and selection of specific design details. The general public were invited to all advisory committee meetings with a public comment period at the conclusion of each meeting.



- The project team held a series of **five neighborhood walks**. City staff and design team led these informal walks with occasional participation by outside subject experts. Neighbors could learn more about the project and provide specific “on the spot” input to the design team during these neighborhood walks. Each walk had a designated topic: traffic, signals and stop signs; human-centered design and accessibility; landscape and urban design; reviewing the proposed conceptual design alternatives, and ultimately, the preferred design alternative.
- The project team held **six public meetings** during the planning and design phases. The project team held these meetings to gather input from the broader community and to

provide the community an opportunity to “check-in on” the Advisory Committee process and decision-making.

- The project team prepared three **project booklets and flyers** in hard copy and electronic formats. The first publication summarized the project issues, technical information, and design concepts from the first set of Advisory Committee meetings. The project team hoped for additional input prior to selection of a final preferred alternative. The second publication focused on the preferred concept, while the third focused on construction impacts.
- The project team engaged in targeted outreach **to business, religious, and community leadership** to understand the needs of their communities throughout the design and construction process. Project staff also attended neighborhood events to distribute information, raise awareness, and solicit input on the project.

City of Cambridge Community Development Department | [westernavenue.info](http://westernavenue.info)



Community  
design process  
June 2010

**Western Avenue Reconstruction**

Figure 6: Cover of the Community Design Booklet



- Project staff also sent a **general mailing** to approximately 4,000 residents immediately prior to project start. This mailing had information to inform the community of the project and to invite participation in the stakeholder process. Approximately 300 people responded and expressed interest in receiving project updates by email.
- Finally, during the **construction phase**, project staff posted updates on the project website updates and communicated by email and mailing flyers. Updates included regular “look-ahead” communications with upcoming construction activities. Project staff put specific emphasis on expected roadway and sidewalk closures, parking changes, overnight and weekend work, and construction work anticipated to cause unusual levels of noise and/or vibration.

## (2) Project Issues and Alternatives Considered

Early in the design process, project staff heard from the public that Western Avenue did not feel safe for vulnerable street users. The width of Western Avenue contributed to people driving at higher than desired speeds, while the long crossing distances at non-signalized locations made it difficult to cross Western Avenue for people on foot. In addition, people on bikes identified that missing segments of the bicycle lane on Western Avenue as important parts of the corridor. People on bikes also identified the location of the bicycle lane within the cross-section as difficult and very uncomfortable for less confident riders with potential for “dooring” incidents and close proximity to large vehicles like trucks and buses.

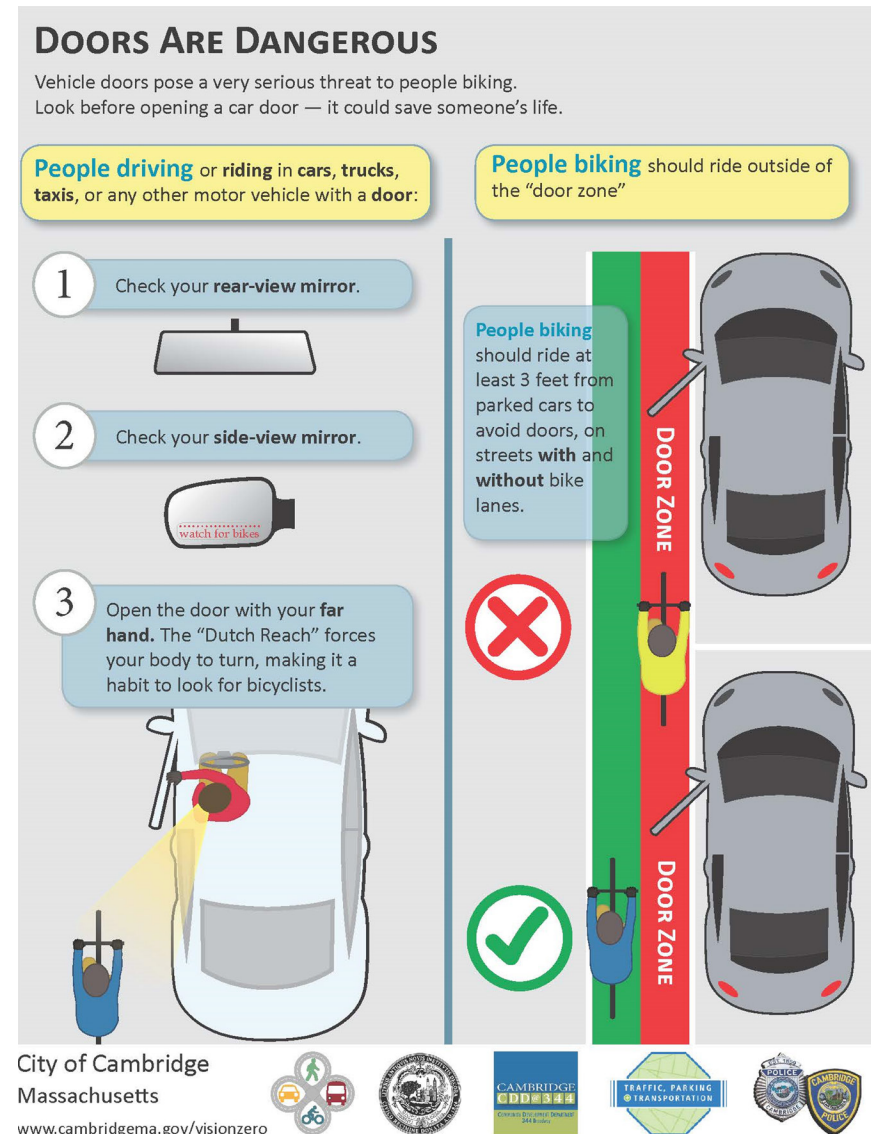


Figure 7: Dooring prevention & avoidance illustration from “Cambridge Street Code: Rules and Etiquette for Getting There Together”, City of Cambridge, MA, USA, p. 9, (2016).

Project staff also heard that MBTA buses using Western Avenue often had trouble pulling from curb-lane bus stops back into traffic, and that people boarding buses often had difficulties as MBTA buses could not often pull to the curb at bus stops. This making boarding especially difficult to disabled and elderly riders. In addition, project staff heard from the public about the lack of bus stop amenities, especially shelters.

To address these and other issues, project staff with input from advisory committee members and the public discussed a number of potential cross-sections. As a result, project staff evaluated and sought public input on five cross sections for Western Avenue.

These cross-sections varied with several different priorities, including:

- One-way versus two-way vehicular traffic
- One lane versus two lanes of vehicular traffic, for all or part of the corridor
- Dedicated turn lanes versus combined through and turn lanes with various signalization strategies
- Parallel versus back-in-angle parking
- Various types and locations of bicycle facilities such as bicycle lanes, separated bicycle facilities of various configurations, and contraflow bicycle facilities

### (3) Preferred Alternative

With information gathered through the public process, project staff selected the preferred alternative that was expected to change the character of the corridor, lower speeds, and provide a separated bicycle facility, additional pedestrian crossings, and opportunities for urban design, landscape, and streetscape improvements.





The preferred alternative had a cross-section that included, as seen in the bottom of Figure 8, a:

- Curb-to-curb roadway width of 36' with two 10.5-foot travel lanes and two 7.5-foot parking lanes<sup>5</sup>
- Six-foot wide one-way grade-separated bicycle facility with a 3' buffer, at sidewalk level
- Ten-foot wide sidewalk on both sides of the corridor including planting areas, similar to the pre-construction condition

In addition, the preferred cross section had other significant improvements incorporated that included:

- Curb extensions at unsignalized crosswalks to shorten crossing distances and improve sightlines for people walking and driving
- Dedicated bicycle signals with a leading bicycle interval, two-stage left turn boxes for bicycles, and green thermoplastic markings at potential conflict areas for visibility
- “Floating” bus stops<sup>6</sup> to speed up bus service, relieve conflicts between people on bikes and buses, provide accessible boarding conditions for passengers who have mobility issues and provide space for shelters and trash cans
- Bus shelters at Green Street and Putnam Avenue and benches at other bus stops

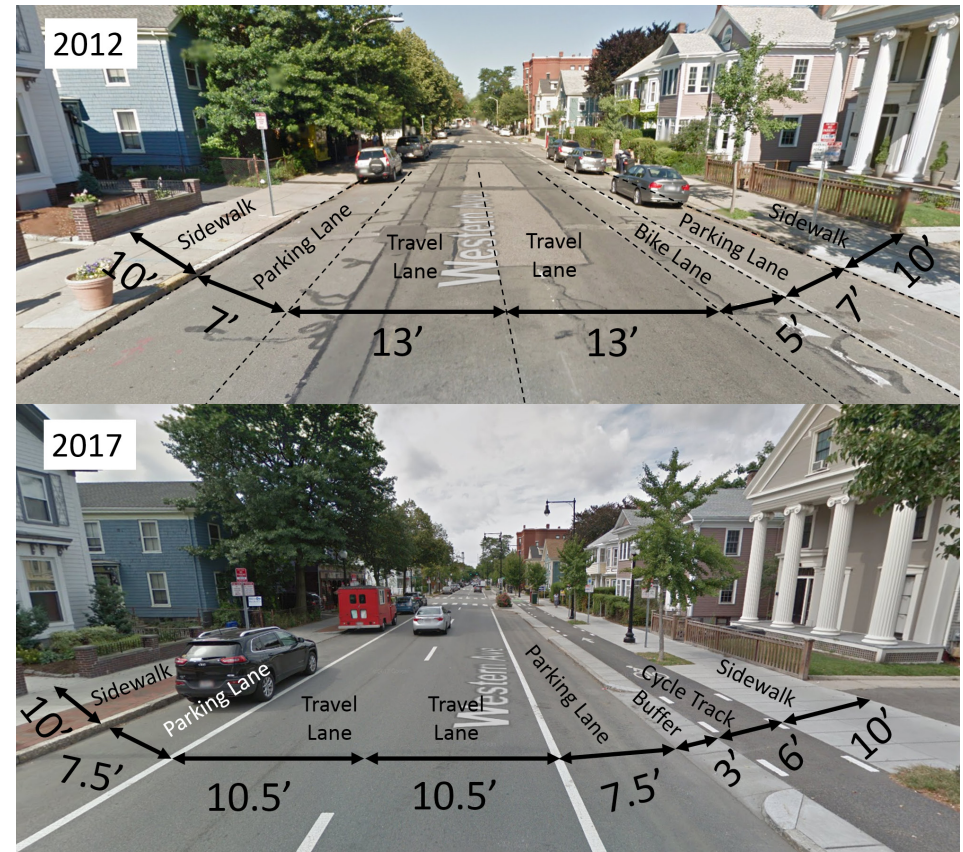


Figure 8: Comparison of Pre and Post-Construction Cross-Section

- Elimination of an infrequently used bus stop at Dodge Street to improve bus operations
- Raised side-street treatments at minor intersections, to emphasize priority for people on foot and bike, resolve

<sup>5</sup> One important exception to the general cross-section was implemented between Green and Pleasant Streets, where traffic volumes were significantly lower than along the remainder of the corridor. In this section a single travel lane was provided, consistent with an existing roadway section immediately upstream. With this change, it was possible to enlarge existing James Cronin Park from 3,300 to 6,500 square feet, and the redesigned open space became a signature feature of the project.

<sup>6</sup> Curb extension bus-stops with a separated bicycle facility bypassing the bus stop zone are sometimes called “floating” as the bus stop area is separated from the pedestrian zone from by bicycle facilities and is “floating” right next to the travel lanes in an area that has typically been used for parking.

accessibility challenges for people with mobility issues, and reduce turning speeds for people in cars

- Six additional crossings for people walking across Western Avenue, an increase from 13 to 19, to provide additional connections to key destinations and provide visual reminders of the pedestrian environment
- Reconstruction and expansion of LED roadway lighting system, and addition of human-scale lighting, with particular emphasis at crossing locations for people on foot to improve conditions for people walking and bicycling and transit users
- Preservation of healthy trees and planting a number of new trees with structural planting soils to promote long-term tree health to improve landscaping along Western Avenue
- Incorporation of pocket parks and landscaped planters, including seating, public art, stormwater features, and rain gardens to improve landscaping and reinforce neighborhood character



- Use of pervious asphalt for the separated bicycle facility, to provide stormwater benefits, promote air and water exchange to trees, and inhibit ice formation and promote more rapid snow melting at the riding surface

Construction began with major utility reconstruction in September 2012, and was completed with final paving in August 2015 and final street markings in 2016.





## E. OPERATIONS AND BEHAVIOR COMPARISON PRE- AND POST-CONSTRUCTION

### Awards & Recognition

In 2014, StreetsBlog named this project as a finalist for the **StreetsBlog Streetsie Award**, for the best urban street transformation in the US.

In 2015, People for Bikes named the Western Avenue protected bike lane as the **best new bike lane** in the US.

This section of the report is a comparison between the pre-construction (2009) and post-construction (2016) condition for all users of Western Avenue—people on foot, on bicycle, in public transit, and in motor vehicles—and includes comparison of operations and behavior. This comparison will help City staff to understand the effects of the various changes and to what extent the preferred design achieved project goals. Though expanded upon in the conclusions, the result of this comparison indicate that Western Avenue accommodates more trips on non-vehicular modes, with significantly higher numbers of people walking, bicycling, and in transit. The analysis also indicates that people walking and biking on Western Avenue are likely to have a better experience as a result of the increased dedicated and separated space. This is seen in increases to two indices, bicycle level of comfort and pedestrian level of service, found in the pedestrian and bicycle subsection. More people driving are driving at the speed limit, which is linked to improved safety for people walking and biking.

It is harder to quantify the experience for people driving and in buses as vehicular analysis shows that queues and travel times for buses and cars during the PM peak hour remain long. Comparing only vehicular operations is also challenging as the roadway was over capacity in both 2009 and 2016, thus a strict comparison of data points may not provide a clear understanding of changes to vehicular traffic operations. In addition, in both the pre- and

post-construction data collection, traffic operations on the regional roadways that connect with Western Avenue, that is Massachusetts Avenue and Memorial Drive, likely affected traffic operations for people in cars and on buses in the project area. Even though data collection efforts targeted a “typical day” in 2009 and 2016 and used similar, comparable methods for data collection, the presence of these regional roadways at both ends of the project area likely influenced traffic operations for people in cars and buses on Western Avenue in ways that the data collection could not measure. This is discussed in more detail in the following sections.

## (1) Safety

### Speed

Post-construction speed data indicates that people are driving more slowly on Western Avenue: the 85th-percentile speed<sup>7</sup> has decreased by up to 25% since 2009. A reduction in speed contributes to safety for everyone. Elements, such as, pedestrian curb extensions, highly visible crosswalks, narrower travel lanes, and visual narrowing of the overall roadway through sidewalk widening and additional landscaping/urban design treatments, may contribute to this speed reduction. The posted speed limit both before and after construction was 25 mph. That 85th-percentile speeds in 2016 were closer to 25 mph suggests that the post-construction condition encourages people to drive at or closer to the speed limit. Figure 9 provides a summary, with additional information on traffic speed found in the technical appendix.

<sup>7</sup> This measure is the speed at or below which 85 percent of vehicles travel during free-flow conditions at the observed locations.

<sup>8</sup> Field work was performed on Wednesday October 12, 2016 between 3:05 and 4:35 pm. Traffic at this location was observed to be relatively free-flowing during non-peak hours, and was not notably influenced by nearby signalized intersections or other factors.

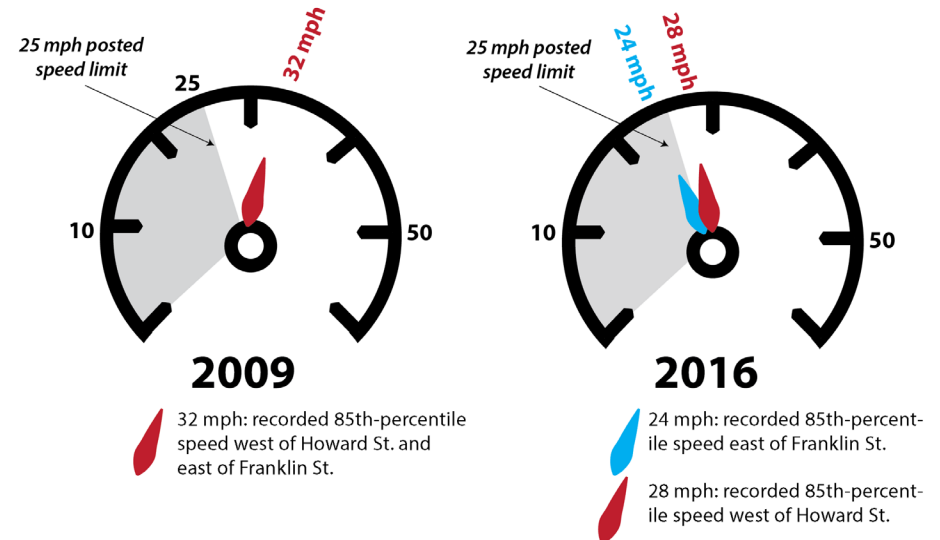


Figure 9: Posted Speed Limit and 85th Percentile Speeds

### Pedestrian Yield Study

While there was no pre-construction evaluation, a pedestrian yield study was performed at the western perpendicular crosswalk at Kinnaird Street for the post-construction condition, comparing the rate of drivers yielding to people on crossing on foot with and without a curb extension. A photograph of the location is found in Figure 10. Additional information on the pedestrian yield study methodology is found in the technical appendix.

