Appendix B—Bicycle and Pedestrian Infrastructure Overview

INFRASTRUCTURE CONSIDERATIONS

MPO staff noted several characteristics of the bicyclist and pedestrian environment in order to assess the five selected Fairmount Line station areas. Although staff documented the majority of conditions in the field, some information was gathered using existing data. Staff also used resources such as Google Maps and Bing Maps when documenting field notes in the office to collect additional measurements and ensure accuracy. Appendix B explains how MPO staff acquired the data used in the *Fairmount Line Station-Access Analysis* report and provides definitions for various elements that contribute to the quality of the bicycle and pedestrian environment. The topics covered below include bicycle facilities, bike racks, pedestrian signals, sidewalks, curb ramps, detectable warnings, pavement markings, traffic calming infrastructure, and interim improvements.

Bicycle Facilities

The Boston Bike Network Plan documents bicycle facilities in the City of Boston from 2007 to the present and lays out plans for future bicycle infrastructure, indicating where new facilities will be installed and identifying locations where existing conditions will be improved. MPO staff received Boston Bicycle Network shapefiles (current as of October 22, 2015) from the City of Boston in order to map the current and future bike network in the five selected Fairmount Line station areas. Staff separated the network into existing and proposed facilities in order to illustrate the locations of current bicycle facilities and the areas where new bicycle facilities are anticipated. The bicycle facilities included in the Boston Bike Network are explained below, based on descriptions produced for the City of Boston by Toole Design Group.[130]

Advisory Lane

On low-volume, narrow roads that measure less than 30 feet without parking and less than 44 feet with parking, a dashed bicycle lane with a minimum width of five feet, known as an advisory lane, is provided on both sides of the road. Motor vehicles may enter the bicycle lane to give way to oncoming vehicles.

[130] *Boston Bike Network Bike Facility Descriptions*; Peter Robie; Toole Design Group; City of Boston; August 2015.

Advisory Lane

Source: http://streets.mn/2014/09/30/writers-round-up-advisory-bike-lanes/.

Buffered Bike Lane

A buffered bike lane is an exclusive lane for bicycle travel that measures a minimum width of five feet and is accompanied by a two- to three-foot striped buffer zone adjacent to a vehicle travel lane to provide separation from motor vehicles. The MassDOT Separated Bike Lane Planning & Design Guide states that, regardless of the type of street buffer, a six-foot buffer width is recommended.[131] In constrained conditions, a minimum street buffer width of two feet is allowed, although a minimum one-foot width is permitted alongside a raised bike lane.[132]

[131] *Separated Bike Lane Planning & Design Guide*; Massachusetts Department of Transportation; November 2015; page 34.

[132] *Separated Bike Lane Planning & Design Guide*; Massachusetts Department of Transportation; November 2015; page 34.

Buffered Bike Lane

Source: https://www.reddit.com/r/bicycling/comments/1m8zlh/boston_did_this bike lane_right_extrawide/.

Bike Lane

A bike lane is an exclusive lane for bicycle travel that is a minimum of five feet wide.

Bike Lane

Source: http://streetsmarts.bostonbiker.org/.

Buffered Climbing Lane

Buffered climbing lanes are provided on roads with steep grades where bicycle lanes cannot be provided on both sides of the road. In these cases, an exclusive bicycle lane measuring a minimum of five feet wide and accompanied by a two- to three-foot striped buffer zone is provided in the uphill direction and a marked shared-lane is provided in the downhill direction. Streets with buffered climbing lanes may also be described as streets with a buffered bike lane on one side.

Buffered Climbing Lane

Source: http://edmontonbikes.ca/2013-on-street-bike-routes/.

Bus Bike Lane

A bus bike lane is a lane for shared bus and bicycle travel that measures a minimum width of 11 feet. Motor vehicles are prohibited in bus bike lanes except where signs indicate otherwise.

Bus Bike Lane

Source: http://thetysonscorner.com/transportation-officials-want-to-widen-rt-123-again/.

Climbing Lane

Climbing lanes are found on roads with steep grades where bicycle lanes cannot be provided on both sides of the road. An exclusive bicycle lane measuring a minimum of five feet is provided in the uphill direction and a marked shared-lane is provided in the downhill direction.

Climbing Lane

Source: http://la.streetsblog.org/2012/03/06/santa-monica-debuts-two-new-bikeway-designs/.

Contraflow Bike Lane

On one-way streets, bicyclists may operate in two directions via a contraflow bike lane that measures a minimum of five feet and exclusively serves bicycle travel in the opposite direction of motor vehicle travel. Bicycles traveling in the same direction as motorists should have a bicycle lane or, if necessary, share the lane of travel with automobile drivers.

Contraflow Bike Lane

Source: http://www.bmorebikes.com/fawn-st-contraflow-bike-lane/.

Cycle Track

A cycle track is a physically separated bicycle facility protected from motor vehicle traffic via bollards, flexposts, medians, on-street parking, or planters. MassDOT recommends that flexible delineator posts and rigid bollards be installed within the center of a street buffer and placed between 10 and 80 feet apart from one another along a roadway.[133] If parking stops are used to provide physical separation, MassDOT recommends their installation be consistently spaced along a roadway between parking stops, with a 9- to 12-foot separation between each stop.[134] Ideally, cycle tracks are constructed at or near sidewalk level. MassDOT refers to cycle tracks as separated bike lanes, explaining that they are spaces along roadways that serve bicyclists exclusively.[135] The MassDOT definition mentions that horizontal and vertical elements physically divide separated bike lanes from pedestrian and motor vehicle spaces.[136]

[133] *Separated Bike Lane Planning & Design Guide*; Massachusetts Department of Transportation; November 2015; pages 36-37.

[134] *Separated Bike Lane Planning & Design Guide*; Massachusetts Department of Transportation; November 2015; page 36.

[135] *Separated Bike Lane Planning & Design Guide*; Massachusetts Department of Transportation; November 2015; page 2.

[136] *Separated Bike Lane Planning & Design Guide*; Massachusetts Department of Transportation; November 2015; page 2.

Cycle Track

Source: http://www.cambridgema.gov/CDD/Transportation/design/bicycling/cycletracks.aspx.

Cycle Track/Bike Lane

A cycle track/bike lane street is a street with a cycle track on one side and a bike lane on the other.

Cycle Track/Bike Lane

Source: http://www.peopleforbikes.org/blog/entry/at-last-feds-move-toward-a-green-light-for-protected-bike-lanes.

Existing Facility Replaced by Cycle Track Elsewhere

This designation specifically addresses a circumstance on Blue Hill Avenue where there is an existing bike lane and the proposed facility is a bidirectional cycle track on one side of Blue Hill Avenue. MassDOT recommends a width of 10 feet for two-way bike lanes with less than 150 cyclists per peak hour.[137] However, where conditions are constrained, MassDOT states that a two-way bike lane may measure a minimum of eight feet wide.[138]

Existing Facility Replaced by Cycle Track Elsewhere

Source: https://spokesdunedin.wordpress.com/2012/11/10/protected-bike-lanes/.

Neighborway

Neighborways, also known as bicycle boulevards, are quiet, low-volume streets that are designed for slower speeds and give priority to bicyclists and pedestrians. These streets are designated by neighborway or bicycle boulevard pavement markings and signed as bicycle routes. Traffic-calming devices may be installed along the corridor to reduce vehicular speeds and increase driver awareness of pedestrians and bicycles.

[137] *Separated Bike Lane Planning & Design Guide*; Massachusetts Department of Transportation; November 2015; page 31.
[138] *Separated Bike Lane Planning & Design Guide*; Massachusetts Department of Transportation; November 2015; page 31.

Neighborway

Source: http://www.bikewalklincolnpark.com/2011/10/quick-and-easy-primer-on-bicycle.html.

Parking Buffered Bike Lane

A parking buffered bike lane is an exclusive lane for bicycle travel that measures a minimum of five feet wide and is accompanied by a two- to three-foot striped buffer zone adjacent to on-street parking to provide separation from motor vehicles.

Parking Buffered Bike Lane

Sources (left to right): http://cyclingchristchurch.co.nz/2015/02/02/last-stop-boston-and-reflections-on-us-cycling/; http://chi.streetsblog.org/2013/09/10/eyes-on-the-street-new-buffered-bike-lanes-on-madison-avenue/; http://spacing.ca/edmonton/2014/07/02/four-wild-cheap-ideas-edmonton-can-introduce-right-now-protect-cyclists/.

Priority Shared-Lane Markings

Priority shared-lane markings are found on multi-lane streets with two or more travel lanes in a single direction where shared-lane markings are centered in the outside travel lane. Priority shared-lane markings can be supplemented with dashed longitudinal lines and/or colored pavement to denote bicycle prioritization, encouraging motor vehicles to pass using the inside travel lane.

Priority Shared-Lane Markings

Sources (left-to-right): https://www.bostonglobe.com/metro/2013/11/24/new-sharrows-steroids-debut-allston-brighton-avenue/ZfqrBJVsbhPVF0Ux4j5PFI/story.html. http://www.caeconomy.org/reporting/entry/oakland-introduces-color-to-bike-lanes-to-increase-safety.

Shared-Lane Markings

Where exclusive bike lanes are not feasible and speeds are less than 35 miles per hour, shared-lane pavement markings, also known as "sharrows," designate that bicycles and motor vehicles must share a travel lane. Importantly, research using Chicago census block group data indicates that areas where sharrows were installed experienced a significantly smaller drop in the number of injury crashes per year per 100 bicyclists (6.7 fewer injuries) than streets where bike lanes were added (27.5 fewer injuries) and even than streets where bicycle infrastructure was not added (13.5 fewer injuries).[139]

Shared-Lane Markings

Source: http://sdotblog.seattle.gov/2009/09/24/sharing-the-road-with-sharrows/.

[139] *The Relative (In)Effectiveness of Bicycle Sharrows on Ridership and Safety Outcomes*; Nicholas N. Ferenchak and Wesley E. Marshall; University of Colorado Denver; Transportation Research Board 2016 Annual Meeting; August 2015; page 2.

Shared Street

Shared streets are streets designed for slow speeds with a single grade or surface shared by all users: motorists, transit users, bicyclists, and pedestrians. Traffic-calming devices are typically installed on shared streets to maintain slow speeds.

Shared Streets in Grenoble, France

Sources (left-to-right): http://ca.france.fr/en/discover/grenoble. https://lesoeuvresdeben.wordpress.com/category/travel-blog/.

Shared Street in Boston's Downtown Crossing Area

Source: http://www.panoramio.com/photo/39944914.

Shared-Use Path

A shared-use path is an off-road pathway that is physically separated from motorized travel for shared-use by bicyclists and pedestrians.

Shared-Use Path

Sources (left-to-right): http://www.thevoiceofdowntownboston.com/bike-riding-through-downtown-boston-where-to-go/. https://rootsrated.com/stories/6-reasons-why-boston-is-an-awesome-city-for-outdoor-lovers.

Suggested Local Route

Suggested local routes were offered as popular routes during the Boston Bike Network planning process but ultimately did not receive a facility recommendation.

Bike Racks

When in the field, MPO staff marked the locations of bicycle racks they encountered. Bike parking serves an important role in supporting bicycle transportation because a lack of bike racks reduces the convenience and practicality of bicycle travel. The City of Boston maintains a shapefile of bike rack locations but the file only contains those racks that have been installed on public property and at MBTA stations with Pedal and Park facilities.[140] MPO staff documented bike rack location and type in order to supplement the data provided by the City of Boston. The APBP has created a guidebook that facilitates the successful selection and installation of useful bicycle parking.[141] MPO staff assessed bicycle parking in the Fairmount Line station areas using APBP criteria and recommendations.

While the guide addresses both short- and long-term bicycle parking, this study discusses short-term bicycle parking facilities because they were the only type observed by staff. APBP suggests that users likely would value the shelter and convenience of long-term bicycle parking more than the ease and convenience of

[140] *Bike Parking*; City of Boston; http://www.cityofboston.gov/bikes/parking.asp.
[141] *Essentials of Bike Parking: Selecting and Installing Bicycle Parking That Works*; Association of Pedestrian and Bicycle Professionals (APBP); September 2015; http://c.ymcdn.com/sites/www.apbp.org/resource/resmgr/Bicycle_Parking/EssentialsofBikeParking_FINA.pdf.

short-term facilities when parking for two hours or longer.[142] Therefore, MPO staff recommend installing long-term bicycle parking at locations where bicyclists are expected to park for two or more hours.

Bike Rack Performance Criteria

APBP identifies five characteristics of good bicycle parking. The first is that a bike rack should support a bike upright without putting stress on its wheels.[143] This is done by providing two points of contact with the bike, at least six inches apart, horizontally on a bike's frame.[144] It also may be accomplished with one point cradling the bicycle's wheel and at least one other point supporting the bike's frame securely.[145] APBP specifies that the high point of the rack should measure at least 32 inches tall.[146]

The second criterion for good bicycle parking is that it should accommodate a diverse array of bicycles and attachments.[147] This means that, if installed with proper clearances, a bike rack should serve nearly all common bike styles and attachments instead of restricting the width, height, or length of bicycles, wheels, or attachments.[148]

In addition, effective bicycle parking should allow users to lock a bike's frame and at least one wheel with a U-lock.[149] APBP explains that rack tubes with a two-inch cross section or larger can complicate the use of smaller U-locks.[150] A single U-

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[142] *Essentials of Bike Parking: Selecting and Installing Bicycle Parking That Works*; Association of Pedestrian and Bicycle Professionals (APBP); September 2015; page 1.
[143] *Essentials of Bike Parking: Selecting and Installing Bicycle Parking That Works*; Association of Pedestrian and Bicycle Professionals (APBP); September 2015; page 5.
[144] *Essentials of Bike Parking: Selecting and Installing Bicycle Parking That Works*; Association of Pedestrian and Bicycle Professionals (APBP); September 2015; page 5.
[145] *Essentials of Bike Parking: Selecting and Installing Bicycle Parking That Works*; Association of Pedestrian and Bicycle Professionals (APBP); September 2015; page 5.
[146] *Essentials of Bike Parking: Selecting and Installing Bicycle Parking That Works*; Association of Pedestrian and Bicycle Professionals (APBP); September 2015; page 5.
[147] *Essentials of Bike Parking: Selecting and Installing Bicycle Parking That Works*; Association of Pedestrian and Bicycle Professionals (APBP); September 2015; page 5.
[148] *Essentials of Bike Parking: Selecting and Installing Bicycle Parking That Works*; Association of Pedestrian and Bicycle Professionals (APBP); September 2015; page 5.
[149] *Essentials of Bike Parking: Selecting and Installing Bicycle Parking That Works*; Association of Pedestrian and Bicycle Professionals (APBP); September 2015; page 5.
[150] *Essentials of Bike Parking: Selecting and Installing Bicycle Parking That Works*; Association of Pedestrian and Bicycle Professionals (APBP); September 2015; page 5.

lock should be able to capture one wheel and part of the closed loop of a bike frame.[151]

Another important quality of a good bike rack is that it provides security and longevity suitable to its intended location.[152] This relates most directly to choosing rack materials and coatings that are appropriate for their situations, and selecting tamper-resistant mounting hardware for vulnerable locations.[153] For the majority of general-use bike racks, the most appropriate, and common, materials are steel and stainless steel.[154]

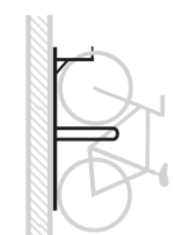
Finally, APBP addresses the fact that bike racks should be intuitive.[155] Users encountering the rack for the first time should be able to discern that it is bicycle parking, and they should not need written instructions in order to use the rack as intended.[156]

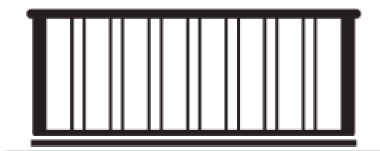
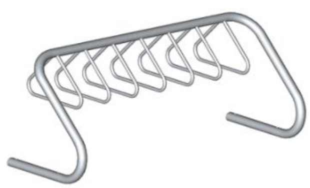
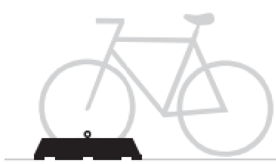
Acceptable and Unacceptable Bike Rack Styles

According to the Association of Pedestrian and Bicycle Professionals, there are three styles of bicycle racks that, when properly designed and correctly installed, meet all of the performance criteria listed above. Some bike racks, classified as high-density, may be appropriate for certain constrained circumstances, even though they do not meet all performance criteria. APBP cites seven racks that should be avoided based on performance concerns (see figure below).

[151] *Essentials of Bike Parking: Selecting and Installing Bicycle Parking That Works*; Association of Pedestrian and Bicycle Professionals (APBP); September 2015; page 5.
[152] *Essentials of Bike Parking: Selecting and Installing Bicycle Parking That Works*; Association of Pedestrian and Bicycle Professionals (APBP); September 2015; page 5.
[153] *Essentials of Bike Parking: Selecting and Installing Bicycle Parking That Works*; Association of Pedestrian and Bicycle Professionals (APBP); September 2015; page 5.
[154] *Essentials of Bike Parking: Selecting and Installing Bicycle Parking That Works*; Association of Pedestrian and Bicycle Professionals (APBP); September 2015; page 5.
[155] *Essentials of Bike Parking: Selecting and Installing Bicycle Parking That Works*; Association of Pedestrian and Bicycle Professionals (APBP); September 2015; page 5.
[156] *Essentials of Bike Parking: Selecting and Installing Bicycle Parking That Works*; Association of Pedestrian and Bicycle Professionals (APBP); September 2015; page 5.

Styles of Bike Racks

Style	Image	Description
1) Acceptable:		
Inverted U (Staple, Loop)		• Common style • Appropriate for many uses • Two points of ground contact • Can be installed in series on rails • Available in many variations
Post and Ring		• Common style • Appropriate for many uses • One point of ground contact • Less prone to unintended perpendicular parking than Inverted U • Can convert parking meter posts
Wheelwell-Secure		• Includes element that cradles one wheel • Design and performance vary by manufacturer • Typically contains bikes well: desirable for long-term parking/ large-scale installations (e.g., campus) • Accommodates fewer bicycle types and attachments than Inverted U and Post and Ring styles
2) Appropriate for Some, but Not All, Circumstances/Users/Bicycles (High Density):		
Staggered Wheelwell-/ Secure		• Variation of wheelwell-secure rack designed to stagger handlebars vertically or horizontally to increase parking density • Reduces usability • Limits types of bikes accommodated • Contains bikes well • Helps fit more parking into constrained spaces
Vertical		• Typically used for high-density indoor parking • Not accessible to all users or all bikes • Can be used in combination with on-ground parking to increase density of overall parking • Creates safety concerns not inherent in on-ground parking
Two-Tier		• Typically used for high-density indoor parking • Performance varies widely

Style	Image	Description
		• Models for public use include lift assist for upper-tier parking • Recommend testing before purchasing • Creates safety concerns not inherent in on-ground parking • Requires maintenance for moving parts
3) Unacceptable:		
Wave (Undulating, Serpentine)		• Not intuitive or user-friendly • Real-world use of this style often falls short of expectations • Supports bike frame at only one location when used as intended
Schoolyard (Comb, Grid)		• Does not allow locking of frame • Can lead to wheel damage • Inappropriate for most public uses • Useful for temporary attended bike storage at events and in locations with no theft concerns • Sometimes preferred by recreational riders who may travel without locks and tend to monitor their bikes while parked
Coathanger		• This style has a top bar that limits the types of bikes it can accommodate
Wheelwell		• Racks that cradle bicycles with only a wheelwell: - Do not provide suitable security - Pose a tripping hazard - Can lead to wheel damage
Bollard		• Typically, does not appropriately support a bike's frame at two separate locations

Style	Image	Description
Spiral		• Possible aesthetic appeal • Functional downsides related to access, real-world use, and the need to lift a wheel to park
Swing Arm Secured		• Intended to capture a bike's frame and both wheels with a pivoting arm • In practice, accommodates limited types of bikes • Have moving parts that create unnecessary complications

Sources: 1) *Essentials of Bike Parking: Selecting and Installing Bicycle Parking That Works*; Association of Pedestrian and Bicycle Professionals (APBP); September 2015; 2) http://www.chinabikerack.com/products/.