Results showed more drivers yielding to pedestrians crossing from the side with curb extensions. Curb extensions appear to improve visibility of pedestrians.<sup>8</sup> As seen in Figure 11, the pedestrian approach from the north side, with a curb extension,



Figure 10: Pedestrian yield study location, Western Ave. at Kinnaird Street

has a higher average rate of motorists yielding to pedestrians waiting to cross (78%) compared to the pedestrian approach from the south side without a curb extension (62%).

People walking across Western Ave from a curb extension are waiting directly adjacent to the vehicle travel lane, putting them in the direct line of sight of people driving, unlike people crossing from an sidewalk without a curb extension. This crossing may be partially obstructed by cars in the parking lane. Curb extensions help prioritize people walking along the corridor with improved visibility and may create safer crossings. This improved safety condition is likely replicated at other curb extensions along the corridor. Additional information on the pedestrian yield study is provided in the technical appendix.

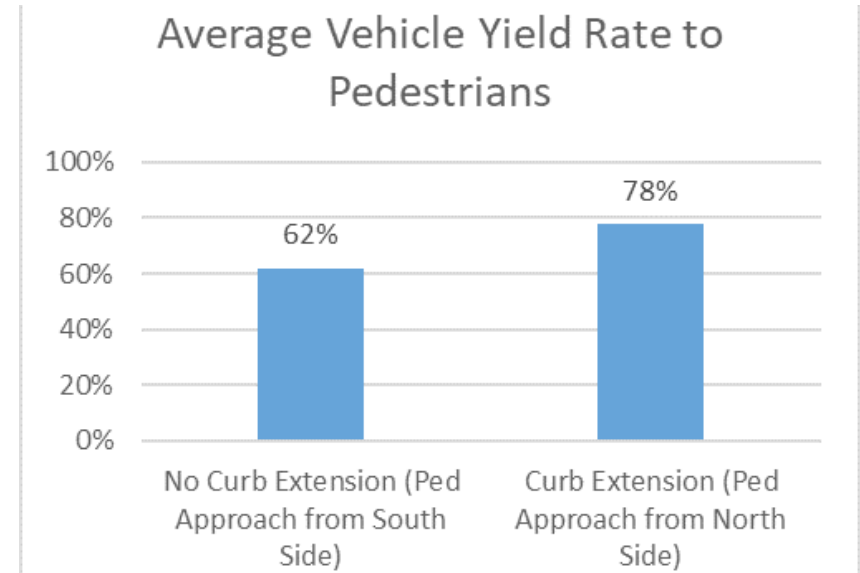


Figure 11: Average Vehicle Yield Rate at Kinnaird Street Crossing

## Crashes

Reported crashes are an important indicator of street safety. However, particularly when the number of reported incidents are low, it can be difficult to draw any statistically valid conclusions over a limited period of time. Safety must be evaluated in the context of establishing a crash rate, i.e., number of crashes with respect to volume, usually translated to a crashes per mile-traveled indicator. As an example, if the number of users increases and the number of crashes remains the same, that would be a decreasing crash rate, which would indicate increasing safety. In lieu of per-mile crash rates, we provide crash and street user counts in the absence of mileage calculations.



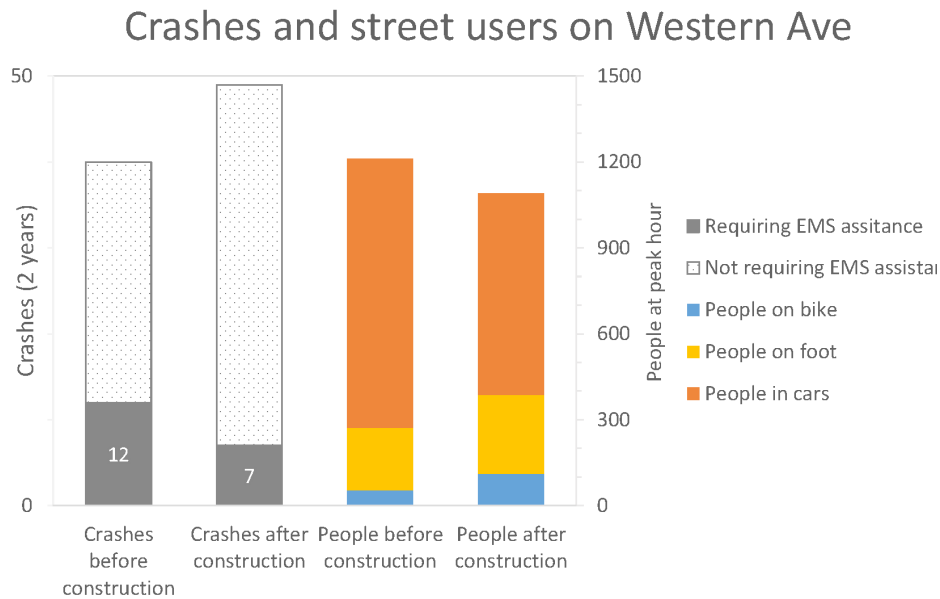


Figure 12: Crashes requiring emergency medical assistance

The Cambridge Police Department (CPD) ran an initial crash analysis for the two years before and after construction, that is, 2011 to 2012 and 2016 to 2017, respectively. CPD kept detailed digital crash records only in the post-construction period; in the pre-construction period, CPD has summary digital crash records.

CPD data indicate that fewer crashes on Western Avenue are severe, as seen in Figure 12. CPD uses a call for emergency medical services (EMS) as a proxy for crash severity; however, it is important to note that not all calls to EMS are for actual injuries. Some EMS calls are made out of an abundance of caution, particularly when people on foot and bike are involved. In the two years before construction, twelve crashes had EMS assistance, while after, seven had EMS assistance. This also holds true

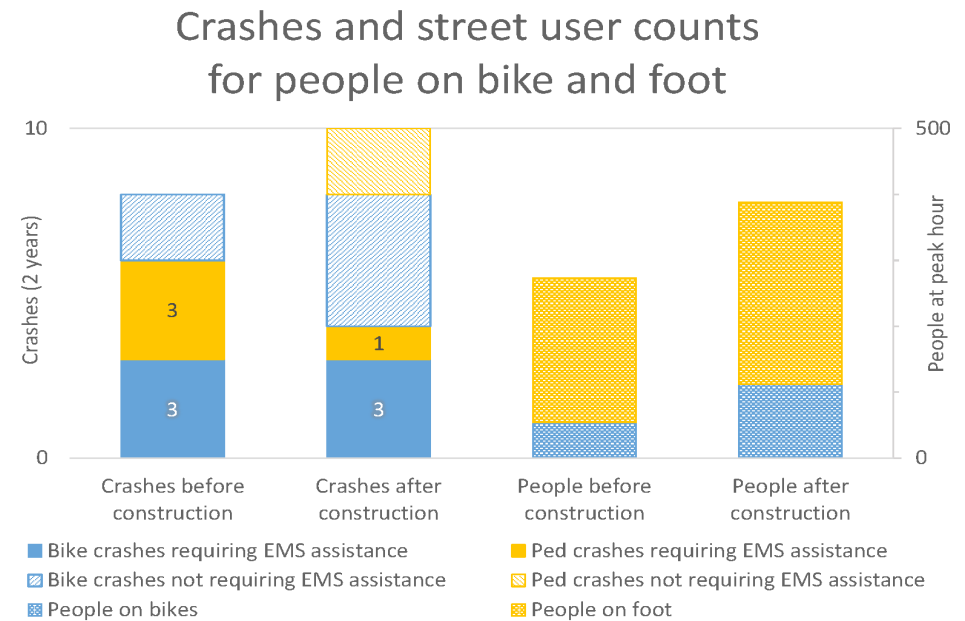


Figure 13: Crashes for people on foot and bicycle requiring assistance

looking only at crashes with people walking and biking; in the two years before construction, six crashes with people walking and biking had EMS assistance, while after, only four, as seen in figure 13.

As mentioned before, examining crash rates are the typical way to analyze changes to street safety; in absence of a calculation of a per-mile crash rate, in both figures 12 and 13, we present counts of people walking and biking for before and after construction to give a sense of how crash rates might have changed. Given that the numbers of people walking and bicycling on Western Ave have increased, but the numbers of reported crashes have not, this would indicate a decrease in the crash rate, and an improvement in safety for those users.

CPD also examined crash location, time of day, seasonality, and motor vehicle size as additional potential factors for crashes. CPD noted that seasonality may be an important factor. In the post-construction period, all of the crashes on Western Avenue between 5:00 PM and 6:00 PM were in spring and autumn. Given that during spring and autumn, sunset aligns with Western Avenue, the CPD suggested that evening sun glare may contribute to crashes on Western Avenue. For additional crash analysis, see technical appendix.

## **(2) Multimodal Analysis**

Since 2009, Western Avenue has become a more multimodal corridor. Data on all users in the corridor from 2016 indicate the following compared to 2009:

- Increase in the number of people walking and biking
- Increase in people riding buses for all routes that travel on Western Avenue
- Increase in total bus boardings at stops on the corridor
- Decrease in the number of cars on the corridor

The increase in people biking is the most striking, ranging from almost double to quadruple the numbers in 2009. A summary of these modal changes seen on Western Avenue can be found in Figure 19 on page 30.

## ***Pedestrian and Bicyclist Demographics***

Project staff collected data on people walking and biking for the post-construction condition to better understand the types of users along the corridor. Though this data was not collected before construction in 2009, with significant improvement in facilities for people walking and biking, like the raised bicycle and pedestrian crossings, curb extensions, separated bicycle facility and bicycle signals, it is likely that less confident and more vulnerable populations such as children, adults with young children, and seniors feel more comfortable walking and bicycling along the corridor.

While it will not be possible to determine the effect that the improvements had on the user mix within the Western Avenue corridor as a result of a lack of pre-construction data, it may prove useful to compare the user demographic mix on Western Avenue with other Cambridge or regional roadways that do not have a similarly protected facility for comparison in other project evaluations.

Figures 14 and 15, next page, illustrate the observed demographics in the post-construction condition. For complete demographic findings and data on bicycle helmet use, see the technical appendix.

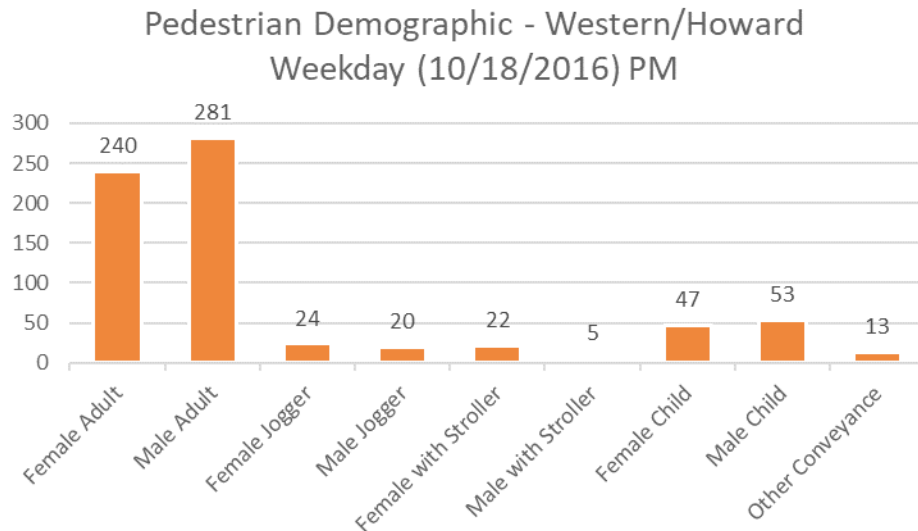


Figure 14: Pedestrian Demographic -- Western/Howard Weekday PM

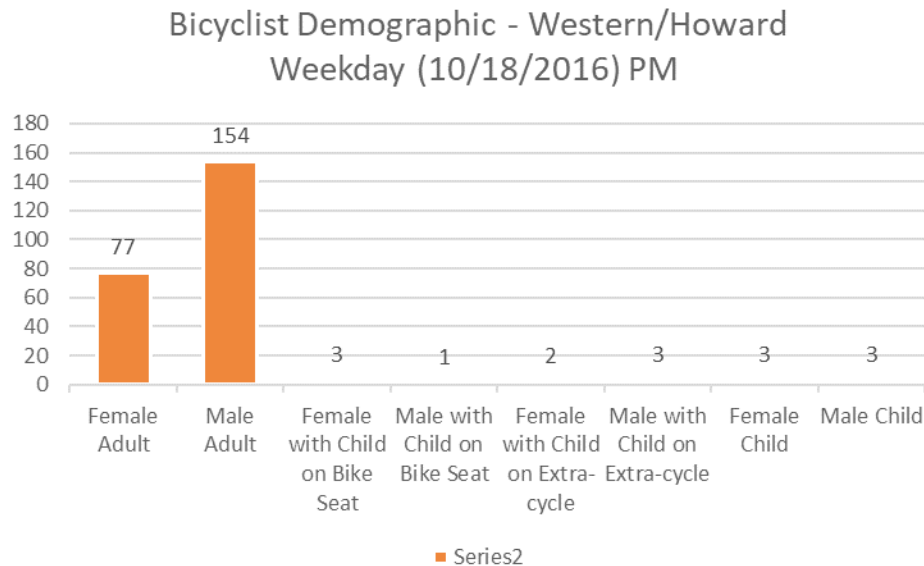


Figure 15: Bicyclist Demographic -- Western/Howard Weekday PM

## Pedestrian and Bicycle Analysis

### Pedestrian Level of Service

Pedestrian Level of Service (LOS) measures the perception of the typical person walking and their experience based on a number of factors including the wait time to cross, the size of the space devoted at street corners, and crosswalk space. It is based on the 2010 HCM multimodal level of service. An LOS A indicates an optimal pedestrian environment, while LOS F indicates the worst environment. Generally, pedestrian LOS has improved at Western Avenue intersections due to increased sidewalk space and enhanced crosswalks. All intersections in the 2016 analysis scored an LOS A or B, as seen in Figure 16, next page. The exception is the intersection of Memorial Drive and Western Avenue where the southern leg of Memorial Drive lacks a crosswalk. In 2009, all intersections except for Western Avenue at Green Street had components with scores lower than an LOS B (2009 methodology detailed in technical appendix).<sup>9</sup>

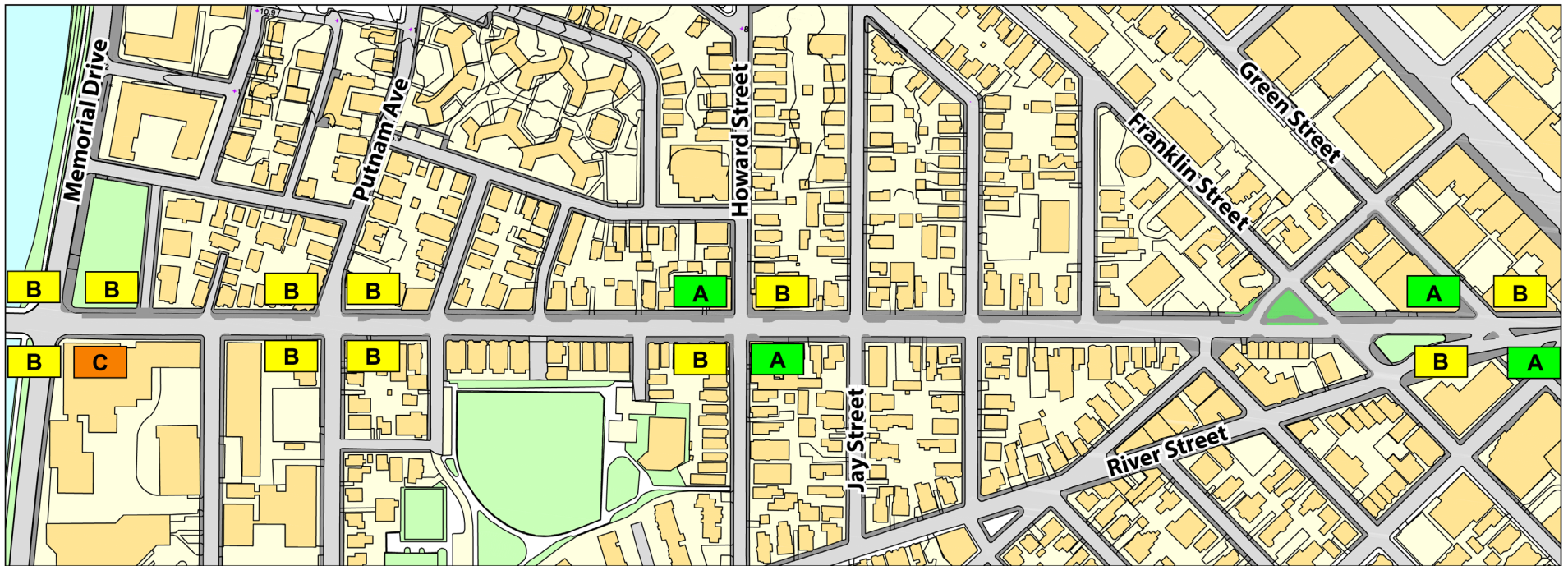
<sup>9</sup> The results between the 2009 and 2016 analyses are not directly comparable, as the 2009 methodology provides LOS for "major" and "minor" streets, as well as separate LOS results for waiting time, corner circulating space and crosswalk space. The methodology used for the 2016 analysis is based on a composite result for these factors.