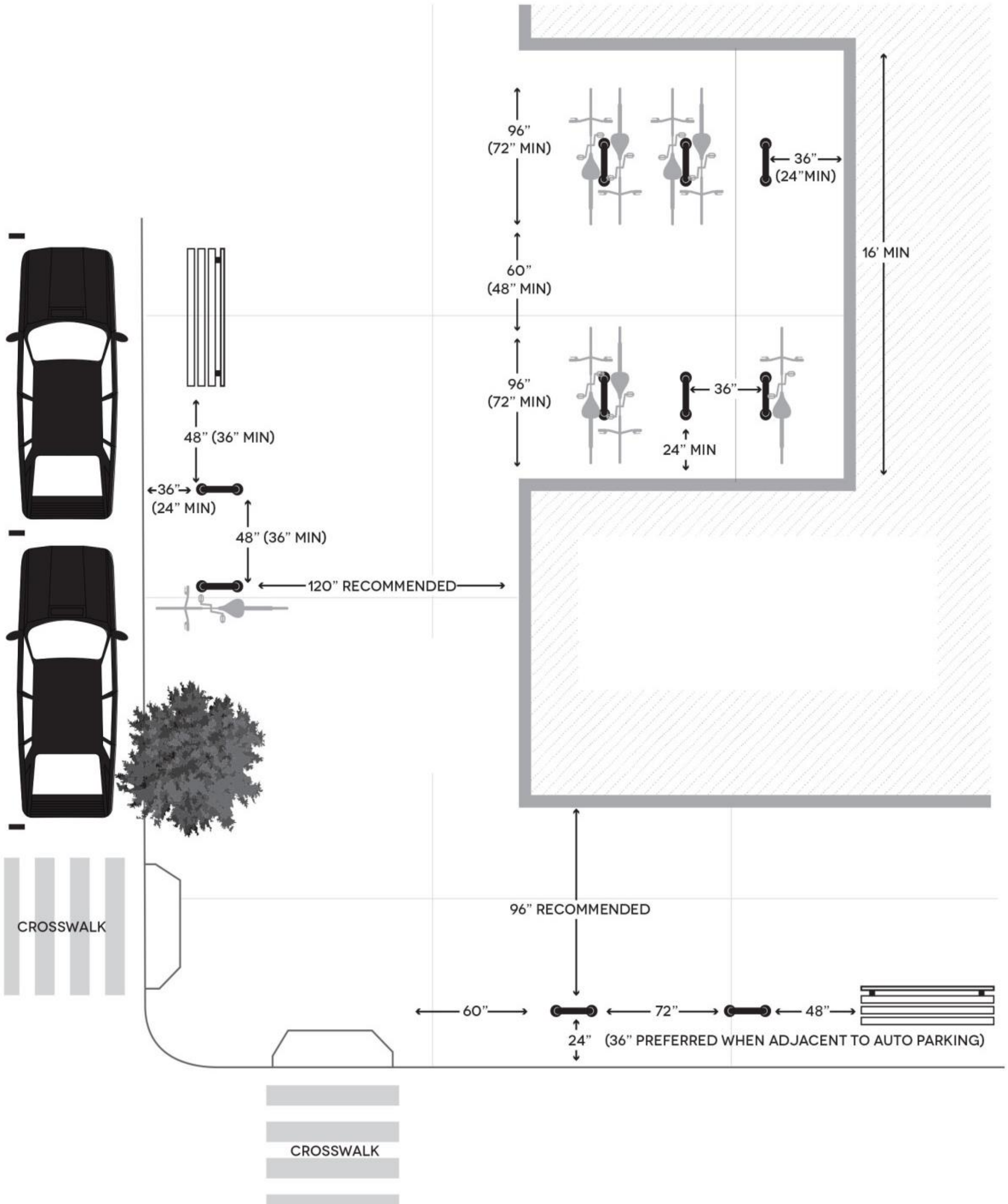
Placement

A typical bicycle footprint measures approximately six-feet long and two-feet wide, although cargo bikes and bikes with trailers can reach 10 feet or longer.[157] This is important to take into consideration when deciding where to install bike racks, as not all arrangements will accommodate all bicycles. In especially tight spots, APBP recommends considering wheelwell-secure bike racks as they may be located next to walls and they constrain the bicycle footprint more reliably than post-and-ring and inverted-U racks.[158] Another consideration when installing bike racks is the importance of maintaining the pedestrian through zone when adding racks to sidewalks.[159] This is done by aligning racks with existing sidewalk obstructions to provide all sidewalk users with a clear line of travel.[160] Finally, to avoid conflicts with opening car doors when sidewalk racks are adjacent to automobile street parking, the racks should be placed between parking stalls.[161] Below is the APBP diagram that illustrates minimum spacing requirements for inverted-U or post-and-ring racks that park one bicycle on each side of the rack.[162]

[157] *Essentials of Bike Parking: Selecting and Installing Bicycle Parking That Works*; Association of Pedestrian and Bicycle Professionals (APBP); September 2015; page 10.
[158] *Essentials of Bike Parking: Selecting and Installing Bicycle Parking That Works*; Association of Pedestrian and Bicycle Professionals (APBP); September 2015; page 10.
[159] *Essentials of Bike Parking: Selecting and Installing Bicycle Parking That Works*; Association of Pedestrian and Bicycle Professionals (APBP); September 2015; page 10.
[160] *Essentials of Bike Parking: Selecting and Installing Bicycle Parking That Works*; Association of Pedestrian and Bicycle Professionals (APBP); September 2015; page 10.
[161] *Essentials of Bike Parking: Selecting and Installing Bicycle Parking That Works*; Association of Pedestrian and Bicycle Professionals (APBP); September 2015; page 10.
[162] *Essentials of Bike Parking: Selecting and Installing Bicycle Parking That Works*; Association of Pedestrian and Bicycle Professionals (APBP); September 2015; page 10.

Recommended clearances are listed first and, where appropriate, they are followed by minimum clearances in parentheses.

Bike Rack Placement



Essentials of Bike Parking: Selecting and Installing Bicycle Parking That Works; Association of Pedestrian and Bicycle Professionals (APBP); September 2015; page 10.

Pedestrian Signals

Pedestrian signals facilitate those crossing roadways on foot by informing them when it is safe to cross the street. These signals display two symbols to communicate to pedestrians when it is safe to cross a roadway: a walking person and an upraised hand.[163] The steady walking person signal, symbolizing Walk, informs pedestrians that it is their turn to begin crossing in the direction of the signal;[164] this is known as the walk interval.[165] The flashing upraised hand signal, symbolizing Don't Walk, means that pedestrians should not start to cross the roadway, but that those who already have begun to cross should proceed to the far side of the street;[166] this is known as the pedestrian change interval.[167] Pedestrians should not cross to the far side of the street if a traffic control device indicates that pedestrians only have time to proceed to the median of a divided highway or other island or pedestrian refuge area.[168] The steady upraised hand signal, symbolizing Don't Walk, tells pedestrians not to enter the roadway.[169] MUTCD standards dictate that the first three or more seconds of the steady upraised hand signal following the pedestrian change interval should serve as a buffer interval, during which traffic from conflicting vehicles should continue to wait for a green light.[170] MPO staff noted the following pedestrian signal conditions when conducting fieldwork.

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[163] *Manual on Uniform Traffic Control Devices, Part 4: Highway Traffic Signals, Chapter 4E: Pedestrian Control Features, Section 4E.01: Pedestrian Signal Heads*; Federal Highway Administration; December 2009; page 495.

[164] *Manual on Uniform Traffic Control Devices, Part 4: Highway Traffic Signals, Chapter 4E: Pedestrian Control Features, Section 4E.02: Meaning of Pedestrian Signal Head Indications*; Federal Highway Administration; December 2009; page 495.

[165] *Manual on Uniform Traffic Control Devices, Part 4: Highway Traffic Signals, Chapter 4E: Pedestrian Control Features, Section 4E.06: Pedestrian Intervals and Signal Phases*; Federal Highway Administration; December 2009; page 498.

[166] *Manual on Uniform Traffic Control Devices, Part 4: Highway Traffic Signals, Chapter 4E: Pedestrian Control Features, Section 4E.02: Meaning of Pedestrian Signal Head Indications*; Federal Highway Administration; December 2009; page 495.

[167] *Manual on Uniform Traffic Control Devices, Part 4: Highway Traffic Signals, Chapter 4E: Pedestrian Control Features, Section 4E.02: Meaning of Pedestrian Signal Head Indications*; Federal Highway Administration; December 2009; page 495.

[168] *Manual on Uniform Traffic Control Devices, Part 4: Highway Traffic Signals, Chapter 4E: Pedestrian Control Features, Section 4E.02: Meaning of Pedestrian Signal Head Indications*; Federal Highway Administration; December 2009; page 495.

[169] *Manual on Uniform Traffic Control Devices, Part 4: Highway Traffic Signals, Chapter 4E: Pedestrian Control Features, Section 4E.02: Meaning of Pedestrian Signal Head Indications*; Federal Highway Administration; December 2009; page 495.

[170] *Manual on Uniform Traffic Control Devices, Part 4: Highway Traffic Signals, Chapter 4E: Pedestrian Control Features, Section 4E.06: Pedestrian Intervals and Signal Phases*; Federal Highway Administration; December 2009; page 497.

Characteristics

MPO staff noted whether a signal's pedestrian crossing phase was accompanied by an audible indication of the pedestrian signal intervals to provide crossing information to pedestrians in a non-visual format. The MUTCD does not require installation of accessible pedestrian signals that provide information through audible tones, vibrating surfaces, and/or speech messages in order to communicate in a non-visual format. However, the MUTCD does include guidance that says accessible pedestrian signals should be provided where engineering judgement determines such signals would be appropriate.[171] MPO staff also identified which pedestrian signals provide a countdown to inform those crossing of the amount of time that remains in the pedestrian change interval in order to traverse a roadway safely. The MUTCD states that a pedestrian change interval of more than seven seconds should include a pedestrian change interval countdown display for this purpose.[172] Finally, at each intersection, MPO staff noted whether pedestrian signal phases were concurrent with vehicular traffic or whether they stopped vehicular traffic altogether to allow for an exclusive pedestrian crossing phase.

Timing

MPO staff used a stopwatch to measure the length of time pedestrians are given to cross at each pedestrian signal. Staff recorded the seconds when the steady walking person is visible, indicating that pedestrians are free to begin to cross the roadway, and the number of seconds the upraised hand flashes to warn pedestrians that there may not be enough time remaining in the pedestrian signal phase for an individual to cross the street safely. As pedestrians, MPO staff could not consistently observe the vehicular traffic lights. This, combined with the varied reaction times of automobile drivers to the illumination of a green light, prevented accurate measurement of the pedestrian signal buffer intervals. Staff calculated two crossing speeds: one divides crossing lengths using only the measured pedestrian change interval durations; the other assumes that each pedestrian signal conforms with MUTCD standards by adding the requisite three-second buffer interval to the recorded pedestrian change interval durations.[173] The

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[171] *Manual on Uniform Traffic Control Devices, Part 4: Highway Traffic Signals, Chapter 4E: Pedestrian Control Features, Section 4D.03: Provisions for Pedestrians*; Federal Highway Administration; December 2009; page 450.

[172] *Manual on Uniform Traffic Control Devices, Part 4: Highway Traffic Signals, Chapter 4E: Pedestrian Control Features, Section 4E.07: Countdown Pedestrian Signals*; Federal Highway Administration; December 2009; page 499.

[173] *Manual on Uniform Traffic Control Devices, Part 4: Highway Traffic Signals, Chapter 4E: Pedestrian Control Features, Section 4E.06: Pedestrian Intervals and Signal Phases*; Federal Highway Administration; December 2009; page 497.

combined duration of the pedestrian change interval and the buffer interval must not be shorter than the calculated pedestrian clearance time.[174]

MUTCD guidance states that pedestrian clearance time should allow an individual traveling at a walking speed of three-and-a-half feet per second to leave the curb at the end of the Walk interval and reach either the far side of the traveled way or a median of sufficient width to allow pedestrians to wait.[175] The FHWA states that crossing times at all intersections should be adjusted to suit the speeds of older adults and people with disabilities, as every intersection will be used by a variety of pedestrians.[176] Specifically, the FHWA recommends that walking speeds of no more than three-and-a-half feet (1.065 meters) per second be used to calculate crossing times, as research shows that the majority of pedestrians walk at speeds slower than four feet (1.22 meters) per second, and 15 percent of pedestrians walk more slowly than three-and-a-half feet per second.[177]

Crossing Length

Using the GoogleMaps measurement tool and aerial satellite imagery, MPO staff measured pedestrian crossing lengths to determine whether the clearance time provided by the combined duration of the pedestrian change interval and the buffer interval would allow an individual to cross the entire segment at a speed of three-and-a-half feet per second. Understanding the rate at which pedestrians are expected to cross a roadway serves as an indication of the accessibility of a pedestrian crossing. Elderly individuals and those with disabilities may not feel comfortable crossing a street if they are not able to do so in the time the signal provides, which may discourage such individuals from walking at all in certain locations.

In order to improve a sense of safety and encourage walking within the Fairmount Line station areas, it is important to identify which crossings require longer pedestrian crossing phases. At intersections where the pedestrian signal phase is

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[174] *Manual on Uniform Traffic Control Devices, Part 4: Highway Traffic Signals, Chapter 4E: Pedestrian Control Features, Section 4E.06: Pedestrian Intervals and Signal Phases*; Federal Highway Administration; December 2009; page 497.

[175] *Manual on Uniform Traffic Control Devices, Part 4: Highway Traffic Signals, Chapter 4E: Pedestrian Control Features, Section 4E.06: Pedestrian Intervals and Signal Phases*; Federal Highway Administration; December 2009; page 497.

[176] *Designing Sidewalks and Trail for Access, Part II of II: Best Practices Design Guide, Chapter 8: Pedestrian Crossings, Section 8.6: Crossing Times*; Federal Highway Administration; September 2001; page 8-17.

[177] *Designing Sidewalks and Trail for Access, Part II of II: Best Practices Design Guide, Chapter 8: Pedestrian Crossings, Section 8.6: Crossing Times*; Federal Highway Administration; September 2001; page 8-17.

exclusive, staff recorded only the longest uninterrupted crossing lengths because such intersections are only as accessible as the timing provided for crossing the widest segment. Interruptions took the form of medians, islands, and other pedestrian refuge areas. These were considered as interruptions only if they measured at least six feet wide, thereby providing sufficient room for a pedestrian with a bicycle, or a stroller, to wait for the next pedestrian phase;[178] or if they included cut-throughs or curb ramps to ensure that the interruptions were fully accessible.[179]

Sidewalks

One way the transportation system supports pedestrian travel is by providing sidewalks. Sidewalk characteristics can promote pedestrian access in numerous ways: minimal obstacles; wide pathways; minimal protruding objects; minimal changes in level; moderate grades and cross slopes; rest areas outside of the pedestrian zone; good lighting; firm, stable, and slip-resistant surfaces; and clearly defined pedestrian, furniture, and frontage zones.[180] As MPO staff traveled through the five station areas by bike and on foot, they documented sidewalk conditions. Although staff did record each of the characteristics cited above, they paid the greatest attention to sidewalk width.

The FHWA explains that, within the sidewalk corridor, there should be four pedestrian zones to accommodate the needs of pedestrians.[181] The zones and their minimum widths are listed in the “Minimum Widths for Sidewalk Zones” table below.[182] A sidewalk width of five feet is necessary to allow a single wheelchair

[178] *Urban Street Design Guide, Intersection Design Elements, Crosswalks and Crossings, Pedestrian Safety Islands*; National Association of City Transportation Officials; Island Press; October 2012; http://nacto.org/publication/urban-street-design-guide/intersection-design-elements/crosswalks-and-crossings/pedestrian-safety-islands/.

[179] *NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan, Volume 10: A Guide for Reducing Collisions Involving Pedestrians, Section V: Strategies for Addressing the Problem, Strategy 9.1 A3: Construct Pedestrian Refuge Islands and Raised Medians*; Charles V. Zegeer, Jane Stutts, Herman Huang, Michael J. Cynecki, Ron Van Houten, Barbara Alberson, Ronald Pfefer, Timothy R. Neuman, Kevin L. Slack; Kelly K. Hardy; Transportation Research Board; 2004; page V-21.

[180] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 4: Sidewalk Corridors;* Federal Highway Administration (FHWA); September 2001; page 4-1.

[181] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 4: Sidewalk Corridors, Section 4.1: Sidewalk Corridor Width, Section 4.1.2: The Zone System;* Federal Highway Administration (FHWA); September 2001; page 4-3.

[182] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 4: Sidewalk Corridors, Section 4.1: Sidewalk Corridor Width, Section 4.1.2: The Zone System;* Federal Highway Administration (FHWA); September 2001; page 4-4.

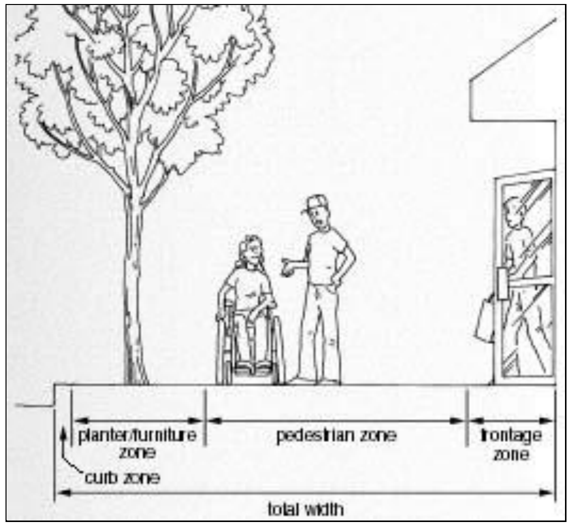
user to turn around or two wheelchair users to pass one another.[183] No frontage zone is needed if at least two- and a-half feet of open space are available between the property line and the sidewalk corridor.[184] In such cases, the minimum width recommended for the sidewalk corridor is seven- and a-half feet instead of the minimum eight- and-a-half feet of right-of-way that the FHWA generally recommends. [185] In some locations, it may be possible to increase the widths of sidewalk corridors by reducing traffic lane widths to the City of Boston's 10-foot-wide minimum travel lane.[186] The National Association of City Transportation Officials (NACTO) Urban Street Design Guide explains that such widths would have a positive impact on the safety of streets without affecting traffic operations; and, they are appropriate in urban areas.[187] Where it is not possible to widen the sidewalk, especially in areas where the pedestrian zone is less than three feet wide, protruding objects and permanent obstacles should be removed from the pedestrian zone.[188]

Minimum Widths for Sidewalk Zones

Zone	Minimum Width
Curb Zone	6 inches
Planter/Furniture Zone	24 inches (2 feet)
If Planting Street Trees	***48 inches (4 feet)***
Pedestrian Zone	60 inches (5 feet)
Frontage Zone	30 inches (2.5 feet)
Total Sidewalk Corridor	10 feet

[183] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 4: Sidewalk Corridors, Section 4.1: Sidewalk Corridor Width, Section 4.1.4: Improving Access on Narrow Sidewalks;* Federal Highway Administration (FHWA); September 2001; page 4-13.
[184] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 4: Sidewalk Corridors, Section 4.1: Sidewalk Corridor Width, Section 4.1.2: The Zone System;* Federal Highway Administration (FHWA); September 2001; page 4-4.
[185] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 4: Sidewalk Corridors, Section 4.1: Sidewalk Corridor Width, Section 4.1.2: The Zone System;* Federal Highway Administration (FHWA); September 2001; pages 4-3 & 4-4.
[186] *Boston Complete Streets Guidelines, Minimum Widths for Roadway Lanes*; City of Boston; 2013; page 103.
[187] *Urban Street Design Guide, Street Design Elements, Lane Widths*; National Association of City Transportation Officials; Island Press; October 2012; http://nacto.org/publication/urban-street-design-guide/street-design-elements/lane-width/.
[188] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 4: Sidewalk Corridors, Section 4.1: Sidewalk Corridor Width, Section 4.1.4: Improving Access on Narrow Sidewalks;* Federal Highway Administration (FHWA); September 2001; page 4-12.