### Pedestrian Level of Service Factors

- Street corner circulation area
- Wait time and area
- Flow rate of pedestrians arriving to cross
- Pedestrian volumes
- Walking speed to cross street
- Number of travel lanes



## Pedestrian Level of Service 2016



Western Ave Post-Construction Evaluation  
Prepared for the City of Cambridge  
McMahon Associates  
July 2016

Figure 16: Pedestrian Level of Service - 2016

Observations of people walking along the corridor noted that the majority wait to cross with pedestrian signals. The most notable location where people crossed outside of a marked crossing was between Pleasant and Kinnaird Streets (near Soden Street), which is the longest segment without a marked crosswalk. The intersection at Soden Street is also the only significant side street without a crossing across Western Avenue for people walking, suggesting consideration of one in the future. At driveways, it was common for people driving to yield those on foot, indicating the enlarged sidewalk space contributes to safer yielding behavior.

### Eastbound contraflow cyclists

Western Avenue serves as the westbound half of a one-way pair of streets between Central Square and the Charles River, with River Street being the companion street in the opposite direction. People bicycling are expected to use Western Avenue in the westbound direction only, and use River Street for eastbound travel. However, in both the pre- and post-construction years, project staff observed people biking on Western Avenue in both directions including the contraflow direction, i.e. eastbound.

Based on the data collected in 2016, people still bicycle in the contraflow direction on Western Ave, whether legally on the sidewalk or otherwise. However, this does not appear to be occurring more often than in the previous condition. Additional

The 2016 data indicate that approximately 10-20 cyclists per hour, during the peaks as well as Saturday, utilize all, or part, of the Western Avenue corridor in the eastbound, or wrong, direction.

The separated bicycle facility design attempted to reduce unintended cyclist and pedestrian conflicts, sometimes a criticism of separated facilities at sidewalk level like the one here. Elements of the design include:

- Landscaping placed between cycle track and sidewalk area
- Crosswalk markings placed on the cycle track where pedestrians are expected to access crosswalks in roadway or bus stops. The crosswalks raise awareness of potential conflicts and indicate priority for pedestrians

Although some pedestrians were observed walking on the cycle track, the large majority were observed on the sidewalk.

information on the data collection for people bicycling in the contraflow direction is found in the technical appendix.

In the pre-construction condition, Western Avenue had a conventional on-road bicycle lane, approximately 5 feet wide between the parking and travel lane with fair-to-good pavement conditions. On the other hand River Street had a narrower bicycle lane and narrower street cross-section. In addition, the River Street bicycle lane was directly adjacent to the curb, included drainage structures, often had roadway debris, and was in poor-to-fair condition. Because of this disparity, in the pre-construction condition, people bicycling may have chosen to use Western Avenue in the counterflow direction for the better pavement condition and wider street.

With the recent completion of the Western Avenue project, the difference in the quality of bicycle facility between these two streets is even more significant. In some sense, people bicycling may now perceive Western Avenue to be even easier to use in the contraflow direction (i.e. eastbound), as the separated bicycle facility appears to be similar to a off-road or multi-use facility and sufficient width for two cyclists to pass each other. Though the difference is even more significant, there are fewer contraflow cyclists as a percentage of the total cyclists in the post-construction condition. It may be reasonable to expect that the percentage of people bicycling contraflow on Western Avenue will decrease if the River Street bicycle facility is improved.

### Bicycle Level of Comfort

The Cambridge Bicycle Level of Comfort (BLC) Analysis<sup>10</sup> is a planning tool used to quantify the level of comfort that a person bicycling is likely to perceive while riding on any street or path. It is based on the premise that a person's level of comfort on a bicycle increases as separation from vehicular traffic increases and as traffic volumes and speeds decrease. Scoring is based on a "weakest link" methodology. The worst score for each segment is

#### Bicycle Level of Comfort Factors

- Facility type
- Speed limits
- Parking conditions
- Roadway design
- Mixed traffic
- Operating stress
- Bus frequency stress

what determines the segment score. The result of the analysis is a numerical comfort ranking for every street and path in the city, from greatest comfort (BLC 1) to least comfort (BLC 5).

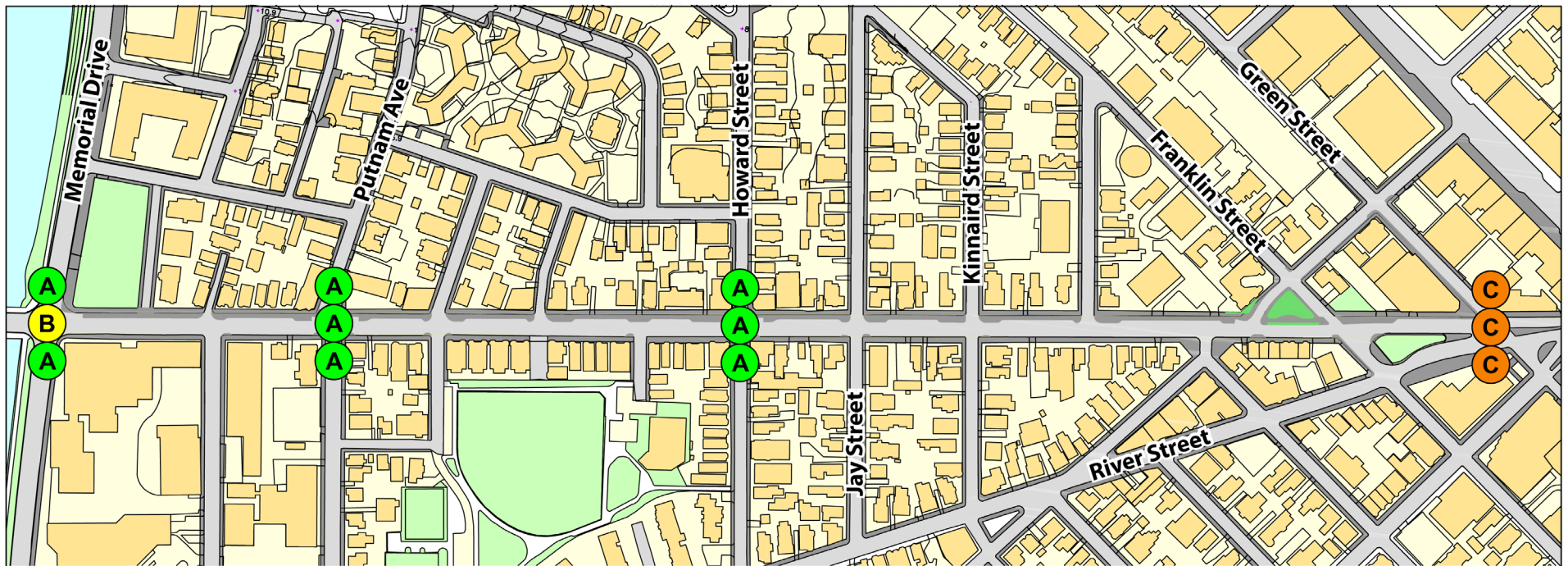
In 2016, Western Avenue, with its separated bicycle facility, scores a BLC 1 (high comfort), from Howard Street to Putnam Avenue, BLC 2 from Green Street to Howard Street, and BLC 4 from Putnam Avenue to Memorial Drive. Green Street to Howard Street scores a BLC 2 due to the on-street bicycle lane from Green Street to Pleasant Street. Putnam to Memorial Drive scores at BLC 4 due to the transition out of the separated bicycle lane and into the right turn lane on Western Avenue, which reintroduces turning and mixed traffic. Overall, the BLC has improved on Western Avenue from 2009 when the entire corridor lacked a separated facility. The BLC was not evaluated in 2009 as it was not a typical methodology in use at that time. However, project staff estimate that the pre-construction condition would likely have scored a BLC 4, if evaluated at the time.

One indication of the value of the separated bicycle facility in improving cyclist comfort is that almost all cyclists observed in the evaluation made use of the separated bicycle facility - very few were observed biking in the travel lanes on Western Ave. Some, but not all cyclists were observed using the turn box to make left turns. One location for further investigation for cyclist safety and comfort is at Putnam Avenue, where vehicles turning right (including those violating the No Turn On Red) block the separated bicycle facility and/or the entire intersection box.

<sup>10</sup> For more information about Bicycle Level of Comfort, please refer to the Cambridge Bicycle Plan: <http://www.cambridgema.gov/CDD/Transportation/bikesincambridge/bicyclenetworkplan>



# Bicycle Level of Service 2016



Western Ave Post-Construction Evaluation  
Prepared for the City of Cambridge  
McMahon Associates  
July 2016

### Bicycle Level of Service

AM  
PM  
SAT

Figure 17: Bicycle Level of Service - 2016

## Bicycle Level of Service

Bicycle Level of Service (LOS) was evaluated along the corridor at four intersections during the AM peak, PM peak, and Saturday midday in 2016. Bicycle LOS is based on the 2010 Highway Capacity Manual (HCM) for multimodal level of service (MMLOS).

In 2016 bicycle LOS was rated an “A”, the highest score, at three of the four intersections for almost all time periods, as seen in Figure 17, previous page. Although this methodology was not used in 2009, this suggests likely improvement from the pre-construction condition. In 2016, the intersection of Green Street and Western Avenue was rated a C where the bicycle facility is not separated and is, instead, an on-street bicycle lane.

## Transit Riders

### Bus Stop Ridership

Bus ridership is evaluated in two ways: the total passenger boardings and exits (alightings) at each stop and the total count of passengers carried (load) in the corridor. For this report, passenger load is the sum of all passengers carried on all routes for the peak hour at the peak passenger load point (see box, left column). On Western Avenue, this includes passengers on MBTA bus routes 64, 70, and 70A.

### Bicycle Level of Service Factors

- Bicycle speed
- Intersection delay
- Conflicts with bicyclists
- Vehicle volumes
- Vehicle speeds

The total number of boardings by stop in 2009 and 2016 is displayed in Figure 18 (next page), as well as the PM peak hour bus passenger load between Kinnaird Street and Howard Street for all routes. As shown in the figure, there was an increase in bus boardings at three of four stops (excluding the Western Ave @ Dodge Street stop that was eliminated to improve stop spacing and travel time) and a higher passenger load during the PM peak hour. Further details on ridership by stop are provided in the technical appendix.

### Peak Passenger Load Point

The point along a bus route at which the largest number of passengers are on the bus.

To provide comparison between pre- and post-construction conditions, several data sources were compiled:

- Central Transportation Planning Staff (CTPS) manual passenger counts from 2006-2007 to establish pre-construction ridership patterns. This data set includes individual stop ridership and passenger loads.<sup>11</sup>
- Automatic Passenger Count (APC) data from Fall 2015 were used for the post-construction condition.<sup>12</sup>
- MBTA schedule cards from Spring 2009 and Spring 2016 to determine changes in service frequency.

<sup>11</sup> Automatic Passenger Counter (APC) data was not available for these routes prior to Fall 2012.

<sup>12</sup> Spring 2016 data was not used, due to data gaps which would make it infeasible to calculate a “typical” day.

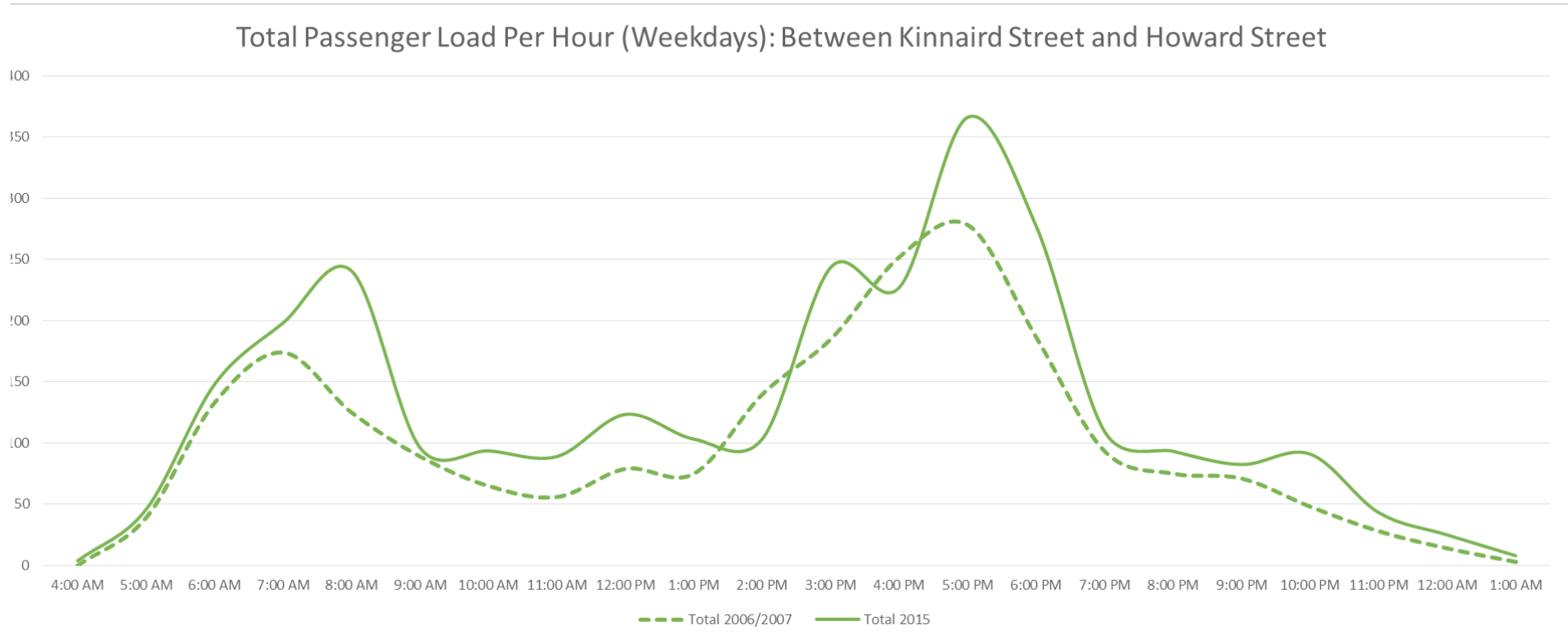


Figure 18: Total passenger load per hour on all routes combined

### Bus Route Ridership

Total ridership on all routes combined (64, 70, 70A) increased significantly from 2006/7 to 2015, from 2,236 to 2,851, or 28%. For all routes combined, the peak passenger load point in both years is between the Kinnaird Street and Howard Street stops.<sup>13</sup>

Figure 19, next page, shows the average weekday passenger load, by hour, between Kinnaird and Howard Streets for all routes

combined. As the graph illustrates, the volume of passengers on the bus at this point along the routes is generally higher in 2015 than it was in 2006/2007. The passenger load increases the most during the morning and afternoon peaks, around 8:00 AM and 5:00 PM. Although an increase in passenger loads signifies an increase in transit passengers, it also means more people along Western Avenue experience the peak hour congestion at these times. While transit trips in the study area increased between

<sup>13</sup> Based on total average daily ridership



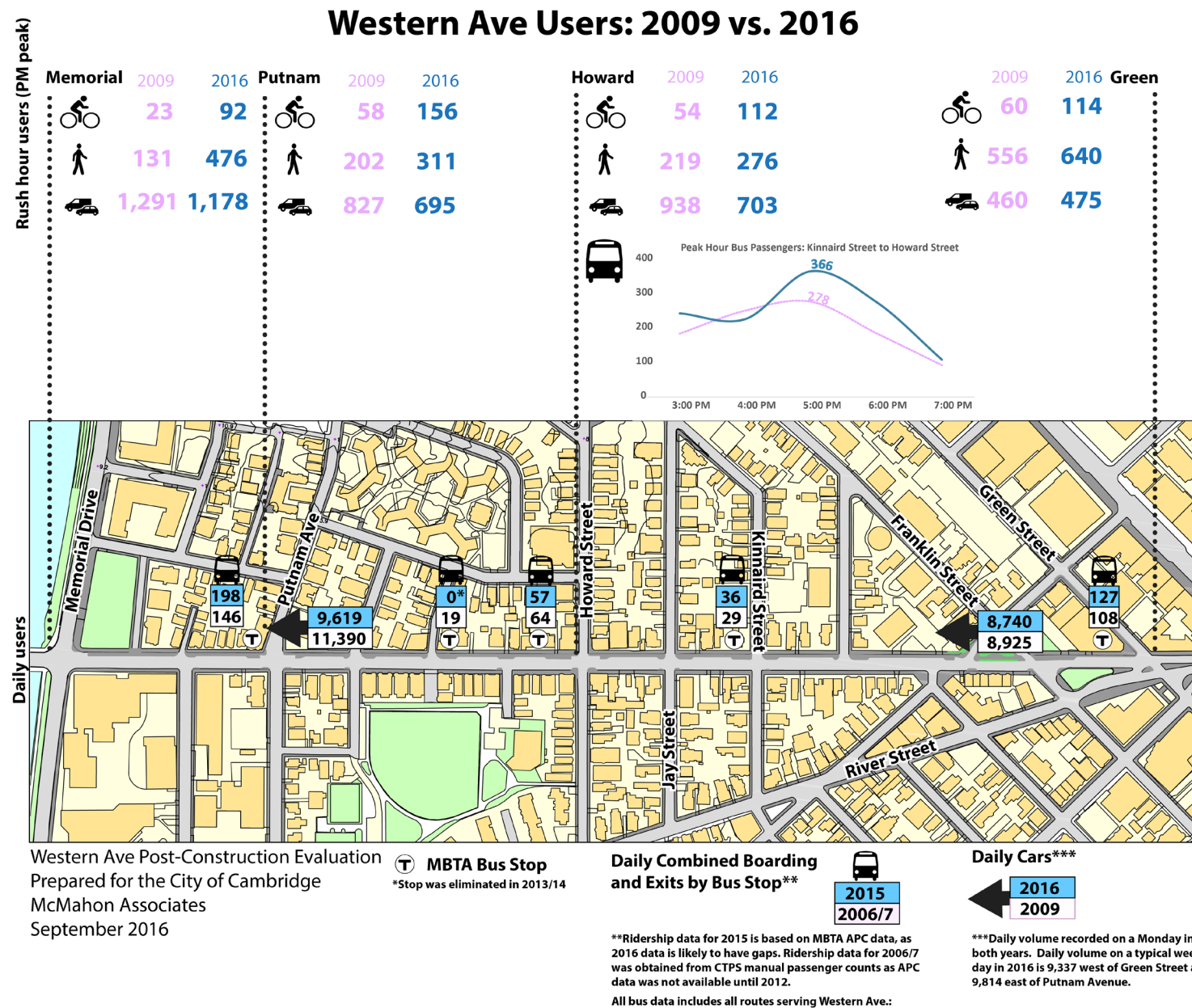


Figure 19: User Volumes along the Corridor

2009 and 2016, it is not clear that this project had a direct effect on the ridership increase. Passengers carried by buses on Western Avenue often board at Central Square, Kendall Square, or University Park and travel through the corridor toward Boston, Watertown, and Waltham. Further detail on passenger loads by route is provided in the technical appendix.