Sidewalk Zones



Source: http://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/sidewalk2/sidewalks204.cfm#the.

MPO staff measured sidewalks using a surveyor's wheel, a measuring tape, or the GoogleMaps measurement tool and satellite imagery. Staff took measurements primarily at locations where it appeared as though the pedestrian zone was narrower than five feet. There should not be any obstructions within the pedestrian zone, as this is the area of the sidewalk corridor that is designated for pedestrian travel.[189] Utilities and pedestrian amenities should be located in the planter/ furniture zone in order to ensure that light poles, fire hydrants, street trees, and other amenities do not act as obstacles to safe and comfortable pedestrian travel.[190] A planter/ furniture zone also provides a buffer between traffic and pedestrians.[191] Staff measured the width of the pedestrian zone where it appeared as though utilities or pedestrian amenities had been located within the five-foot corridor that should be reserved exclusively for pedestrian travel.

[189] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 4: Sidewalk Corridors, Section 4.1: Sidewalk Corridor Width, Subsection 4.1.2: The Zone System, Sub-Subsection 4.1.2.3: Pedestrian Zone;* Federal Highway Administration (FHWA); September 2001; page 4-6.

[190] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 4: Sidewalk Corridors, Section 4.1: Sidewalk Corridor Width, Section 4.1.2: The Zone System;* Federal Highway Administration (FHWA); September 2001; page 4-4.

[191] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 4: Sidewalk Corridors, Section 4.1: Sidewalk Corridor Width, Section 4.1.2: The Zone System;* Federal Highway Administration (FHWA); September 2001; page 4-6.

Curb Ramps

Curb ramps offer pedestrians an accessible path and are required at all altered or newly constructed streets, roads, highways, and street-level pedestrian walkways at any intersection with curbs or other barriers to access.[192] Curb ramps may either cut through curbs or be built up to them.[193] The entirety of a curb ramp, aside from side flares, must be contained within its crosswalk.[194] Whether or not they are marked, it is understood that crosswalks are located at every intersection.[195] When traveling through the five Fairmount Line station areas, MPO staff marked the locations of curb ramps and indicated the curb ramp's structural design type relative to the sidewalk. These types are described below.

Perpendicular Curb Ramps

Although a variety of designs may be considered, a perpendicular curb ramp that is oriented at a 90-degree angle to the curb is recommended for access from the pedestrian zone to the street.[196] Perpendicular curb ramps are not always possible because they take up additional right-of-way by requiring a wide sidewalk corridor or a curb extension to accommodate the ramp and the required level landing.[197] The severe cross slopes and rapid changes in cross slopes over short distances that characterize perpendicular curb ramps without level landings can be unsafe for wheelchair users to maneuver.[198] The MassDOT Highway Division prefers when curb ramps are paired with a reciprocal curb ramp.[199]

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[192] *ADA Standards for Accessible Design, 28 CFR 35.151 New Construction and Alterations, Section (i): Curb Ramps*; Department of Justice; September 15, 2010; page 13.

[193] *Guide to the ADA Standards, Chapter 4: Accessible Routes, Ramps and Curb Ramps, Section 406: Curb Ramps*; United States Access Board; July 23, 2004; page 122.

[194] *Guide to the ADA Standards, Chapter 4: Accessible Routes, Ramps and Curb Ramps, Section 406: Curb Ramps*; United States Access Board; July 23, 2004; page 126.

[195] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 8: Pedestrian Crossings, Section 8.5: Crosswalks;* Federal Highway Administration (FHWA); September 2001; page 8-10.

[196] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 4: Sidewalk Corridors, Section 4.1: Sidewalk Corridor Width, Section 4.1.2: The Zone System;* Federal Highway Administration (FHWA); September 2001; page 4-4.

[197] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 7: Curb Ramps, Section 7.2: Curb Ramp Types, Section 7.2.1: Perpendicular Curb Ramps;* Federal Highway Administration (FHWA); September 2001; page 7-8.

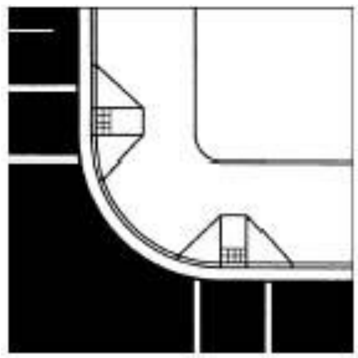
[198] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 7: Curb Ramps, Section 7.2: Curb Ramp Types, Section 7.2.1: Perpendicular Curb Ramps;* Federal Highway Administration (FHWA); September 2001; page 7-6.

[199] *Notes on Walks and Wheelchair Ramps for Designers and Construction Engineers*; Massachusetts Department of Transportation (MassDOT) Highway Division; March 2012; page 4.

Perpendicular curb ramps are aligned with the crossing direction on tight radius corners, resulting in a straight path of travel and causing them to be positioned within the crosswalk.[200] Perpendicular curb ramps also are stationed at the expected crossing location for all pedestrians and are aligned perpendicular to vehicular traffic.[201] In spite of the benefits of this structural design type, perpendicular curb ramps do not provide a straight path of travel on large radius corners and are more expensive than a single diagonal curb ramp.[202]

The image below reflects one type of acceptable design for curb ramps perpendicular to crosswalks.

Design for Curb Ramp Perpendicular to Crosswalk



Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 7: Curb Ramps, Section 7.2: Curb Ramp Specifications; Federal Highway Administration (FHWA); September 2001; page 7-19.

Diagonal Curb Ramps

The alternative is to provide a diagonal curb ramp that is located at the apex of an intersection corner, leading users diagonally into the center of the intersection if

[200] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 7: Curb Ramps, Section 7.2: Curb Ramp Types, Section 7.2.1: Perpendicular Curb Ramps;* Federal Highway Administration (FHWA); September 2001; page 7-8.

[201] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 7: Curb Ramps, Section 7.2: Curb Ramp Types, Section 7.2.1: Perpendicular Curb Ramps;* Federal Highway Administration (FHWA); September 2001; page 7-8.

[202] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 7: Curb Ramps, Section 7.2: Curb Ramp Types, Section 7.2.1: Perpendicular Curb Ramps;* Federal Highway Administration (FHWA); September 2001; page 7-8.

they are moving down the ramp in a straight path.[203] The MassDOT Highway Division states that, where intersection geometry precludes use of paired ramps, apex ramps serving two directions may be used.[204] When apex curb ramps are used, the ramp must be fully contained by both crosswalks that the apex curb ramp is serving.[205] For people with visual impairments who use the curb to identify the transition from the sidewalk to the street, diagonal curb ramps can enhance their ability to detect the intersection by allowing a pedestrian's normal path of travel to intersect a curb instead of a curb ramp.[206]

While diagonal curb ramps require less space and are less expensive than the perpendicular option because there is only one curb ramp per corner, diagonal curb ramps introduce areas of potential conflict between pedestrians and motorists who are traveling straight and turning.[207] Additional disadvantages of diagonal curb ramps include the difficulties they introduce for most people with disabilities, as the ramps do not align with the proper crossing direction.[208] Furthermore, wheelchair users must turn at both the top and bottom of diagonal curb ramps and it is difficult to create the level area at the bottom of a diagonal curb ramp that wheelchair users need for maneuvering purposes.[209] Finally, diagonal curb ramps may cause a visually impaired individual to mistake the ramp for a perpendicular curb ramp, which could cause the individual to travel into the

[203] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 7: Curb Ramps, Section 7.2: Curb Ramp Types, Section 7.2.2: Diagonal Curb Ramps;* Federal Highway Administration (FHWA); September 2001; page 7-8.

[204] *Notes on Walks and Wheelchair Ramps for Designers and Construction Engineers*; Massachusetts Department of Transportation (MassDOT) Highway Division; March 2012; page 4.

[205] *Notes on Walks and Wheelchair Ramps for Designers and Construction Engineers*; Massachusetts Department of Transportation (MassDOT) Highway Division; March 2012; page 4.

[206] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 7: Curb Ramps, Section 7.2: Curb Ramp Types, Section 7.2.2: Diagonal Curb Ramps;* Federal Highway Administration (FHWA); September 2001; page 7-10.

[207] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 7: Curb Ramps, Section 7.2: Curb Ramp Types, Section 7.2.2: Diagonal Curb Ramps;* Federal Highway Administration (FHWA); September 2001; pages 7-10 & 7-11.

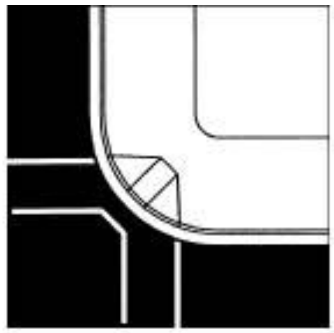
[208] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 7: Curb Ramps, Section 7.2: Curb Ramp Types, Section 7.2.2: Diagonal Curb Ramps;* Federal Highway Administration (FHWA); September 2001; page 7-11.