#### **Bus Ridership & Service Comparison: 2006/7 – 2015**

- Average weekday boardings at all Western Avenue stops combined increased by 66 riders (31%)
- Average weekday alightings (exits) decreased by 15 riders (11%)
- Overall, combined weekday bus stop activity (boardings plus alightings), increased by 51 riders (14%)
- There has been no change in scheduled bus frequency during the AM and PM peak hours

### **(3) Vehicular Analysis**

This section includes an analysis and discussion of changes in daily vehicle volumes, peak hours, heavy vehicles, and travel times, including changes in how people experience peak hour traffic along the corridor. For further detail and data on vehicle volumes, peak hours, level of service, and queues, as well as data collection methodology see the technical appendix.

Changes to vehicle operations along the corridor from pre- to post-construction proved challenging to compare due to the saturated roadway conditions during both conditions. The post-construction analysis shows that vehicles continue to experience the effects of congestion and queuing particularly during the PM peak. The vehicle LOS remains at a generally acceptable level for a dense urban environment, with minor fluctuations in either direction based on the time period.<sup>14</sup>

The key takeaway from this part of the analysis is that while results show more congestion over more hours on the roadway, the conditions on Western Ave follow regional trends and it is not clear that the project design had a significant effect.

#### **Data Collection**

To compare pre- and post-construction vehicular operations, the following data was collected:

- In 2009, data was collected via 72-hour (Saturday-Monday) Automatic Traffic Recorder (ATR) counts. These did not

<sup>14</sup> LOS was measured for the AM, PM, and Saturday midday peaks at Green Street, Howard Street, Putnam Avenue, and Memorial Drive.



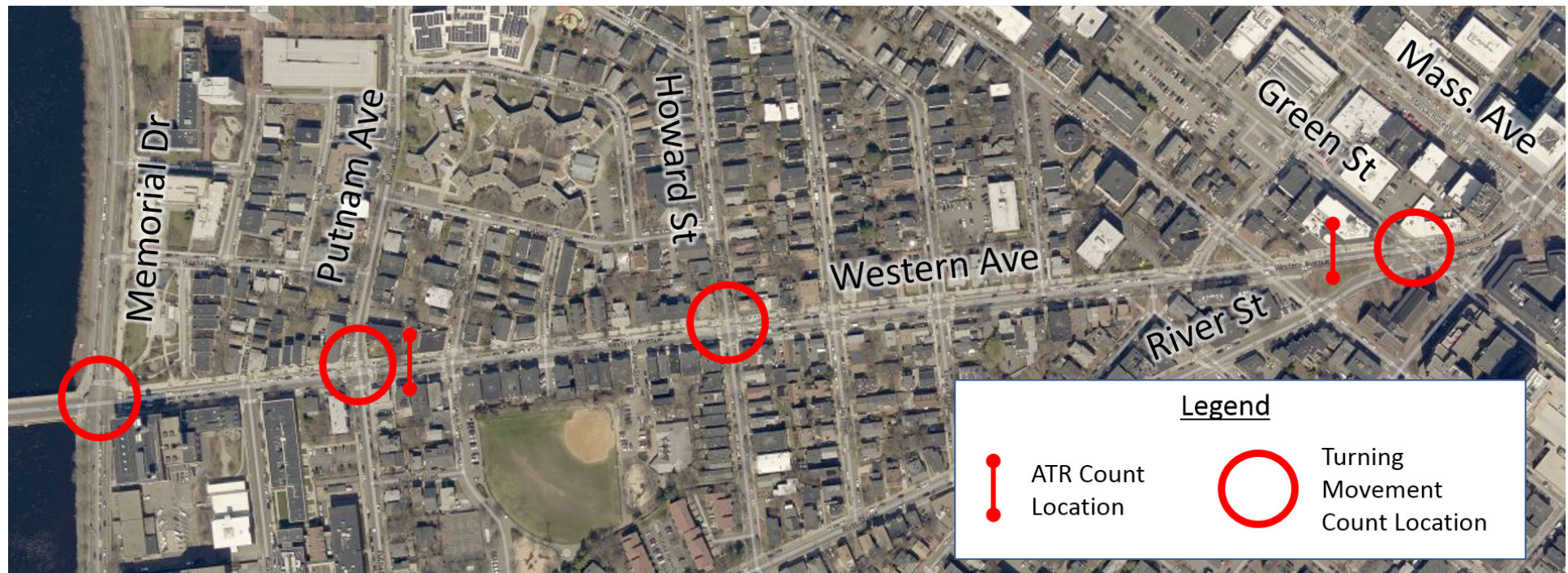


Figure 20: ATR and Turning Movement Count Locations

- include a typical mid-week day.
- In 2016, data was collected via seven-day ATR counts between Monday, May 2, 2016 and Sunday May 8, 2016. The counts were performed just east of Putnam Street, and just west of Green Street.<sup>15</sup>
  - In order to supplement the 2009 data with a more typical mid-week day, additional data from 2006 was obtained from MassDOT, covering the period Monday June 19, 2006 through Tuesday June 20, 2006.
- In 2016, turning movement counts (TMC) were conducted at Memorial Drive, Putnam, Howard, and Green Streets for the weekday AM (7:00 AM – 9:00 AM), weekday PM (4:00 PM – 6:00 PM) and weekend midday (11:00 AM – 12:00 PM) for cars, heavy vehicles, bicycles, and pedestrians.

Figure 20, above, shows the locations of the ATRs in both 2009 and 2016 and the locations of the TMCs in 2016.

<sup>15</sup> Due to a street-sweeping conflict, the Green Street weekend count was re-done on May 14 and 15.



## PEAK HOUR COMPARISON




	AM PEAK 2009   2016	PM PEAK 2009   2016	SAT PEAK 2009   2016
	7:45   7:45	4:45   5:00	11:45   1:00
	7:45   8:00	5:00   5:00	12:00   1:00
	7:45   8:00	5:00   5:00	12:00   12:00

Figure 21: Multimodal Peak Hour Comparison

### Vehicular Volumes

The 2009 and 2016 data sets were used to draw conclusions regarding overall change in weekday daily, weekday peak, Saturday daily, and Saturday mid-day volumes. The key findings include the following:

- Weekday AM and PM peak hour traffic volumes on Western Avenue *increased* at the ATR location west of Green, but *decreased* at the ATR location east of Putnam Street.
- Daily traffic volumes *decreased* at both locations (This includes weekday daily, Saturday daily, and Saturday mid-day).

### Peak Hour Times and Heavy Vehicle Percentage

As shown in Figure 21, above, the peak period with the highest volumes of people driving remained the same during the weekday morning peak and shifted later during weekday afternoons and Saturdays. Peak periods of people walking and bicycling shifted in similar ways to people driving.

The percentage of people recorded as driving heavy vehicles during peak hours decreased from 2009 to 2016. This decrease appears to be unrelated to the new street situation on Western Avenue. Project staff assume that the decrease may be the result of outside factors such as increased truck exclusions in the surrounding neighborhood or changes in how truck exclusions are enforced in the area. Although Western Avenue appears in the City of Cambridge Truck Routes & Restrictions map,<sup>16</sup> as a truck route, people driving trucks are prohibited from driving on Memorial Drive, Soldier's Field Road, Kinnaird Street, and Putnam Avenue. In addition, there are limited options for a truck trying to make westbound trips to turn from Massachusetts Avenue to Western Avenue.

*Peak hour observations note that ambulances were able to proceed through traffic, suggesting that despite congestion, emergency vehicles can still be given priority.*

<sup>16</sup> <https://www.cambridgema.gov/~media/Files/Traffic/RoutesRestrictions.pdf?la=en>

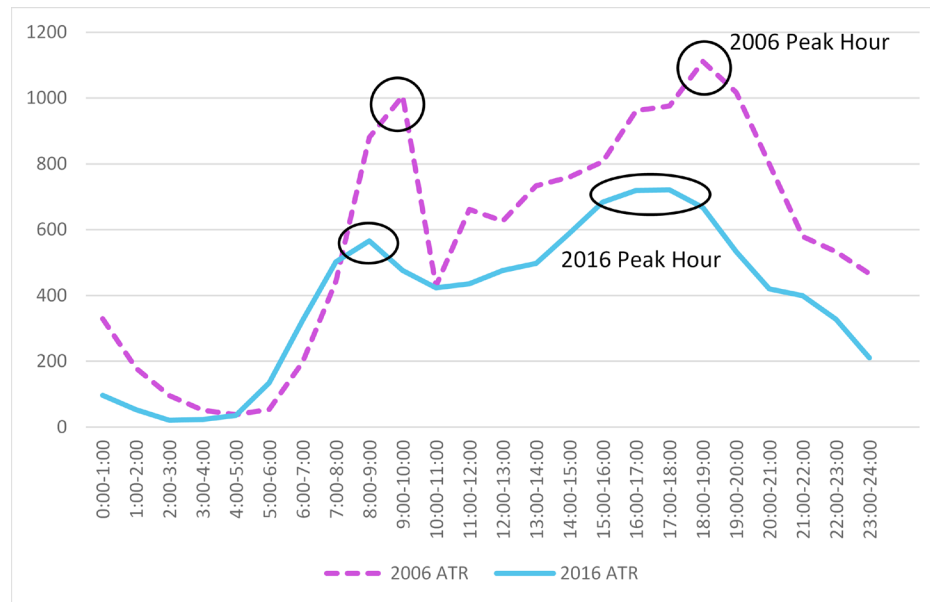


Figure 22: ATR counts by time of day in 2006 and 2016.

### Peak Hour Spreading

Figure 22, above, compares total traffic volume measured with ATRs by time of day in 2006 and 2016. Over the course of the day, vehicle volumes have decreased in 2016 compared to 2006. However, the graph illustrates the regional trend of “peak hour spreading” where traffic volumes are relatively high for longer in the peak periods, rather than one distinct, very high “peak hour” volume. This means that the peak hour volumes are only slightly elevated compared to the hours between peak travel hours.

There are many factors beyond the Western Avenue reconstruction that could be contributing to changes in vehicles volumes over a seven-year period. Western Avenue connects major roadways of Boston and Cambridge, which are heavily influenced by regional travel patterns. Also, while the vehicle volumes recorded on ATRs do not appear to be increasing, the peak hour tables, based on turning movement counts (TMC) show different trends, of increasing peak hour volumes. As these are taken from different sources, the data sets may not provide a direct comparison.<sup>17</sup>

### Vehicular Queues

Vehicle queues, or the total length of cars backed up waiting to move through an intersection, were analyzed for both pre- and post-construction time periods using Synchro capacity analysis software. As a result of the reduction of one travel lane at the Memorial Drive and at Green Street intersections, and that these locations form the start and end point of the Western Avenue project area, project staff supplemented the intersection models with field measurements. Project staff conducted these field measurements at two intersections in 2016:

- Western Avenue at Green Street
- Western Avenue at Memorial Drive

Pre-construction queues were calculated using Synchro in 2009 at four corridor intersections. Detailed in-field queue observations were not performed at these four locations:

<sup>17</sup> The ATR data is precise to the hour (and what was available for comparison to 2006), but the peak hour analysis is precise to the 0:15 minute interval. A shift of 15 minutes in the Peak hour table may not be noticeable in the hourly ART data.

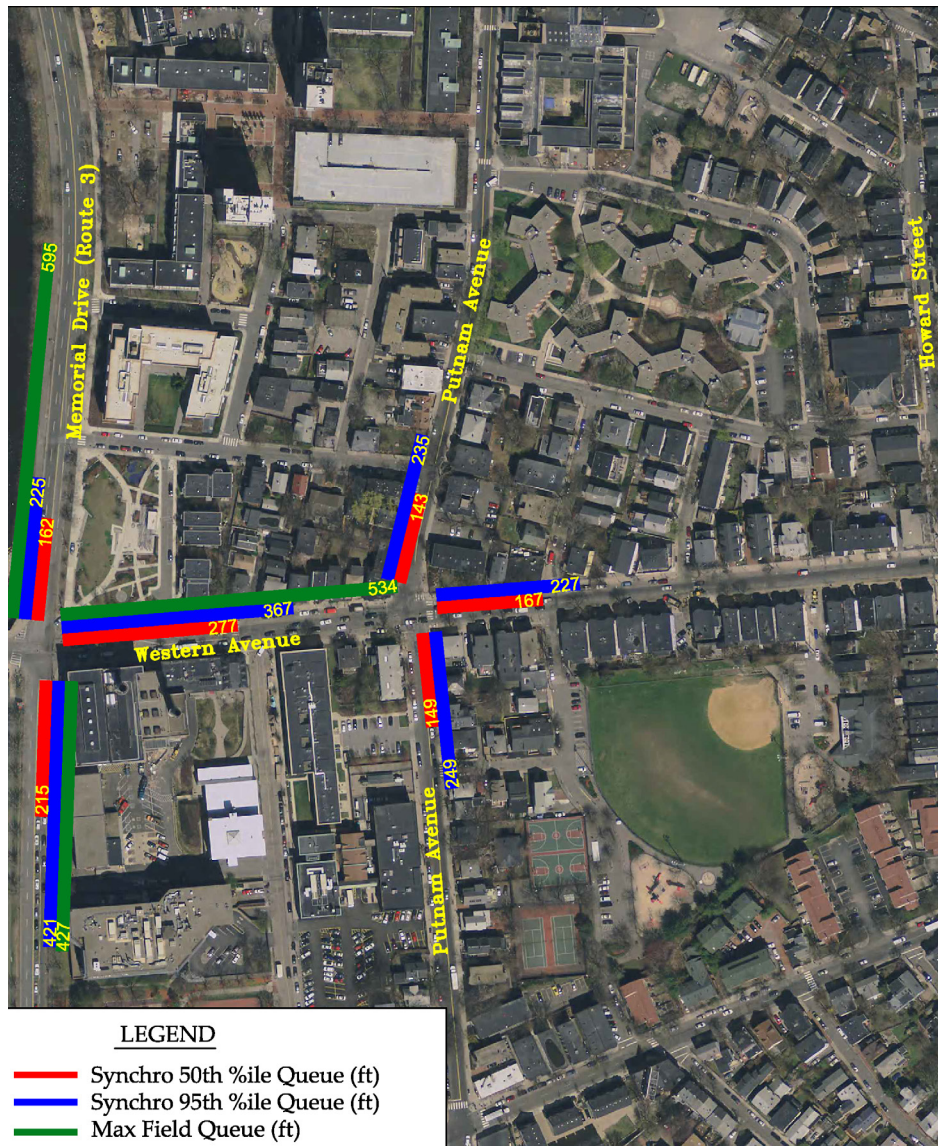


Figure 23: Comparison of field measured and Synchro Analyzed Queues from 2016

- Western Avenue at Green Street
- Western Avenue at Howard Street
- Western Avenue at Putnam Street
- Western Avenue at Memorial Drive

Queues were recorded during peak hours from 7:45-8:45 AM and from 4:00-6:00 PM. The 2016 field measured queues were compared to 2016 Synchro analyzed queues. These queue lengths were then compared to the maximum queues calculated by Synchro for the pre-build, 2009 condition. Results are hard to compare although generally, the calculated queues in 2016 are longer. However, the Synchro estimates don't accurately reflect reality; field measured queues are typically longer, as seen in Figure 23, left.

There are a number of reasons why the Synchro analysis may differ from field conditions during congested, peak periods:

- Traffic counts, used as the basis for a Synchro analysis, can only measure up to the capacity of the road. The analysis during highly congested periods is therefore constrained since it is not possible to measure a number beyond the maximum number of cars a signal can process at one time. Field measurements of queue lengths provides additional detail to understand the maximum number of cars demanding to get through a signal at a given time.
- Operations at the major cross-streets of Memorial Drive and Massachusetts Avenue at each end of the Western Avenue



study area influence operations along Western Avenue as well as intersections outside of the project study area. Massachusetts Avenue and small intersecting streets such as Blackstone Street are not included in the Synchro model.

- Driver behavior impacts capacity in a way that Synchro may not be accounting for, both in 2009 and 2016. For example:
  - During the PM peak in 2016, staff observed that drivers use the the left-most lane on Western Avenue between Memorial Drive and Putnam Avenue less than the middle and right lanes.<sup>18</sup> As a result, this reduces vehicular capacity in this segment because available space remains unused. The Synchro analysis assumes a more balanced lane utilization and therefore, does not account for this reduced capacity, which may be result in the difference from the longer queues observed in the field at Memorial Drive and Putnam Avenue intersections.

Due to higher demand for the middle and right lanes, drivers switching travel lanes between Putnam Avenue and Memorial Drive may also create friction and delay. At times, staff observed a continuous stream of drivers turning left from Blackstone Street and Putnam Avenue onto Western Avenue, resulting in the left lane of Western Avenue being blocked to through vehicles. Staff also observed that the long queues and congestion on Western Avenue west of the Putnam Avenue intersection resulting in extending queues on Western Avenue east of the Putnam Avenue intersection.

<sup>18</sup> Demand may be higher for the middle/right lanes due to the upcoming right turn onto Interstate 90 from Soldier's Field Road over the bridge, or the wish to continue straight on Western Ave over the bridge.

## COMPONENTS OF TRAVEL TIME ANALYSIS



	 Vehicle	 MBTA Bus
DATA SOURCE	Travel times manually recorded in a personal vehicle	Travel times derived from MBTA APC data and Running Time Reports prepared for each route in its entirety (far longer than the Western Ave corridor)
YEARS COMPARED	2009   2016	2012   2016
DAYS COMPARED	Four individual days over two week period in Spring 2016	Data composite for Fall 2012 and Spring 2016
GEOGRAPHIC LIMITS	Green Street to Soldier's Field Road	Green Street bus stop to Putnam Street bus stop
TIME PERIOD	PM Peak: 4:00-7:30PM	AM Peak 8-9AM PM Peak 5-6PM
METHODS	Individual running times by time	Median and 90th percentile running times
OTHER FACTORS		Bus dwell time (time bus is stationary at a bus stop)

Figure 24: Components of Vehicle and Bus Travel Time Evaluation

## Travel Time

Travel time, the amount of time it takes for a vehicle to get from one end of Western Avenue to the other, was measured based on trip time recordings in a personal vehicle and MBTA bus running time reports.<sup>19</sup> Both sets of data show an increase in travel time, for buses and cars in the PM peak period from the pre- to post-construction condition. However, the travel time runs performed in a personal vehicle show the longest travel time occurring at 7:00 PM, while the bus run time data indicates the longest travel time along this segment occurs at 5:00 PM. Though these times do not align, the methodology used for both, detailed in Figure 24, previous page, varies significantly, illustrating challenges in comparing the two. As each data set is created differently, it is best to understand them separately while noting the overall trend that both show increased travel times when compared to the pre-construction condition.

For vehicles, all travel time runs are either the same or longer in 2016 than those recorded in 2009, with 7:00 PM resulting in the largest increase, from 4 to 12 minutes. Note that these travel times include traffic on the bridge between Memorial Drive and Soldier's Field Road, outside of the project scope. This is consistent with the trend of a later and longer peak hour observed from the traffic count data.

Figure 25, next page, shows the results of the bus travel time analysis, comparing median morning and evening peak period

bus run times. During the AM peak, from 6:00 AM to 10:00 AM, bus travel times decreased or remained constant from 2012 to 2016. During the PM peak, from 3:00 PM to 7:00 PM bus travel times increased at 5:00 PM and 6:00 PM, as shown by the thicker clock faces. Additional information on the methodology for the bus travel time analysis is provided in the technical appendix.

### **Vehicular Observations along the Corridor for Further Consideration**

- Illegal Right Turn on Reds occurring on both Western Avenue and side streets
- Narrower travel lanes for traffic calming have caused large trucks/tour buses to sometimes straddle both lanes and go over the curb when turning
- Some ridehail drop-off/pick-ups occurred in the travel lane

<sup>19</sup> MBTA APC data and Running Time Reports from Fall 2012 and Spring 2016 were used to determine travel time between stops, and for the corridor as a whole, for the pre- and post-construction conditions, respectively.

Morning and Evening Peak Period Bus Travel Times  
between Green St. and Putnam Ave. Stops on Western Ave.

During the AM peak period, bus travel times remained constant or decreased along Western Ave.

During the PM peak period, bus travel times are slower along Western Ave.

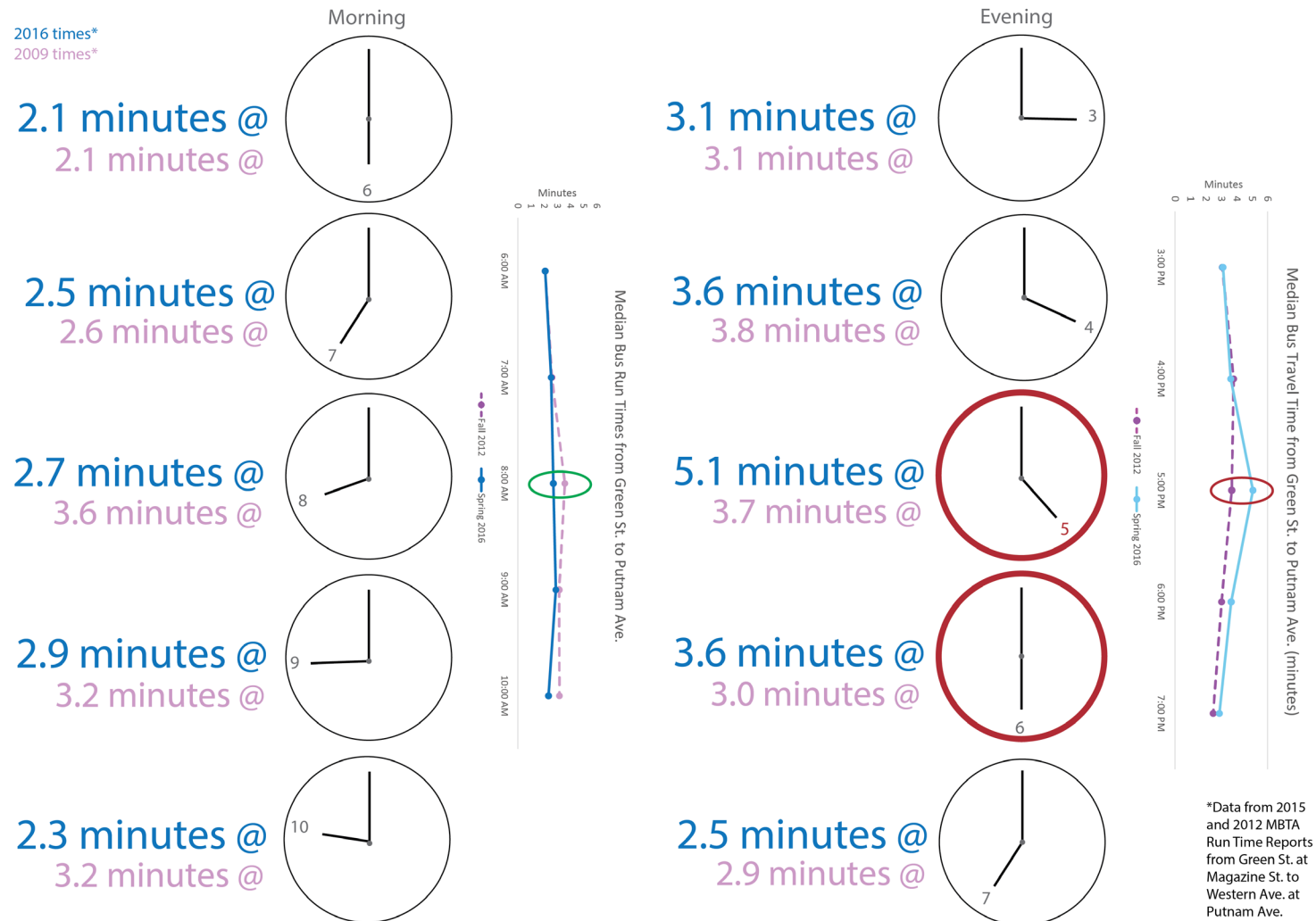


Figure 25: 2012 and 2016 Peak Period Median Bus Run Times



## (4) Parking Utilization

The pre-construction study area on Western Ave included 133 parking spaces (including resident-only, metered parking, etc.). The spaces were identified in the following segments:

- Memorial to Putnam: 17 spaces
- Putnam to Howard: 51 spaces
- Howard to Kinnaird: 26 spaces
- Kinnaird to Green: 39 spaces

The post-construction study area on Western Ave includes 108 parking spaces. The spaces were identified in the following segments:

- Memorial to Putnam: 12 spaces
- Putnam to Howard: 46 spaces
- Howard to Kinnaird: 17 spaces
- Kinnaird to Green: 33 spaces

Parking spaces were removed primarily to accommodate curb extensions, which provide shorter crossing distances and improve yielding for pedestrians, as well as improve sightlines for drivers on side streets attempting to pull into traffic on Western Ave. To mitigate for removal of residential parking on Western Avenue, project staff converted some parking spots from unregulated to residential permits parking on Montague St. overnight and a couple on Blackstone St. at all times.

To better understand parking demand on the corridor, project staff calculated parking utilization rates for each of the four segments along Western Ave every two hours from 8 AM to 8 PM on Wednesday, May 27, 2009 and on Wednesday, May 11, 2016. In addition, project staff calculated overnight parking utilization at approximately midnight, on one weekday in 2009 and on May 5, May 9, and May 10, 2016. In Figure 26, parking occupancy is calculated for midmorning, midafternoon, and overnight hours.

An 85% parking occupancy rate is often considered optimal so that there are about one in every seven parking spaces always available. The utilization is summarized in short segments, so any segment with high utilization is adjacent to a segment with more available spaces. Putnam to Howard is the block that is least utilized while having the largest number of spaces.

### Parking Occupancy Rates at Selected Times in Percentages

Segment	Memorial to Putnam		Putnam to Howard	
Year	2009	2016	2009	2016
10:00 AM	76	75	48	39
2:00 PM	30	100	35	54
Midnight	90	114	80	62

Segment	Howard to Kinnaird		Kinnaird to Green	
Year	2009	2016	2009	2016
10:00 AM	48	33	*	67
2:00 PM	55	58	*	58
Midnight	49	90	*	64

**Note:** A utilization rate above 100% is possible when using a 18-foot parallel parking spot as the standard.

\* = Data was not collected in this segment.

Figure 26: 2009 and 2016 parking utilization rates

Additional information on parking utilization rates is provided in the technical appendix.

Although there are fewer parking spaces after construction, parking utilization rates are not always higher; After construction, average parking utilizations rates along the full corridor vary throughout the day, ranging from 52% at 10 AM to 88% at 8 PM, while overnight parking utilization ranges from 70%-80%.

Certain segments (e.g., Memorial Drive to Putnam) have higher utilization rates than other segments (e.g., Putnam Ave to Howard). Those unable to find a parking space in one segment may be able to find one nearby at any given time since at all times a day there are available spaces on the corridor.

Project staff note that the method for calculating parking utilization may be refined if the parking utilization rate is calculated based on actual use rather than a standard 18-foot parking spot. Instead of assuming that one parking spot is 18 feet, if project staff calculated a parking utilization based on the maximum number of vehicles parked at any given time, the calculation would reveal an even lower parking utilization rate. Project staff note that basing parking utilization on this methodology may be more realistic, since vehicle types and parking behavior are not uniform in the field.

## F. MAINTENANCE

The improvements made along Western Avenue require new maintenance protocols compared to the previous roadway. The porous asphalt on the separated bicycle facility is designed to infiltrate runoff to underlying structural soils in order to promote tree health and reduce the volume of runoff reaching the closed storm drain system. Regular inspection and maintenance are critical to the effectiveness of this pervious facility. The following inspection and maintenance recommendations were adapted from guidance developed by the University of New Hampshire (UNH) Stormwater Center, and are being performed by DPW personnel:

1. Visual Inspections are to be performed to monitor the pavement for surface drainage issues, debris accumulation and surface deterioration, including:
  - Checking for standing water on the surface after a precipitation event (standing water remaining 30 minutes after an event indicates that vacuum cleaning is required).
  - Checking for debris including leaves and trash, and blowing or removing as needed.
  - Checking for damage to the pavement from vehicles which may be heavier than the original design load, and heating/re-rolling pavement if needed.
2. Cleaning activities are performed to maintain infiltration capability. To date, cleaning using vacuum sweeping equipment has been performed three times per year, typically

in April, July, and November.

3. Winter maintenance of the separated bicycle facility includes snow clearance using narrow equipment, with plow blades slightly elevated to avoid damaging the pervious asphalt surface. As anticipated prior to construction, the pervious asphalt is exhibiting superior snow melting characteristics as compared to adjacent impervious roadway and sidewalk surfaces. This has meant that ice and light snow accumulation are not as problematic and are not as likely to result in formation of a solid and dense ice layer if not cleared.

In addition, black ice resulting from melting and refreezing of runoff from adjacent snow banks has been less prevalent on the facility as compared to a conventional, impervious facility. This is due to the ability of meltwater to infiltrate through the surface rather than accumulating and re-freezing, as well as the slightly warmer surface which is a result of air exchange occurring through the pores in the pervious asphalt itself.

When de-icing is required, DPW has been applying conventional road salt (sodium chloride) to date, although consideration is being given to alternative products which would be more optimal for health of adjacent trees and vegetation.

Additionally, overgrown plantings can lead to sightline issues for drivers. New sidewalk plantings must be maintained to prevent these issues.

## G. CONCLUSIONS

Based on the data collected and analyzed in 2016, the Western Avenue project appears to have achieved the initial project goals in a variety of ways.

Major conclusions and observations include:

- Vehicular speeds on Western Avenue have decreased since 2009, and are now closer to the posted speed limit of 25 mph (based on average daily traffic volumes and speeds).
- Drivers appear to yield more for pedestrians when they are more visible to traffic, such as out on a curb extension.
- Overall, crashes in the project area are less severe. Crashes specifically with people biking and walking are also less severe. Given that numbers of people walking and bicycling on Western Avenue have increased, but the numbers of reported crashes have not, in the absence of per-mile crash rates for all users of Western Avenue, this would indicate a decrease in the crash rate. Crashes involving a “hit and run” with a parked car have increased.
- The corridor has become increasingly multi-modal. Bicycle, pedestrian, and bus passenger volumes have increased substantially since the pre-construction condition, while vehicular volumes have decreased.



- The LOS for pedestrians and bicycles is high, while the LOS for vehicles did not change substantially, and overall are at LOS “D” or better, which is considered acceptable for peak hour operations in an urban area.
- The vehicle PM peak has shifted to later in the day and tends to be for a longer duration. There is less of a difference between peak and off-peak volumes in 2016 as compared to the 2009 pre-build condition. This is not unique to Western Avenue, and is consistent with findings on other major roadways in Cambridge and Boston.
- Vehicular travel time, for both automobiles and buses, has increased during the PM peak, indicating that the roadway is oversaturated. This can be partly influenced by the roadways at each end of the corridor which carry high volumes of cross traffic, and may not be wholly attributable to Western Avenue itself.
- Parking utilization rates are higher in some segments of the corridor than others, but there are generally spaces available in most areas or close by.

# POST CONSTRUCTION EVALUATION REPORT

## Western Avenue, Cambridge, Massachusetts

### Technical Appendix

January 2019



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(back of Technical Appendix cover page)



## Western Ave Technical Appendix

This technical appendix provides additional information on data collection and analysis methodologies from the pre- and post-construction conditions as applicable. It also includes detailed tables and charts of analysis results. It is intended to supplement the data and findings presented in the Western Avenue Post Construction Evaluation Report.

### 1. Speed Data

Speed data was recorded at two locations on Western Avenue by Automatic Traffic Recorders (ATRs). As Table 1 shows, the 2009 85th percentile speeds west of Howard Street and east of Franklin Street were 32 mph and 25 mph, while in 2016 85th percentile speeds dropped to 28 mph and 24 mph. Speeds were recorded in the same locations in both years.

**Table 1: 85th Percentile Speeds**

Location	85 <sup>th</sup> Percentile Speed 2009	Posted Speed Limit 2009	85 <sup>th</sup> Percentile Speed 2016	Posted Speed Limit 2016
West of Howard Street	32 mph	25 mph	28 mph	25 mph
East of Franklin Street	32 mph	25 mph	24 mph	25 mph

### 2. Pedestrian Yield Study

A pedestrian yield study was performed for the “post-construction” condition in order to gain insights into how pedestrians and motorists interacted at a typical non-signalized crosswalk.

A pedestrian yield study involves staging a person playing the role of a pedestrian attempting to cross the street at the same time an approaching vehicle is within a defined “dilemma zone.” The dilemma zone is the segment of roadway upstream of the crosswalk where the person driving is:

- close enough to need to actively brake to yield the right of way to a person walking crossing the street; and
- far enough to brake safely, given the conditions of the road including sightlines, stopping distance and vehicle speeds.

The westerly crosswalk at Kinnaird Street was selected for this study. Traffic at this location was observed to be relatively free-flowing during non-peak hours, and was not notably influenced by nearby signalized intersections or other factors.