[209] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 7: Curb Ramps, Section 7.2: Curb Ramp Types, Section 7.2.2: Diagonal Curb Ramps;* Federal Highway Administration (FHWA); September 2001; page 7-11.

middle of the intersection unintentionally, if audible traffic cues are ambiguous or lacking.[210]

The image below reflects one type of acceptable design for curb ramps diagonal to crosswalks.

Design for Curb Ramp Diagonal to Crosswalk



Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 7: Curb Ramps, Section 7.2: Curb Ramp Specifications; Federal Highway Administration (FHWA); September 2001; page 7-20.

Diagonal Curb Ramps

Source: Central Transportation Planning Staff.

[210] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 7: Curb Ramps, Section 7.2: Curb Ramp Types, Section 7.2.2: Diagonal Curb Ramps;* Federal Highway Administration (FHWA); September 2001; page 7-11.

Documentation

MPO staff identified each curb ramp as being either perpendicular, diagonal, or apex. MPO staff differentiated between diagonal and apex curb ramps by marking curb ramps that served only one crossing as diagonal and curb ramps that served two crossings as apex. Staff also noted locations where curb ramps should have been provided, but where they were not present. One of the greatest barriers to movement for pedestrians at pedestrian crossings is a curb without a curb ramp.[211] Staff noted locations where crosswalks led to curbs without ramps, as well as locations where installing curb ramps would improve pedestrian access.

Detectable Warnings

Detectable warnings at locations such as curb ramps and other transitions along sidewalks and public streets, where there are increased hazards for people with vision impairments, serve to alert such individuals that they are approaching a vehicular area or a drop-off along a rail station platform.[212] Detectable warnings are required by the ADA and must be included when altering or constructing curb ramps.[213] Detectable warnings convey information in multiple formats in order to communicate environmental conditions best. The texture of the truncated domes, contrast in color from the surrounding surface, and changes in material resiliency between surfaces all serve to inform pedestrians that they have reached a boundary between the sidewalk and the street.[214] The color contrast between a detectable warning and the surrounding surface can make it easier for pedestrians to identify the location of the curb on the opposite corner of a crossing, especially for wheelchair users, people of short stature, and children.[215]

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[211] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 8: Pedestrian Crossings, Section 8.1: Barriers to Pedestrian Access, Section 8.1.1: Movement Barriers;* Federal Highway Administration (FHWA); September 2001; pages 8-2 & 8-3.

[212] *Guide to the ADA Standards, Chapter 4: Accessible Routes, Ramps and Curb Ramps, Section 406: Curb Ramps*; United States Access Board; July 23, 2004; page 129.

[213] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 6: Providing Information to Pedestrians, Section 6.3: Detectable Warnings;* Federal Highway Administration (FHWA); June 26, 2009; https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/sidewalk2/pdf/07chapter6.pdf.

[214] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 6: Providing Information to Pedestrians, Section 6.3: Detectable Warnings;* Federal Highway Administration (FHWA); September 2001; page 6-6.

[215] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 6: Providing Information to Pedestrians, Section 6.3: Detectable Warnings;* Federal Highway Administration (FHWA); September 2001; page 6-6.

At a minimum, detectable warnings must occupy the space within 24 inches of the back of the curb,[216] and they must span the width of the curb ramp run, which must measure a minimum of 36 inches.[217] Calculations in this report therefore assume that detectable warnings have an area of 864 inches, or six square feet. Staff marked the locations of the detectable warnings that they encountered when assessing the five selected Fairmount Line station areas.

Detectable Warning

Source: http://www.adatile.com/replaceable_wet_set.php.

Pavement Markings

While conducting fieldwork, Staff noted pavement markings such as crosswalks, bike lanes, sharrows, and bike boxes, and indicated on field maps locations where markings had faded and needed re-painting. Staff also noted what types of crosswalk markings were used; and identified locations where quick, inexpensive pavement markings could be added to station areas to provide immediate, if temporary, improvements.

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[216] *Guide to the ADA Standards, Chapter 4: Accessible Routes, Ramps and Curb Ramps, Section 406: Curb Ramps*; United States Access Board; July 23, 2004; page 129.
[217] *Guide to the ADA Standards, Chapter 4: Accessible Routes, Ramps and Curb Ramps, Section 406: Curb Ramps*; United States Access Board; July 23, 2004; page 122.

Crosswalks

MUTCD standards state that, before a marked crosswalk is installed at a location not controlled by a Stop sign, Yield sign, or traffic control signal, an engineering study should be performed.[218] It is recommended that crosswalks be marked using the continental crosswalk design, as research indicates that drivers find it to be the most visible crosswalk marking option.[219]

Other crosswalk markings also are acceptable according to MUTCD standards, which state that crosswalk lines shall consist of solid white lines not less than six inches or greater than 24 inches wide.[220] Although parallel, or standard, crosswalk markings are permissible; they are less visible to motorists than continental crosswalk markings.[221] MPO staff mainly observed crosswalks marked with the ladder pattern in the Fairmount Line station areas studied. When documenting the locations of crosswalks, MPO staff indicated in field notes when crosswalks marked with designs different from the continental and standard patterns were noticed. This was done in order to understand which crosswalks might be less visible than others might. MPO staff also considered the trajectory of existing crosswalks where the configuration appeared counter-intuitive or dangerous. Finally, staff identified locations where there appeared to be strong pedestrian desire lines for street crossings.

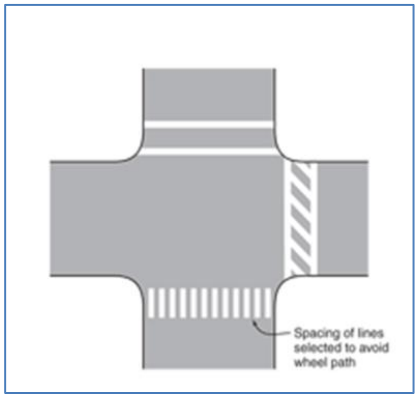
[218] *Manual on Uniform Traffic Control Devices, Part 3: Markings, Chapter 3B: Pavement and Curb Markings, Section 3B.18: Crosswalk Markings*; Federal Highway Administration; December 2009; page 384.

[219] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 8: Pedestrian Crossings, Section 8.5: Crosswalks, Section 8.5.1: Crosswalk Markings;* Federal Highway Administration (FHWA); September 2001; pages 8-11.

[220] *Manual on Uniform Traffic Control Devices, Part 3: Markings, Chapter 3B: Pavement and Curb Markings, Section 3B.18: Crosswalk Markings*; Federal Highway Administration; December 2009; page 383.

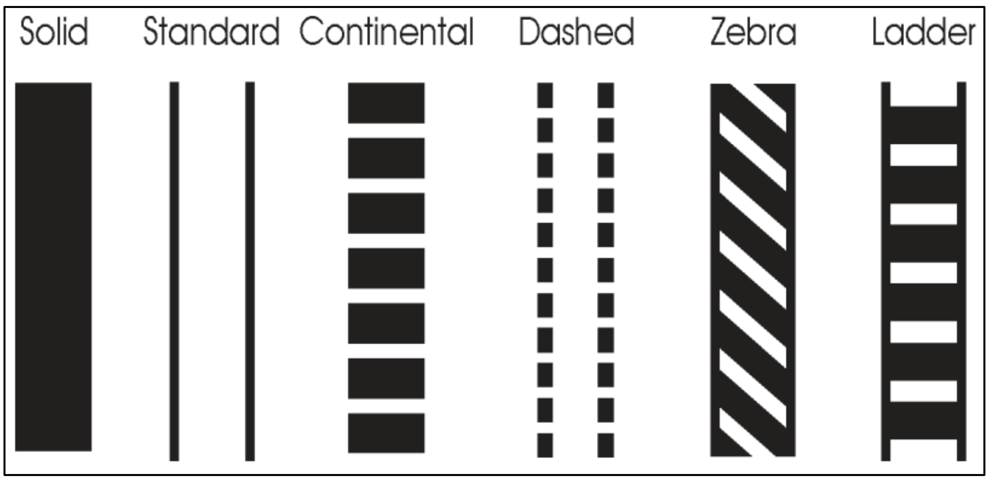
[221] *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide, Chapter 8: Pedestrian Crossings, Section 8.5: Crosswalks, Section 8.5.1: Crosswalk Markings;* Federal Highway Administration (FHWA); September 2001; pages 8-11.

Basic Crosswalk Markings



Source: Manual on Uniform Traffic Control Devices, Part 3: Markings, Chapter 3B: Pavement and Curb Markings, Section 3B.18: Crosswalk Markings; Federal Highway Administration; December 2009; page 384.

Types of Crosswalk Markings



Source: Costs for Pedestrian and Bicyclist Infrastructure Improvements: A Resource for Researchers, Engineers, Planners, and the General Public; Max A. Bushell, Bryan W. Poole, Charles V. Zegeer, and Daniel A. Rodriguez; UNC Highway Safety Research Center; October 2013; page 23.

Bike Boxes

Bike boxes, typically demarcated in green, are included at intersections to provide cyclists with a safe, visible location where they can wait ahead of queuing vehicular traffic during the red signal phase.[222] When bike boxes extend across the entire travel lane, the pavement markings allow cyclists to position themselves for left turns while the signal is red.[223] An additional benefit is that bike boxes prevent conflicts between cyclists and right-turning vehicles when the signal turns green because cyclists are located ahead of vehicular traffic.[224] Bike boxes also group cyclists together, thereby allowing them to clear an intersection quickly; in turn, this reduces the duration of potential conflict with vehicular traffic.[225] Finally, bike boxes provide a buffer between crosswalks and motorists, helping to minimize vehicles encroaching into the pedestrian space.[226]

Bike Box on Speedway in Austin, Texas

Source: http://nacto.org/publication/urban-bikeway-design-guide/intersection-treatments/bike-boxes/.

[222] http://nacto.org/publication/urban-bikeway-design-guide/intersection-treatments/bike-boxes/
[223] *Ibid*.
[224] *Ibid*.
[225] *Ibid*.
[226] *Ibid*.

Traffic-Calming Infrastructure

While they were in the field, staff occasionally noticed speeding vehicles. There were instances when Fairmount Line residents informed MPO staff of locations where vehicles often travel fast enough to cause safety concerns. A study by the AAA Foundation for Traffic Safety identified pedestrians' risk of severe injury or death during a collision relative to impact speed (illustrated in the table below). As impact speed increases, the likelihood of a collision resulting in severe injury or death to a pedestrian grows. Speeding traffic reduces the safety and comfort of an environment for bicyclists and pedestrians and can discourage individuals' decisions to bike or walk in a location.

	Risk of Severe Injury					Risk of Death				
	10%	**25%**	**50%**	**75%**	**90%**	**10%**	**25%**	**50%**	**75%**	**90%**
Impact Speed (mph)	16	23	31	39	46	23	32	42	50	58

Source: Impact Speed and a Pedestrian's Risk of Severe Injury or Death; AAA Foundation for Traffic Safety; September 2011; page 11.

A number of techniques may be deployed in order to slow vehicular traffic and make roads safer for all modes of transportation. They range from simple striping solutions—such as narrowing traffic lanes, using back-in angle parking spaces instead of parallel parking, or changing one-way streets to allow bi-directional travel[227]—to horizontal shifts—like traffic circles and chicanes, narrowing roadways with medians and curb extensions, and vertical deflections in the form of speed tables, speed humps, and raised crossings.[228] In addition, vegetation may be used to reduce the "optical width" of a street to discourage speeding, especially when in the form of vertical elements like trees.[229] A description of each of these traffic-calming measures is provided below.

Narrowing Traffic Lanes

Lane width is one roadway factor that influences driver behavior. While there is not a consensus on the relationship between speed and lane width, studies have found that as the width of a traffic lane increases, so do the speeds at which vehicles travel. One study found that for every one-foot increase in lane width, 85th-percentile vehicular traffic speeds increased by 2.9 miles per hour.[230] The

[227] *Traffic Calming Toolbox*; Project for Public Spaces; http://www.pps.org/reference/livememtraffic/.
[228] *Traffic Calming Measures*; Institute of Transportation Engineers; 2016; http://www.ite.org/traffic/tcdevices.asp.
[229] *Traffic Calming Toolbox*; Project for Public Spaces; http://www.pps.org/reference/livememtraffic/.
[230] *Relationship Between Lane Width and Speed: Review of Relevant Literature*; Parsons Transportation Group; September 2003; page 6.

reduction in driving speed associated with narrower traffic lanes may be attributed to drivers staying in their lanes and steering more accurately as a lane's width decreases.[231] Narrowing lane width discourages speeding by using a psycho-perceptive sense of enclosure.[232] The NACTO Urban Street Design Guide explains that such narrowed widths have a positive impact on streets' safety without affecting traffic operations, and are appropriate in urban areas.[233] In the City of Boston, travel lanes may measure a minimum of 10-feet wide.[234]

Back-In Angle Parking Spaces

Striping parking spaces at a diagonal instead of creating parking spaces parallel to the curb narrows street widths, thereby shortening the "peering distance" for people crossing the street.[235] This type of parking also removes the danger of a motorist opening a car door into the path of a bicyclist.[236] In addition, back-in diagonal parking eliminates the difficulty of backing into moving traffic that motorists encounter when leaving conventionally angled parking spaces.[237] In these ways, back-in angle parking benefits many road users. Another benefit is that it gives motorists clear sight lines when leaving a parking space, minimizing the likelihood of collisions with pedestrians, bicycles, or other vehicles. Back-in diagonal parking also prevents children from running into the street when the doors of a vehicle parked in such a spot are opened;[238] instead, children are directed to the curb.

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[231] *Relationship Between Lane Width and Speed: Review of Relevant Literature*; Parsons Transportation Group; September 2003; page 5.

[232] *Traffic Calming: State of the Practice, Chapter 3: Traffic Calming Measures*; Reid Ewing; Institute of Transportation Engineers; August 1999; page 31.

[233] *Urban Street Design Guide, Street Design Elements, Lane Widths*; National Association of City Transportation Officials; Island Press; October 2012; http://nacto.org/publication/urban-street-design-guide/street-design-elements/lane-width/.

[234] *Boston Complete Streets Guidelines, Minimum Widths for Roadway Lanes*; City of Boston; 2013; page 103.

[235] *Traffic Calming Toolbox*; Project for Public Spaces; http://www.pps.org/reference/livememtraffic/.

[236] *Back-In Angle Parking: What Is It, and When and Where Is It Most Effective?*; Pedestrian and Bicycle Information Center; http://www.pedbikeinfo.org/data/faq_details.cfm?id=3974.

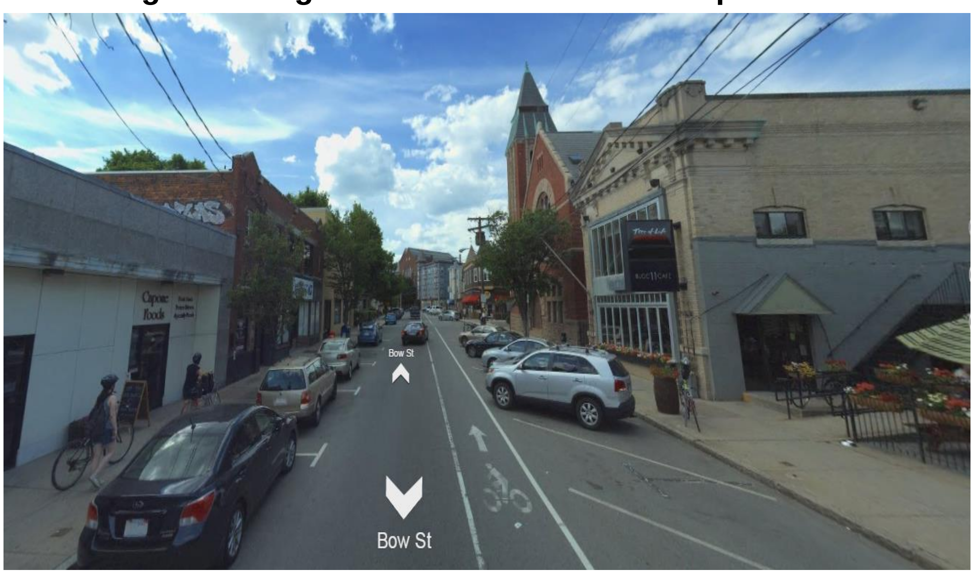
[237] *Back-In Angle Parking: What Is It, and When and Where Is It Most Effective?*; Pedestrian and Bicycle Information Center; http://www.pedbikeinfo.org/data/faq_details.cfm?id=3974.

[238] *What Are The Advantages and Disadvantages of Using Back-In, Head-Out Angled Parking at an Elementary School?;* National Center for Safe Routes to School;

Back-In Angle Parking on South Congress Avenue in Austin, Texas

Source: http://www.clearskyimages.com/blog/location-photography-south-congress-st-austin.

Back-In Angle Parking on Bow Street at Union Square in Somerville



Source: Google Street View, Bow Street, Union Square, Somerville, Massachusetts.

Replacing One-Way Roads with Two-Way Streets

Speeds tend to be higher on one-way streets than on two-way streets because the way that signals are timed on one-way streets causes fewer stops for vehicles.[239] In addition, many claim that a lack of concern for oncoming traffic encourages drivers to speed on one-way streets. Perhaps the most evident difference between traffic flows on one- versus two-way streets, however, is the fact that there are not conflicting left-turn maneuvers at intersections on one-way roads. Left turns at intersections reduce maximum vehicle flows, which limits the speeds at which motorists travel down two-way streets.[240] Therefore, converting a one-way street to two-way travel is one approach for calming traffic speeds.

Additional benefits of two- versus one-way streets include: two-way streets allow drivers to navigate more directly to their destinations;[241] bus stops for both directions of travel are located on the same street, and therefore are easier to find on two-way streets;[242] and bidirectional travel puts all businesses within motorists' sight of by allowing storefront exposure on both sides of the street at intersections.[243] Moreover, the danger of multiple-threat pedestrian crashes—which occur when a driver on a multilane road stops to allow a pedestrian to cross and an on-coming vehicle traveling in the same direction in an adjacent lane strikes the crossing pedestrian[244]—would be less on a two-way street than it would on the same street if traffic traveled in only one direction.

[239] *Two-Way Street Networks: More Efficient than Previously Thought?*; Vikash V. Gayah; Access: Transportation Research at the University of California; Number 41; Fall 2012; page 11.
[240] *Two-Way Street Networks: More Efficient than Previously Thought?*; Vikash V. Gayah; Access: Transportation Research at the University of California; Number 41; Fall 2012; page 12.
[241] *Two-Way Street Networks: More Efficient than Previously Thought?*; Vikash V. Gayah; Access: Transportation Research at the University of California; Number 41; Fall 2012; page 11.
[242] *The Case Against One-Way Streets*; Eric Jaffe; CityLab; January 31, 2013; http://www.citylab.com/commute/2013/01/case-against-one-way-streets/4549/.
[243] *Advantages and Disadvantages of One-Way Streets*; Glatting, Jackson, Kercher, Anglin; October 20, 2007; page 4.
[244] *Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations: Final Report and Recommended Guidelines (FHWA Publication Number HRT-04-100)*; United Stated Department of Transportation Federal Highway Administration; September 2005; page 39.

Traffic Circles/Roundabouts

Traffic circles and roundabouts calm traffic by disrupting straight routes that allow vehicles to gather speed. They are installed for this purpose, and for their ability to help reduce angle collisions; they help traffic flow more efficiently because they eliminate left turns at intersections.[245] In addition, traffic circles and roundabouts have the potential to provide cost savings when installed in place of signalized intersections, although this is dependent upon landscaping costs and maintenance.[246] Finally, traffic circles and roundabouts may act as entrances to special districts or areas by serving as gateway treatments.[247]

Landscaped Traffic Circle

Source: http://www.greenbuildingadvisor.com/sites/default/files/MiniCircle_007_Burden.jpg.