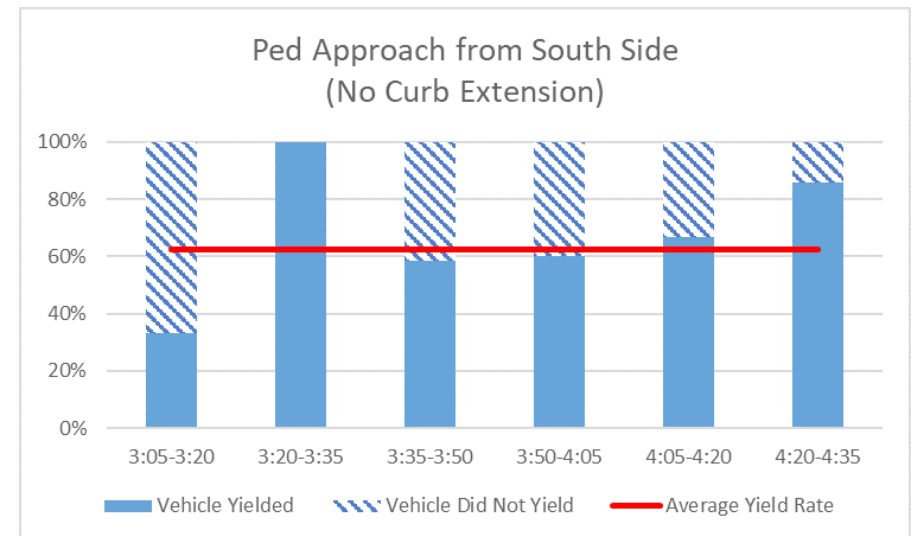


Figure 1: Vehicle Yield Rate - Kinnaird Street – Pedestrians from South

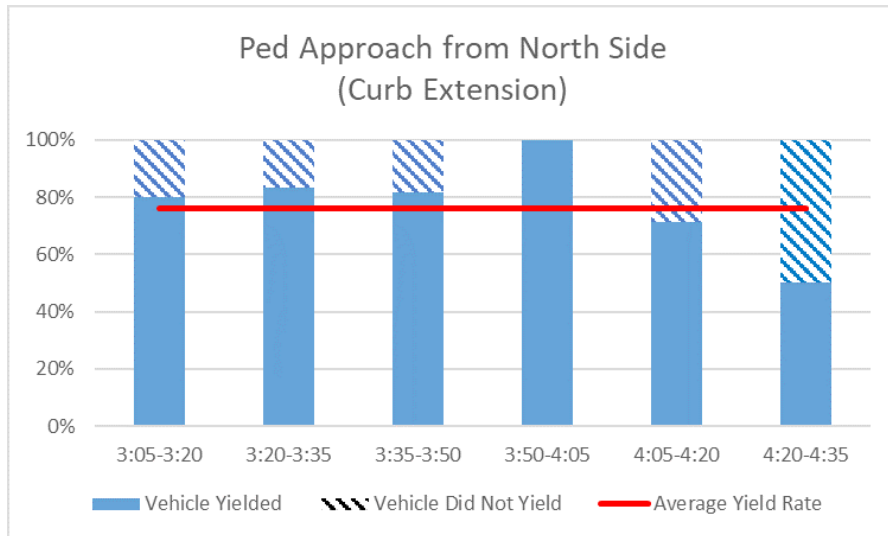


Figure 2: Vehicle Yield Rate - Kinnaird Street – Pedestrians from North

Field work was performed on Wednesday, October 12, 2016, between 3:05 and 4:35 pm. In order to obtain as many data points as possible, staff from the City acted as “staged” pedestrians. Staff were instructed ahead of time as to the approximate limits of the “dilemma zone” as described above, and were also instructed to cross the road both from the north and from the south, preferably during times of free-flowing traffic.

During the test period, it was possible to obtain 102 data points (56 crossing from south to north; and 46 from north to south. Results are shown in Figure 1 and Figure 2.

As noted from Figures 1 and 2, there appears to be some correspondence between the yielding rate at this particular crosswalk and the side of the street that pedestrians approach from. At the subject crosswalk, pedestrians crossing from

south to north do so without the benefit of a curb extension on the south side. The field staff reported that in the 3:05-3:20 pm time frame, they began their crossing maneuvers from the “normal” location at the edge of the curb ramp, approximately seven feet from the edge of the vehicle travel lane. The resultant lower yield rate may be due to the pedestrians’ visibility to motorists being somewhat limited and indirect. Subsequently, the testers advanced into the parking lane and waited there, where they would be in a more direct line of sight, and motorist yielding increased notably. Conversely, pedestrians crossing from the north side do so from an extended sidewalk which places them directly adjacent to the vehicle travel lane. It was observed that motorists yielded at a higher rate to these pedestrians.

### 3. CPD Crash Data

#### *Pre-construction Data*

The Cambridge Police Department ran an initial analysis of crashes in the two years before construction began on Western Avenue. The records ranged from January 1, 2011 to December 31, 2012. These records are summarized digitally, while detailed records are kept in paper. The majority of the analysis is on the summary records, while many of the detailed records were not available for analysis.

Between January 2011 and December 2012, 40 crashes happened on Western Avenue. The largest number of crashes – 10 crashes or 25 percent – were a driver striking a parked vehicle; in most of these crashes – 8 crashes or 20 percent of all crashes, the owner of the vehicle found their vehicle

damaged. Of the 40 crashes, twelve crashes, or 30 percent, were serious enough to result in an injury requiring medical care. Of the 40 crashes, 33 occurred at an intersection and 7 occurred midblock.

People on foot and bike on Western Avenue were involved in twenty percent of crashes or 8 crashes, total. Of these crashes, seven occurred at an intersection. CPD had access to report summaries and additional analysis can be completed with detailed reports. For the crashes resulting in injury, however, six crashes, that is half, involved people on foot or on bike. During 2011 and 2012, three crashes out of 40 involved a bus or large vehicle. Only one crash involved a large vehicle striking a pedestrian or bicyclist. Before construction, time of day, seasonality, and motor vehicle size did not appear to be a significant factor for crash reports.

#### Post-construction Data

The Cambridge Police Department ran an initial analysis of crashes in the two years after construction on Western Avenue. The records ranged from January 1, 2016 to December 31, 2017. These records were mainly available digitally, unlike the preconstruction records.

In this time period, 49 crashes happened on Western Avenue. The largest number of crashes – 12 crashes or about 25% -- were a driver striking a parked vehicle with the owner returning to their vehicle to find it damaged. See Figure 3 for crashes with autos and counts of street users. Of the 49 crashes, seven crashes, or fourteen percent, were serious enough to result in a call to EMS. Of the 49 crashes, 34 occurred at an intersection while 15 occurred midblock.

#### Motor vehicle crashes: "Hit-and-run" crashes with parked cars and all other crashes

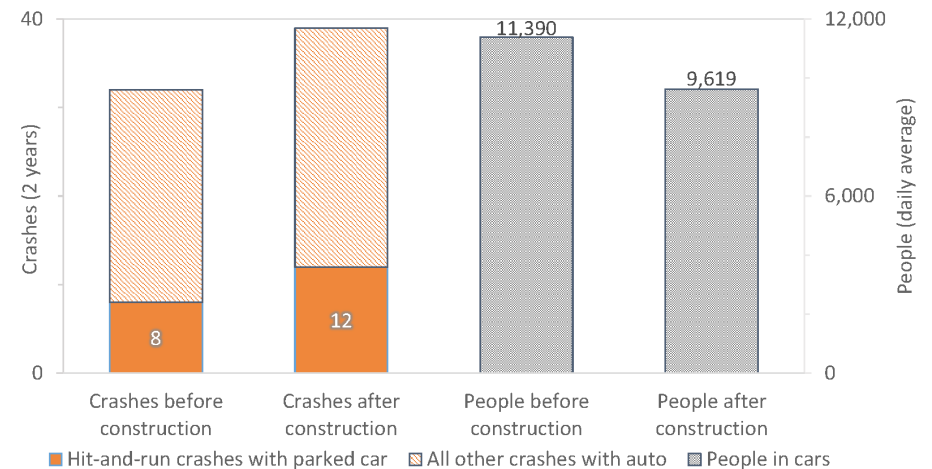


Figure 3: Motor vehicle crashes: "hit-and-run" with parked cars versus all other Motor vehicle crashes

People on foot and bike on Western Avenue were involved in twenty percent of crashes, or 10 crashes, total. Of these 10 crashes, nine occurred in a crosswalk or marked bicycle crossing. Detailed reports were available for most of these crashes. For crashes resulting in an injury, however, four crashes, that is 57 percent, involved people on foot or bike. During 2016 and 2017, three crashes of 49 involved a bus or large vehicle; however, none of these crashes required medical attention. After construction, time of day and motor vehicle size did not appear to be a significant factor for crash reports. However, in the PM rush hour, it appears that some seasonality may be at play; crashes in the 5:00 PM hour only happen in the autumn and spring. This is a total of six crashes, while in the preconstruction period there were only two in the same time



period. For motor vehicle drivers, driver and passenger safety seem to be stable, but a slight increase in the number of property damage-only incidents (i.e. damage to parked or stopped car) was recorded, at approximately two more per year.

#### 4. MBTA Bus Ridership

Ridership details by individual bus stop are shown in Table 2:

**Table 2: Average Weekday Ridership by Stop – Fall 2006/Winter 2007 and Fall 2015**

Outbound Stop	Fall 2006/Winter 2007		Fall 2015	
	On	Off	On	Off
Western Ave @ Green St*	106	2	121	6
Western Ave @ Kinnaird St	24	5	33	3
Western Ave @ Howard St	17	47	29	28
Western Ave @ Dodge St**	5	14	N/A	N/A
Western Ave @ Putnam St	59	87	95	103
Total	211	155	278	140

\* Western Ave @ Green St only served by peak-hour Route 64.

\*\* Western Ave @ Dodge St was closed in summer 2015.

Combined boarding and alighting changes at all Western Avenue stops is shown in Table 3:

**Table 3: Change in Western Ave Bus Stop Activity (Ons and Offs): 2006/2007 to 2015**

Period	2006/2007	2016	Change	Change (%)
Ons	211	277	66	31%
Offs	155	140	-15	-10%
<b>Totals</b>	<b>366</b>	<b>417</b>	<b>51</b>	<b>14%</b>

**Table 5: 2015 Average Weekday Bus Passenger Loads**

Outbound	64	70/70A	TOTAL
GREEN ST @ MAGAZINE ST		2248	2248
WESTERN AVE @ GREEN ST	331	N/A	331
WESTERN AVE @ KINNAIRD ST	576	2275	2851
WESTERN AVE @ HOWARD ST	577	2276	<b>2852</b>
WESTERN AVE @ DODGE ST	577	2275	2851
WESTERN AVE @ PUTNAM AVE	586	2257	2843

*Peak loads noted in red, bold, italic*

**Table 4: 2006/7 Average Weekday Bus Passenger Loads**

Outbound	64	70/70A	TOTAL
GREEN ST @ MAGAZINE ST		1861	1861
WESTERN AVE @ GREEN ST	331	N/A	331
WESTERN AVE @ KINNAIRD ST	358	1878	<b>2236</b>
WESTERN AVE @ HOWARD ST	354	1852	2206
WESTERN AVE @ DODGE ST	352	1845	2197
WESTERN AVE @ PUTNAM AVE	336	1833	2169

*Peak loads noted in red, bold, italic*

Table 4 and Table 5 show the average weekday passenger loads at each stop in the corridor for both 2006/7 and 2015. Figure 4 shows the average weekday passenger load, by hour, between Kinnaird and Howard Streets. It is shown both by individual bus route, and for all routes combined.

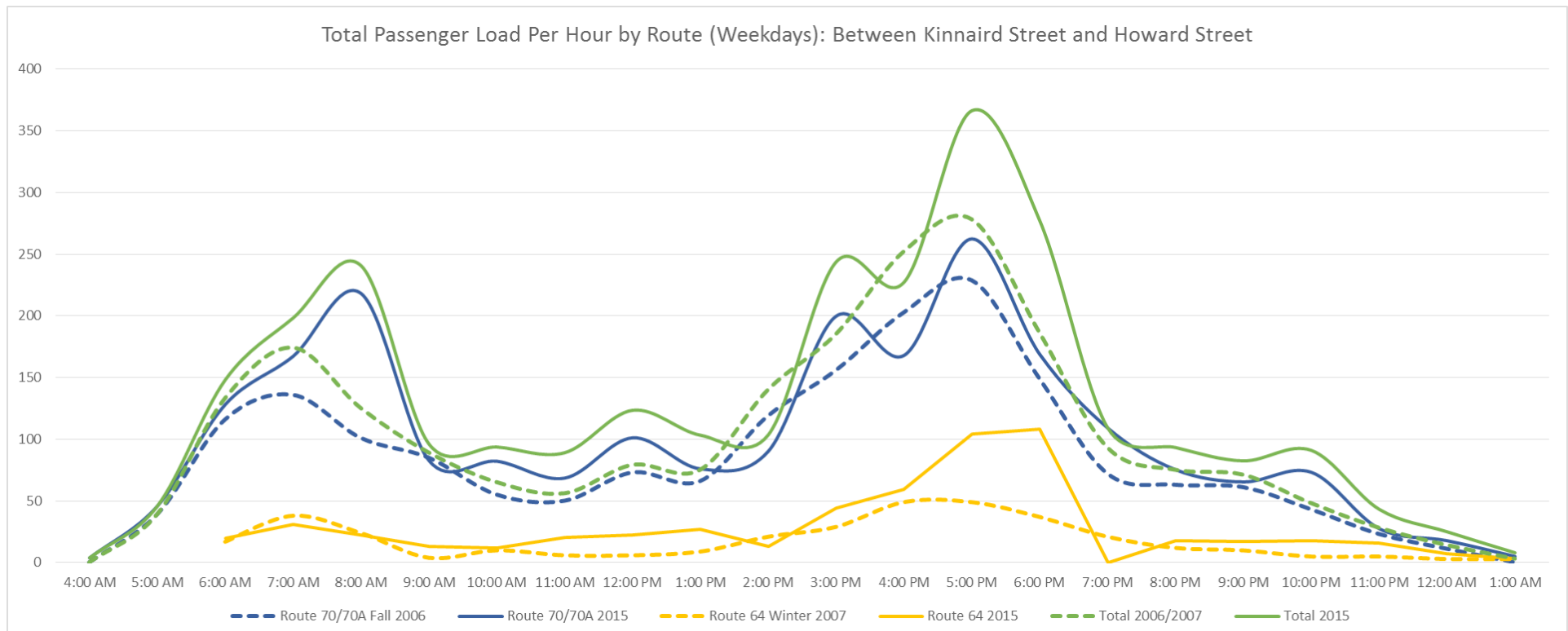


Figure 4: 2006/7 and 2015 Hourly Bus Passenger Loads between Kinnaird Street and Howard Street

## 5. Bicyclist and Pedestrian Demographics

Pedestrian and bicycle counts,<sup>1</sup> and demographic and behavioral observations, were performed as follows:<sup>2</sup>

- Western Avenue/Putnam Avenue; Thursday October 13, 2016; 4 PM – 6 PM
- Western Avenue/Howard Street; Thursday October 13, 2016; 4 PM – 6 PM
- Western Avenue/Putnam Avenue; Saturday October 15, 2016; 12 PM – 3PM
- Western Avenue/Howard Street; Tuesday October 18, 2016; 3 PM – 6 PM

Results from the observations are documented in figures 5 to 8. As depicted, although pedestrians are typically more evenly split by gender, there are generally twice as many male cyclists as female cyclists. As this data was not collected in 2009, a comparison cannot be made. This data can serve as a point of comparison to future studies on Western Avenue or in the City of Cambridge to better understand cyclist demographics.

<sup>1</sup> Unlike the post-construction counts performed in May 2016 and documented elsewhere in this report, the October counts did not include detailed turning movement information. As the October counts were performed primarily to collect demographic and behavioral information, and as the October volumes are reasonably similar to the May volumes, the actual volume figures are omitted in order to avoid duplication.

<sup>2</sup> The weather was sunny and temperature was between 55 and 65 degrees during all count periods.

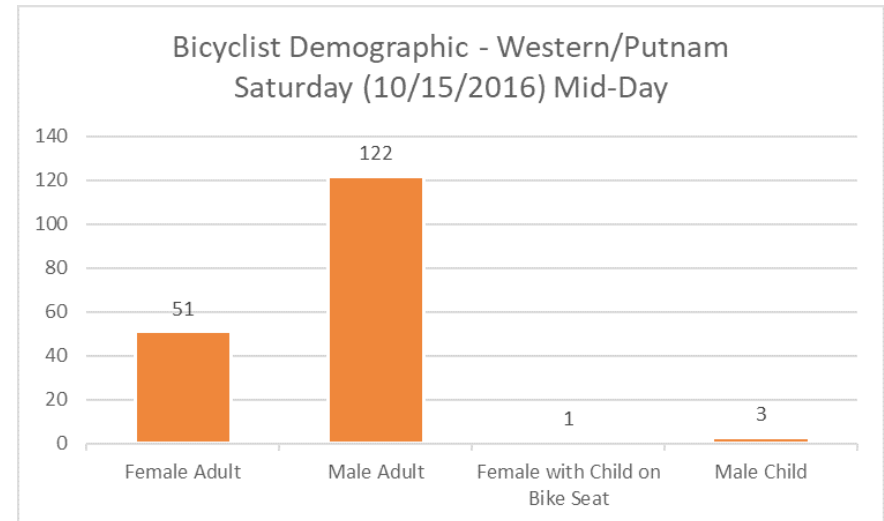


Figure 5: Bicyclist Demographic – Western/Putnam Saturday Mid-Day

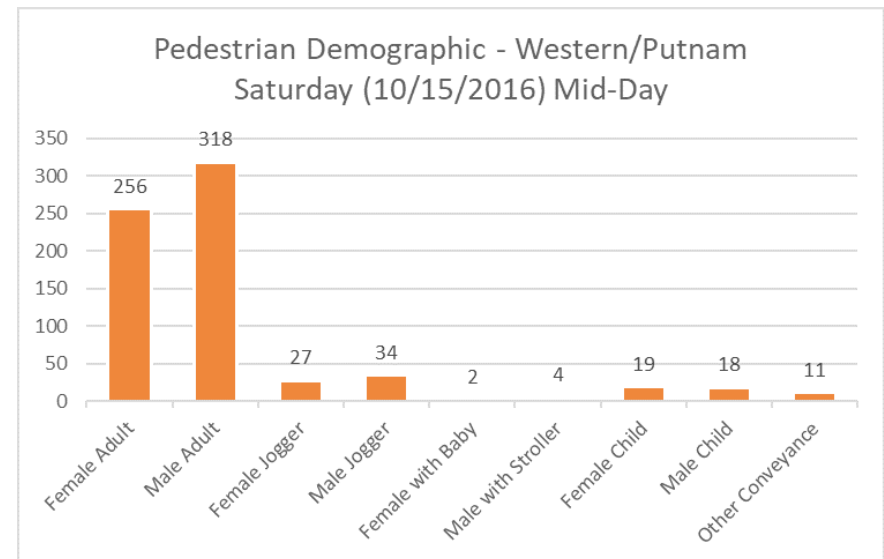


Figure 6: Pedestrian Demographic – Western/Putnam Saturday Mid-Day



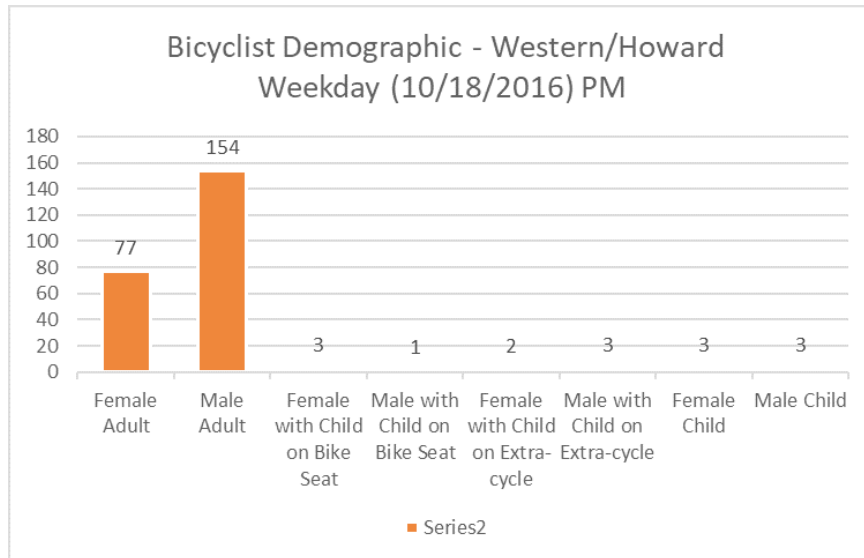


Figure 7: Bicyclist Demographic – Western/Howard Weekday PM

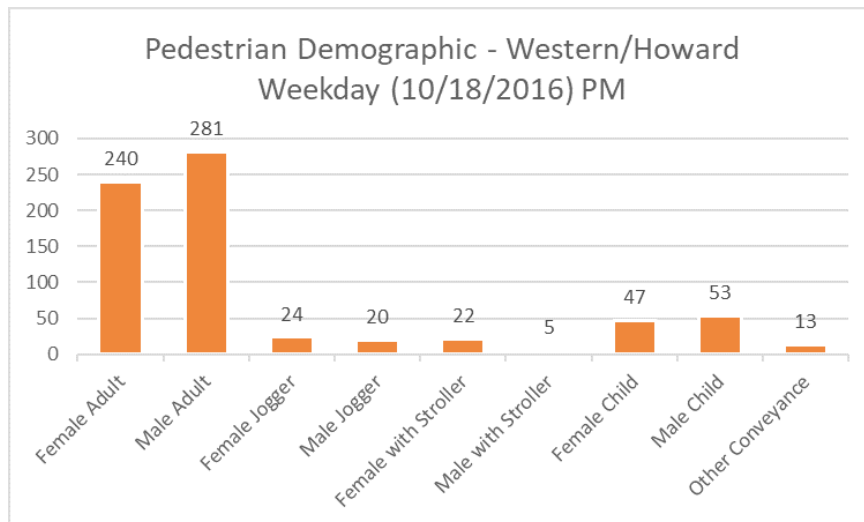


Figure 8: Pedestrian Demographic – Western/Howard Weekday PM

## 6. Bicycle Helmet Use

The use/non-use of bicycle helmets was also recorded at several of the locations/times noted above. Combined results from two of the weekday time periods (using results from two different days) are shown in Figure 9, by gender.

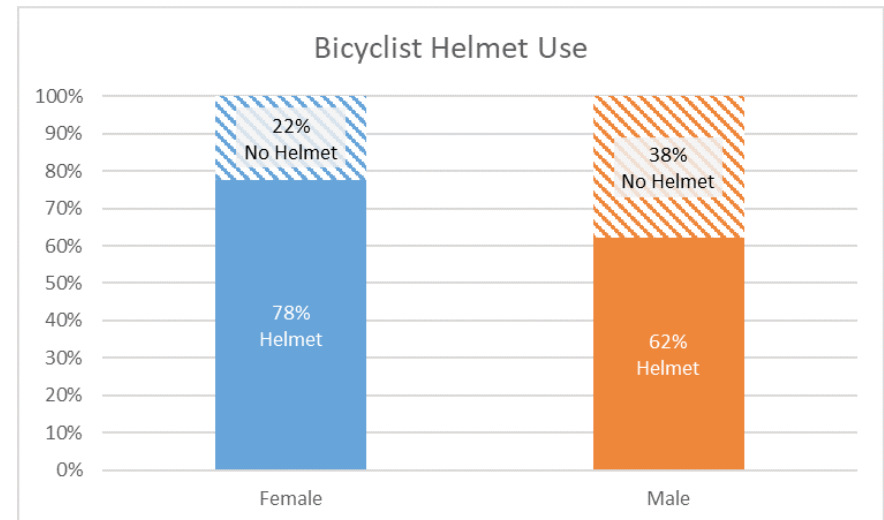


Figure 9: Bicyclist Helmet Use

## 7. Eastbound [Contraflow] Bicycle Movements

The 2009 pre-construction traffic surveys counted cyclists moving in the opposite direction of the vehicle flow (contraflow) on Western Ave, whether legally on the sidewalk or otherwise, as did both the May and October 2016 post-construction traffic surveys.

The data for contraflow cyclists were analyzed in two different ways:

- Total of contraflow movements at each study intersection as a proportion of all bicycle movements at study intersections<sup>3,4</sup>
- Approximate total of contraflow “thru” cyclists as a proportion of all (contraflow and “with traffic”) “thru” cyclists.<sup>5</sup>

Figures 10 and 11 show the results of this analysis. One outcome which should be noted in Figure 10 (“All Movements”) is the substantial decrease in the AM proportion of contraflow riders between 2009 and 2016. This may be partly attributable to the fact that the 2009 data includes a large number of cyclists who entered contraflow on Western Ave at Memorial Drive, but who were not counted again at Putnam Street. If the counts are correct, then it is possible

these cyclists turned onto Blackstone Street before reaching Putnam, for reasons which cannot be definitely determined. It should be noted that a similar phenomenon was not noted in the 2016 counts.

### *Location of Contraflow Cyclists: Separated Facility vs. Sidewalk*

The location of contraflow cyclists on Western Avenue was noted during the October 2016 data collection activities. The proportion of contraflow cyclists who used the separated facility (versus one of the sidewalks), ranged from 65% during a Saturday mid-day period, to 94% during two weekday afternoon peaks.

Although contraflow use of the separated facility is not recommended for a number of reasons, field observers noted that cyclists who ride on the separated facility did not appear to ride recklessly, and observed few near-misses or conflicts with other pedestrians or cyclists. Contraflow cyclists sometimes used the parking-adjacent buffer to pass regular flow cyclists, which can be hazardous as this buffer space is not continuous, is subject to door openings from parked vehicles, and has abrupt vertical drop-offs at driveways.

As is seen in the figures below, the number of contraflow bicycle movements decreased when compared to all

<sup>3</sup> For this analysis, the Memorial Drive, Putnam, and Howard intersections were used. For the Memorial Drive intersection, the analysis disregards thru bicycle movements along Memorial Drive, and bicycle turns to/from Memorial Drive from the Western Avenue Bridge. These movements are not relevant to this study and would have disproportionately impacted the results.

<sup>4</sup> The October 2016 data is limited to the Putnam and Howard intersections, and is for the PM peak only.

<sup>5</sup> These values are an approximation based on the authors’ interpretation of the bicycles counted on the Western Avenue approach/departure at each intersection. No formal bicycle O-D study was performed. This information was not estimated for the October 2016 counts.

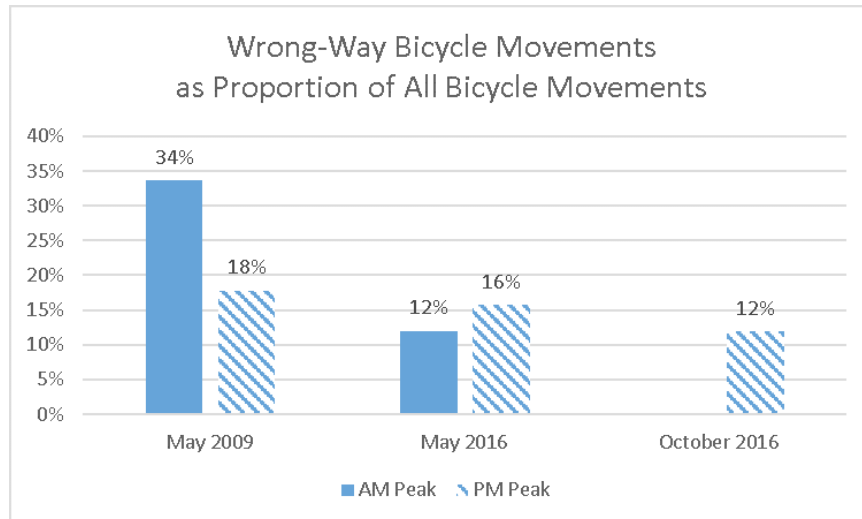


Figure 10: Counterflow Bicycle Movements as Proportion of All Bicycle Movements

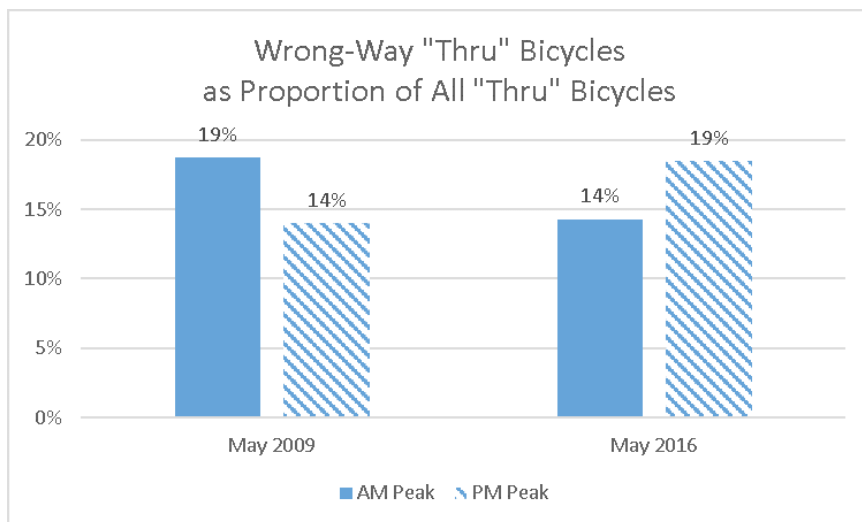


Figure 11: Counterflow "Thru" Bicycles as Proportion of All "Thru" Bicycles

bicycle movements, and decreased during the AM peak, but increased during the PM peak when compared to all "thru" bicycles. The reason for the large drop in wrong-way bicycle movements in the AM peak can only be speculated. It may be due to differences in data collection between 2009 and 2016 or that the presence of a formal cycle track deters cyclists from using the roadway in the opposing direction. Additional data is needed to fully understand cyclist behavior on the corridor.

## 8. Pedestrian Level of Service

The analysis from 2009, detailed in Table 6, shows that all intersections except for Western Avenue at Green Street had elements with scores lower than an LOS B. The results between the 2009 and 2016 analyses are not directly comparable, as the 2009 methodology provides LOS for "major" and "minor" streets, as well as separate LOS results for waiting time, corner circulating space and crosswalk space. The methodology used for the 2016 analysis is based on a composite result for these factors. In 2016, pedestrian storage measurements entailed measuring the distance between the building edge and the curb, or measurements best resembling what this space would be for pedestrians waiting on the sidewalk before crossing an intersection.



**Table 6: Pedestrian Level of Service - 2009**

Intersection/Peak Period/Movement	Corner Waiting Time				Corner Circulating Space		Crosswalk Space			
	Major Street		Minor Street		Space <sup>c</sup>	LOS	Major Street		Minor Street	
	Delay <sup>a</sup>	LOS <sup>b</sup>	Delay	LOS			Space	LOS	Space	LOS
<b>Western Avenue at River Street, Prospect Street and Green Street</b>										
Weekday Morning Peak Hour:	15.0	B	8.0	A	92.5	A	233.9	A	2,519.8	A
Weekday Evening Peak Hour:	15.0	B	8.0	A	46.4	B	157.1	A	797.7	A
Saturday Midday Peak Hour:	15.0	B	8.0	A	81.0	A	252.8	A	1,163.0	A
<b>Western Avenue at Howard Street</b>										
Weekday Morning Peak Hour:	28.8	C	28.8	C	769.5	A	231.5	A	570.5	A
Weekday Evening Peak Hour:	28.8	C	28.8	C	531.5	A	148.5	A	484.9	A
Saturday Midday Peak Hour:	28.8	C	28.8	C	651.3	A	198.6	A	476.9	A
<b>Western Avenue at Putnam Avenue</b>										
Weekday Morning Peak Hour:	31.7	D	31.7	D	809.2	A	364.2	A	392.6	A
Weekday Evening Peak Hour:	31.7	D	31.7	D	469.6	A	193.4	A	258.1	A
Saturday Midday Peak Hour:	31.7	D	31.7	D	699.3	A	299.5	A	359.6	A
<b>Memorial Drive at Western Avenue</b>										
Weekday Morning Peak Hour:	23.8	C	3.4	A	406.8	A	2,097.9	A	825.5	A
Weekday Evening Peak Hour:	19.3	B	3.8	A	394.4	A	2,213.7	A	761.3	A

<sup>a</sup>In seconds.

<sup>b</sup>Level-of-service.

<sup>c</sup>Square feet per person.

## 9. Vehicle Volumes

Table 7 summarizes data from the 2009 and 2016 ATR counts, which were performed on Western Avenue west of Green Street and east of Putnam Street. In 2009 ATR counts were based on 72-hour data collection Saturday-Monday and did not include a typical weekday. In 2016 seven day ATRs were collected Monday May 2nd through Sunday May 8th, providing five weekdays of data plus a full weekend and Monday to match the 2009 data collection effort. Due to the street sweeping schedule of a neighboring district, the Green Street ATR was collected from May 14th to May 15th to recollect weekend data.

**Table 7: Summary of 2009 and 2016 ATR Counts**

2009					2016				
Daily Period	Daily Volume	Peak Period	Peak Volume*	K Factor* (%)	Daily Period	Daily Volume	Peak Period	Peak Volume	K Factor (%)
<b>Western Avenue, west of Green Street</b>					<b>Western Avenue, west of Green Street</b>				
Monday	8,925	AM:	534	6.0	Monday	8,740	AM:	603	6.9
		PM:	688	7.7			PM:	696	8.0
Weekday	NA	NA	NA	NA	Weekday	9,337	AM:	580	6.2
							PM:	735	7.9
Saturday	8,990	Midday:	557	6.2	Saturday	8,457	Midday:	519	6.1
<b>Western Avenue, east of Putnam Avenue</b>					<b>Western Avenue, east of Putnam Avenue</b>				
Monday	11,390	AM:	845	7.4	Monday	9,619	AM:	673	7.0
		PM:	827	7.3			PM:	707	7.4
Weekday	NA	NA	NA	NA	Weekday	9,814	AM:	666	6.8
							PM:	689	7.0
Saturday	11,645	Midday:	704	6.2	Saturday	10,572	Midday:	636	6.0

\*Peak volume is based on the maximum vehicles recorded during a single peak hour.

\*\*Note: "K Factor" is the proportion of daily traffic that occurs during peak hours

Table 8 compares the peak hour data from 2009 and 2016. Hourly count data was not available from the 2009 study so data from 2006 was sourced from MassDOT. The 2006 count data was recorded on Western Avenue to the west of Green Street from Monday June 19, 2006 through Tuesday June 20, 2006. The 2016 ATR data was recorded on Western Avenue to the east of Putnam Street from Tuesday May 3, 2016 through Thursday, May 5, 2016.