[245] *Costs for Pedestrian and Bicyclist Infrastructure Improvements: A Resource for Researchers, Engineers, Planners, and the General Public*; Max A. Bushell, Bryan W. Poole, Charles V. Zegeer, and Daniel A. Rodriguez; UNC Highway Safety Research Center; October 2013; page 17.

[246] *Costs for Pedestrian and Bicyclist Infrastructure Improvements: A Resource for Researchers, Engineers, Planners, and the General Public*; Max A. Bushell, Bryan W. Poole, Charles V. Zegeer, and Daniel A. Rodriguez; UNC Highway Safety Research Center; October 2013; page 17.

[247] *Costs for Pedestrian and Bicyclist Infrastructure Improvements: A Resource for Researchers, Engineers, Planners, and the General Public*; Max A. Bushell, Bryan W. Poole, Charles V. Zegeer, and Daniel A. Rodriguez; UNC Highway Safety Research Center; October 2013; page 17.

Chicanes

Chicanes are concrete islands that divert vehicles horizontally, and reduce speed by offsetting the path of travel. When landscaped, chicanes provide the extra benefit of adding vegetation to the environment. Chicanes may be accompanied by a median island that enforces the roadway markings.

Landscaped Chicanes with Median Island

Source: http://www.pedbikesafe.org/PEDSAFE/cm_images/Chicane4.jpg.

Medians

Medians calm traffic by separating different streams of travel and limiting turning movements along a roadway.[248] Generally, medians are separated from lanes of traffic by a curb; they are located in the center of a road, and they are narrower than islands.[249] Medians provide space for lighting and landscaping, they make pedestrians more visible to motorists and facilitate pedestrian crossings, and they slow the speed of traffic.[250]

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[248] *Costs for Pedestrian and Bicyclist Infrastructure Improvements: A Resource for Researchers, Engineers, Planners, and the General Public*; Max A. Bushell, Bryan W. Poole, Charles V. Zegeer, and Daniel A. Rodriguez; UNC Highway Safety Research Center; October 2013; page 15.

[249] *Costs for Pedestrian and Bicyclist Infrastructure Improvements: A Resource for Researchers, Engineers, Planners, and the General Public*; Max A. Bushell, Bryan W. Poole, Charles V. Zegeer, and Daniel A. Rodriguez; UNC Highway Safety Research Center; October 2013; page 15.

[250] *Costs for Pedestrian and Bicyclist Infrastructure Improvements: A Resource for Researchers, Engineers, Planners, and the General Public*; Max A. Bushell, Bryan W. Poole, Charles V.

Median with Lighting and Trees

Source:
http://envisionmainstreetalpharetta.files.wordpress.com/2013/04/main-street-with-4-lanes-and-parallel-parking.jpg.

Curb Extensions

Curb extensions are traffic-calming measures that extend curb lines into the parking lane of a roadway.[251] These treatments, also called bulb-outs or chokers, typically extend the sidewalk or provide a location for street-side landscaping. By bringing one or both curbs into the street, curb extensions reduce the effective street width and create a pinch point along a roadway.[252] At intersections, curb extensions can create a gateway effect and reduce the crossing distance for pedestrians while increasing the overall visibility of pedestrians by aligning them with the parking lane.[253]

Zegeer, and Daniel A. Rodriguez; UNC Highway Safety Research Center; October 2013; page 15.

[251] *Costs for Pedestrian and Bicyclist Infrastructure Improvements: A Resource for Researchers, Engineers, Planners, and the General Public*; Max A. Bushell, Bryan W. Poole, Charles V. Zegeer, and Daniel A. Rodriguez; UNC Highway Safety Research Center; October 2013; page 14.

[252] *Costs for Pedestrian and Bicyclist Infrastructure Improvements: A Resource for Researchers, Engineers, Planners, and the General Public*; Max A. Bushell, Bryan W. Poole, Charles V. Zegeer, and Daniel A. Rodriguez; UNC Highway Safety Research Center; October 2013; page 14.

[253] *Urban Street Design Guide, Street Design Elements, Curb Extensions, Gateway*; National Association of City Transportation Officials (NACTO); Island Press; October 2012; http://nacto.org/publication/urban-street-design-guide/street-design-elements/curb-extensions/gateway/.

Landscaped Curb Extensions

Source: https://portlandfrogs.files.wordpress.com/2008/04/siskiyou1.jpg.

Speed Humps/Speed Bumps/Speed Tables

Speed humps, speed bumps, and speed tables are vertical traffic-control measures that are approximately three- to-four inches high at their center.[254] All three of these elements generally are comprised of paved asphalt.[255] Speed humps extend the full width of the street, allowing for unimpeded bicycle travel by tapering in height near the drain gutter.[256] Speed bumps tend to be smaller and rise at a steeper grade than speed humps, causing motorists to reduce speeds more significantly, but also making speed bumps more difficult for bicyclists to navigate.[257] Speed tables are flat-topped speed humps, or speed humps that are very long and broad.[258] Occasionally, a pedestrian crossing is included in the flat

[254] *Costs for Pedestrian and Bicyclist Infrastructure Improvements: A Resource for Researchers, Engineers, Planners, and the General Public*; Max A. Bushell, Bryan W. Poole, Charles V. Zegeer, and Daniel A. Rodriguez; UNC Highway Safety Research Center; October 2013; page 17.

[255] *Costs for Pedestrian and Bicyclist Infrastructure Improvements: A Resource for Researchers, Engineers, Planners, and the General Public*; Max A. Bushell, Bryan W. Poole, Charles V. Zegeer, and Daniel A. Rodriguez; UNC Highway Safety Research Center; October 2013; page 17.

[256] *Costs for Pedestrian and Bicyclist Infrastructure Improvements: A Resource for Researchers, Engineers, Planners, and the General Public*; Max A. Bushell, Bryan W. Poole, Charles V. Zegeer, and Daniel A. Rodriguez; UNC Highway Safety Research Center; October 2013; page 17.

[257] *Costs for Pedestrian and Bicyclist Infrastructure Improvements: A Resource for Researchers, Engineers, Planners, and the General Public*; Max A. Bushell, Bryan W. Poole, Charles V. Zegeer, and Daniel A. Rodriguez; UNC Highway Safety Research Center; October 2013; page 17.

[258] *Costs for Pedestrian and Bicyclist Infrastructure Improvements: A Resource for Researchers, Engineers, Planners, and the General Public*; Max A. Bushell, Bryan W. Poole, Charles V. Zegeer, and Daniel A. Rodriguez; UNC Highway Safety Research Center; October 2013; page 17.

portion of a speed table.[259] Each type of these traffic-calming treatments usually is installed in multiples, often as sets of three.[260]

Speed Hump

Source: http://old.mcallen.net/landingpages/lp_traffic/speed_hump.aspx.

Raised Crossings

Raised crossings elevate the pedestrian crossing area to the height of the sidewalk, creating a speed table for an entire intersection.[261] Ramps are included on either side of the crossing for approaching vehicles.[262] The difference between a raised crossing and a raised intersection is that raised crossings are limited to the width of the crosswalk.[263] Raised crosswalks increase motorists' visibility of pedestrians, which encourages motorists to yield at crossings, while simultaneously causing them to slow down for the speed table.[264]

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[259] *Costs for Pedestrian and Bicyclist Infrastructure Improvements: A Resource for Researchers, Engineers, Planners, and the General Public*; Max A. Bushell, Bryan W. Poole, Charles V. Zegeer, and Daniel A. Rodriguez; UNC Highway Safety Research Center; October 2013; page 17.

[260] *Ibid.*

[261] *Costs for Pedestrian and Bicyclist Infrastructure Improvements: A Resource for Researchers, Engineers, Planners, and the General Public*; Max A. Bushell, Bryan W. Poole, Charles V. Zegeer, and Daniel A. Rodriguez; UNC Highway Safety Research Center; October 2013; page 16.

[262] *Ibid.*

[263] *Ibid.*

[264] *Ibid*.

Raised Crossing

Source: https://marrickvillegreens.wordpress.com/vision/people-friendly-streets/.

Street Trees

Street trees provide many benefits to a roadway. In addition to contributing to the aesthetic of a location, street trees may provide shade, filter and absorb stormwater, and improve pedestrian safety when located between the sidewalk and the roadway by providing a buffer between pedestrians and vehicles. Street trees also may improve the safety of a roadway by reducing the travel speeds of motorists because, as vertical elements, street trees help reduce the “optical width” of a roadway.[265] By making a street appear narrower, trees can discourage speeding.

Street Trees on Boston Street in Dorchester

Source: Boston Street, Dorchester, Boston, Katrina Crocker, MPO Staff.

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[265] *Traffic Calming 101*. Project for Public Spaces; http://www.pps.org/reference/livememtraffic/.

Street Trees on Boston Street in Dorchester

Source: Boston Street, Dorchester, Boston, Katrina Crocker, MPO Staff.

Interim Improvements

Interim improvements make it possible to change a street quickly and inexpensively, making it safer and more comfortable for bicyclists and pedestrians. These techniques use materials like paint, flexible bollards, and planters to create inexpensive trials of many types of traffic-calming infrastructure. Interim improvements can provide increased safety at dangerous locations rapidly and they allow traffic improvements to be tested before they are officially constructed. This can save money and help communities determine whether a specific improvement is the right solution for a particular problem area. When successful, interim improvements also can build support for proposed projects.

Separated Bicycle Lane Made of Interim Materials on Mass Ave

Source: https://www.bostonglobe.com/metro/2015/09/09/cyclist-places-potted-plants-mass-ave-create-temporary-bike-lane-plans-install-more/rhH0HV94d1mpImKPy8vfJO/story.html.

Curb Extensions Made of Interim Materials in Austin, Texas

Source: http://www.citylab.com/design/2016/01/polka-dots-help-pedestrian-reclaim-space-in-austin/433749/.

Temporary Protected Intersection in Minneapolis, Minnesota

Source: http://bikeportland.org/2014/06/19/portlanders-protected-intersection-concept-gets-first-street-demo-minneapolis-107534.