**Table 8: Peak Hour Comparison – 2009 - 2016**

	AM Peak 2009	PM Peak 2009	Saturday 2009	AM Peak 2016	PM Peak 2016	Saturday 2016
Vehicular Traffic	7:45 AM	4:45 PM	11:45 AM	7:45 AM	5:00 PM	1:00 PM
Ped	7:45 AM	5:00 PM	12:00 PM	8:00 AM	5:00 PM	12:00 PM
Bike	7:45 AM	5:00 PM	12:00 PM	8:00 AM	5:00 PM	1:00 PM
Heavy Vehicle Percentage along Western Ave	6%	3%	3%	2.3%	1.4%	1.8%

## 10. Vehicular Level of Service

Synchro software was used to calculate vehicular Level of Service (LOS) at the corridor's four signalized intersections in 2009 and 2016. Results are shown in Table 9. The "Does Not Exceed" (DNE) results from 2009 indicate a V/C under-capacity, but the exact ratio is not provided.

## 11. Vehicle Queues

Table 10 provides a comparison of maximum queue lengths for the 2009 Synchro, 2016 field, and 2016 Synchro results. Max queues from 2009 were compared to field measured queues and synchro analyzed queues from 2016 (no other queue measurements were provided in 2009 queue analysis). The 2016 field queues were measured on Tuesday, May 10, 2016 during peak periods from 7:45-8:45 AM and 4:00-6:00 PM.

Table 9: Vehicular LOS Results – 2009/2016

Operating LOS				v/c Ratio			
		2009	2016		2009	2016	
Green St	AM	B	C	Green St	AM	DNE*	WB = 0.82
	PM	B	C		PM	DNE	WB = 0.70
	SAT	C	B		SAT	DNE	WB = 0.78
Howard St	AM	A	B	Howard St	AM	DNE	WB = 0.43
	PM	B	B		PM	DNE	NB = 0.41
	SAT	A	B		SAT	DNE	WB = 0.37
Putnam Ave	AM	B	C	Putnam Ave	AM	DNE	WB = 0.72
	PM	D	C		PM	NB > 1.00	WB = 0.67
	SAT	C	C		SAT	DNE	WB = 0.77
Memorial Dr	AM	D	D	Memorial Dr	AM	NB&SB > 1.00, WB L&T > 1.00	WB = 1.08
	PM	E	D		PM	DNE	WB = 1.03
	SAT	D	C		SAT	DNE	WB = 0.98

\* DNE = Does not exceed

Table 10: Maximum Queue Length Comparison

Max Q Length Comparison							
Intersection	Movement	AM			PM		
		2009 Synchro	2016 Field	2016 Synchro	2009 Synchro	2016 Field	2016 Synchro
Western Avenue at Memorial Drive	WB	-	380	370	-	534	367
	NB	-	339	383	-	427	421
	SB	710	365	475	446	595	225
Western Avenue at Green Street	EB	-	158	117	174	150	134
	WB	-	167	361	-	161	319
	NB	153	133	73	-	574	165

\* Volume exceeds capacity, queues reported to be significantly longer in field



As seen in Table 10, 2016 Synchro and field-measured queues are generally longer than the 2009 Synchro queues, with some exceptions at the Western/Green/River intersection.

In general, observed and measured queues at the Memorial Drive intersection are longer than those calculated by Synchro for 2016 during the PM peak, while being fairly close for the AM peak. This was also true in the 2009 pre-construction analysis, which reported that queues from Memorial Drive along Western Avenue reached Putnam Avenue just before the PM peak, and often extended to Howard Street around 6:00 PM. This phenomenon was attributed in 2009 to a lack of capacity at Western/Putnam during the PM peak, with the intersection reaching its saturation point. This pattern was also observed at the intersection in 2016. This approach was reduced from four lanes to three to improve safety for all modes. While traffic volumes have decreased, the intersection continues to experience some traffic congestion during peak periods, which may be due to preference for lane use and factors outside of the corridor.

## 12. Vehicle Travel Time

The travel time runs completed in 2016 include the bridge between Memorial Drive and Soldier's Field Road, suggesting traffic conditions outside of the Western Avenue corridor could impact the results. The traffic signals on these north/south arterials are coordinated independently of Western Avenue and could lead to increased delay one either end of the corridor.

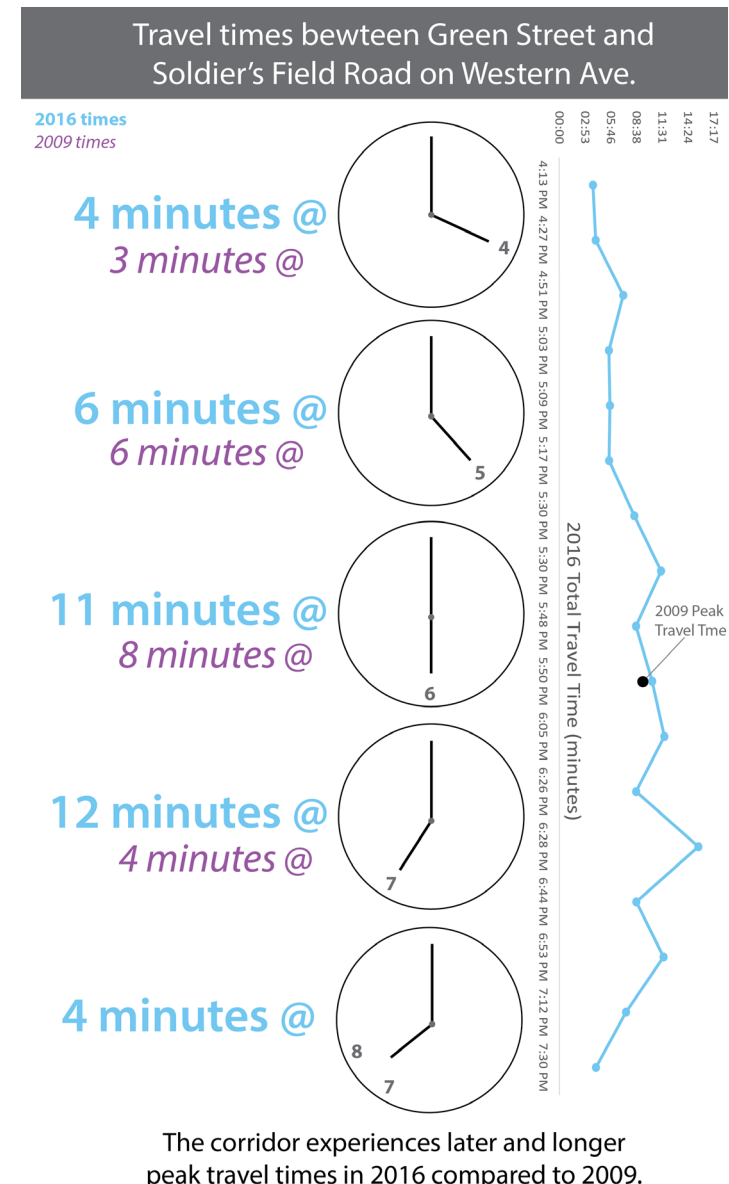


Figure 12: Vehicle Travel Time Comparison

Travel times are influenced by congestion levels along the corridor, particularly during peak periods. The corridor generally experiences later and longer peak travel times in 2016 compared to 2009 (or 2012 for the bus run time comparison), as seen in Figure 11. While the travel times generally increased, some vehicle queue lengths and volumes decreased. A key finding in comparing daily traffic volumes in 2016 compared to the pre-build condition. This is not unique to Western Avenue and is consistent with findings on major roadways in Cambridge and Boston. The resulting increase in vehicular travel time for automobiles and buses, particularly during the evening, indicates the roadway is over saturated. The operations on Western Avenue can be influenced by the major roadways at either end of the corridor, Massachusetts Avenue and Memorial Drive, and may not be attributable to Western Avenue itself. The analysis of “peak spread” for Western Avenue is helpful in understanding the changes in how the corridor operates.

### 13. Bus Travel Time Methodology and Results

MBTA APC data and Running Time Reports from Fall 2012 and Spring 2016 were used to determine travel time between stops, and for the corridor as a whole, for the pre- and post-construction conditions, respectively.<sup>6</sup> The data indicate that both the median and 90th percentile travel times between Green Street and Putnam Street decreased in the morning, and increased in the evening, between Fall 2012 and Spring 2016.

More specifically, for the peak hours 8-9 AM and 5-6 PM:

- Median running times decreased 25% in the AM peak, with the greatest travel time savings realized between Green and Kinnaird Streets.
- Median running times increased 28% in the PM peak, with the most significant increase occurring between Howard and Putnam Streets.
- 90th Percentile running times decreased 47% in the AM peak, with the greatest time savings (100-200 seconds) occurring between Kinnaird and Putnam Streets.
- 90th Percentile running times showed virtually no change during the PM peak, although there was a significant increase in travel times between Howard and Putnam Streets in the 3-4 PM time period.

Figure 13 illustrates median run times over the course of an average day in Fall 2012 and Spring 2016. Figure 12 provides a more focused look at the AM and PM peak hours specifically, with the peak pm still being the biggest challenge for travel times.

<sup>6</sup> Bus travel time data was not collected in 2009.

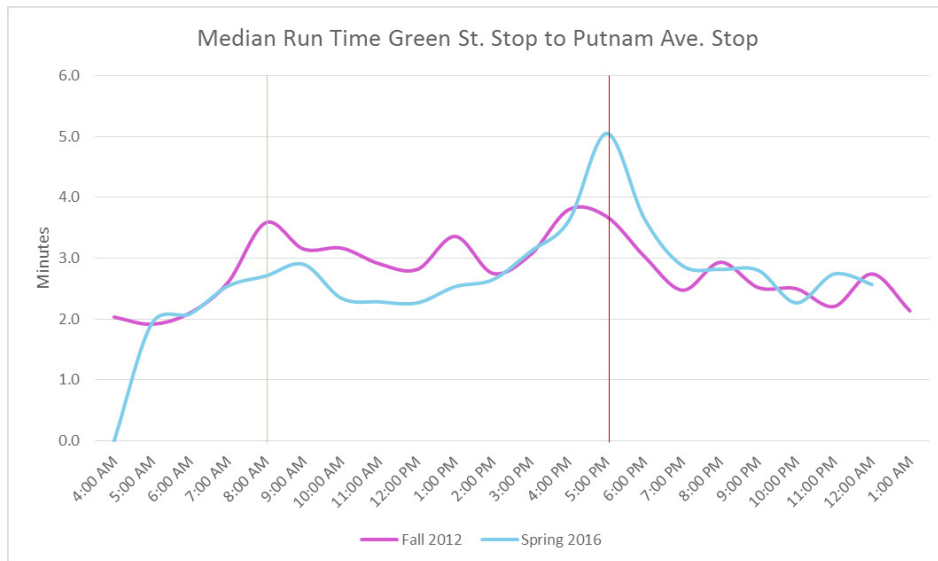


Figure 13: 2012 and 2016 Weekday Median Bus Run Times

## 14. Parking

Utilization rates vary by time of day and corridor segment as shown in Figure 14 through Figure 17. Utilization rates over 100% are possible because the number of available spaces is calculated by determining the number of 18' long parking spaces along a curb segment, while vehicles actually parked may be shorter than typical or parking behavior may be such that additional vehicles fit within a given space.

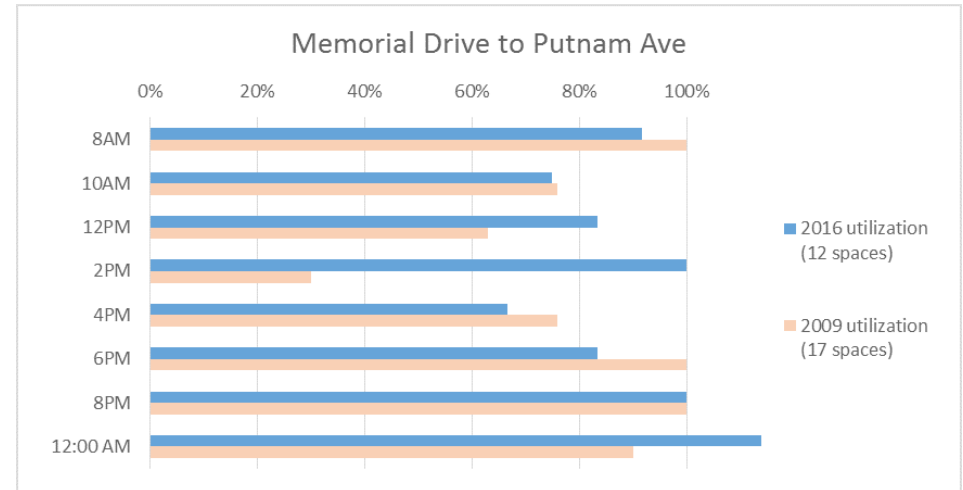


Figure 14: Parking Utilization Rates between Memorial Drive and Putnam Ave in 2009 and 2016 by Time of Day

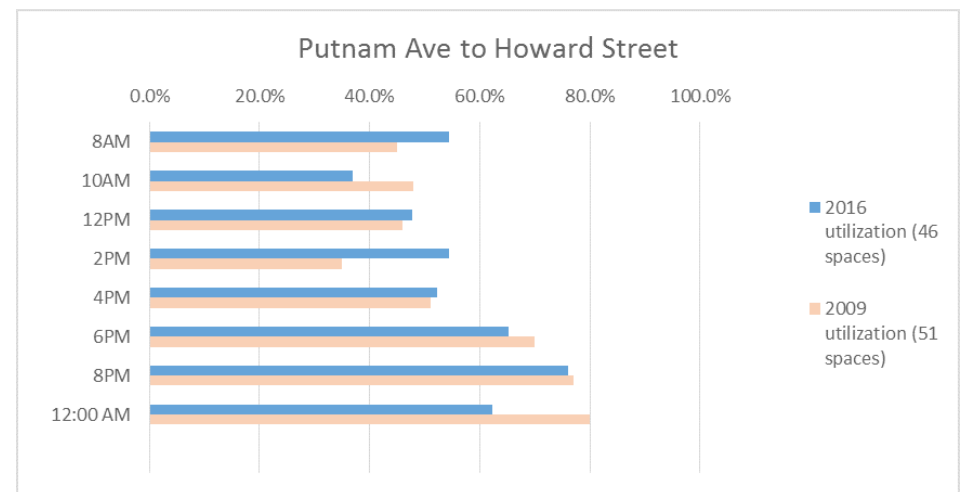


Figure 15: Parking Utilization Rates between Putnam Ave and Howard Street in 2009 and 2016 by Time of Day

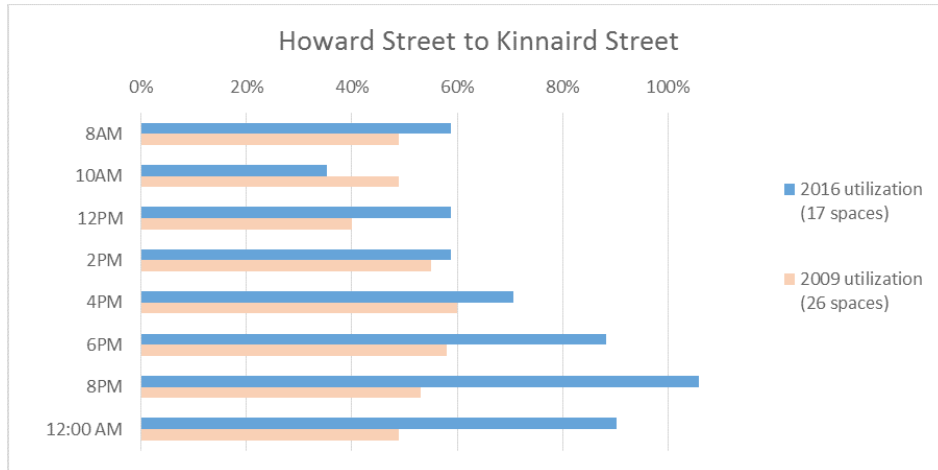


Figure 16: Parking Utilization Rates between Howard Street and Kinnaird Street in 2009 and 2016 by Time of Day

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(last page of Technical Appendix)

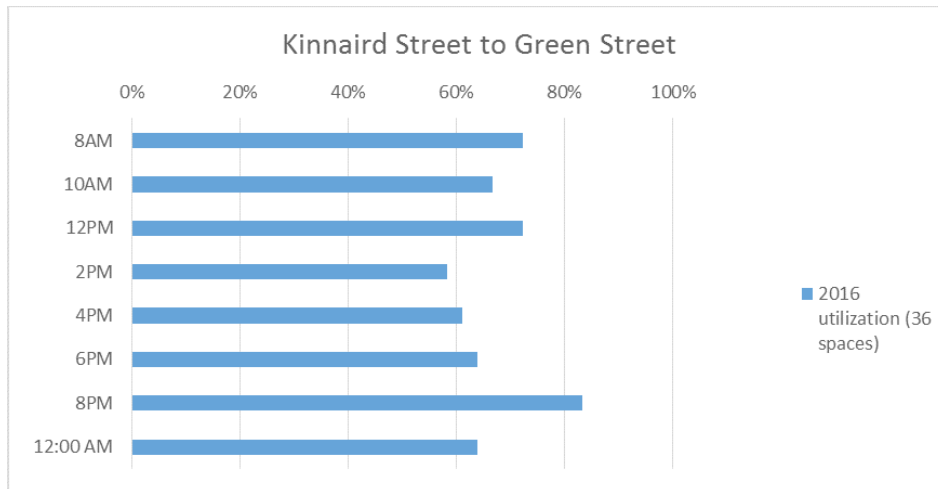


Figure 17: Parking Utilization Rates between Kinnaird Street and Green Street in 2009 and 2016 by Time of Day