APPENDIX C » Design Standards

Introduction

Toole Design Group (TDG) was hired by the City of Saint Paul (City) in mid-March 2015 to confirm the best routes for the downtown bicycle network, develop initial design concepts for the recommended bicycle network alignments, determine potential connections to Downtown from the broader regional bikeway system, and implement the first phase of the Downtown bicycle network on Jackson Street from Shepard Road to 11th Street. TDG prepared this memorandum to document design controls and present design criteria for protected intersections, a new design feature for a bikeway in Saint Paul.

Part 1: Design Controls

Minimum design standards exist to assist engineers with decision making to develop transportation improvements. There are National standards, statewide standards, and local standards that need to be accounted for in the overall design of a roadway corridor. Most of the alignments being considered for the City of Saint Paul downtown bike system are on Minnesota Department of Transportation (MnDOT) Municipal State Aid (MSA) routes that have minimum dimension requirements unless a variance is obtained.

The Saint Paul Street Design Manual, MnDOT State Aid Manual, MnDOT Bikeway Facility Design Manual, AASHTO Guide for the Development of Bicycle Facilities, NACTO Urban Bikeway Design Guide, Massachusetts DOT Separated Bike Lane Planning and Design Guide were reviewed for minimum standards and recommended guidance for bicycle facilities in urban areas. In general, the minimum dimensions are provided in these documents to provide basic function and safety; however, increasing bike lane widths, sidewalk widths, and buffer widths will provide more comfortable facilities for all users.

Many of these design standards and minimum requirements are recommendations rather than requirements. Engineering judgment should be used in all scenarios, decision making documented, and proper design exceptions obtained from appropriate oversight agencies if dimensions less than the minimum design standard are chosen.

Protected Bikeways

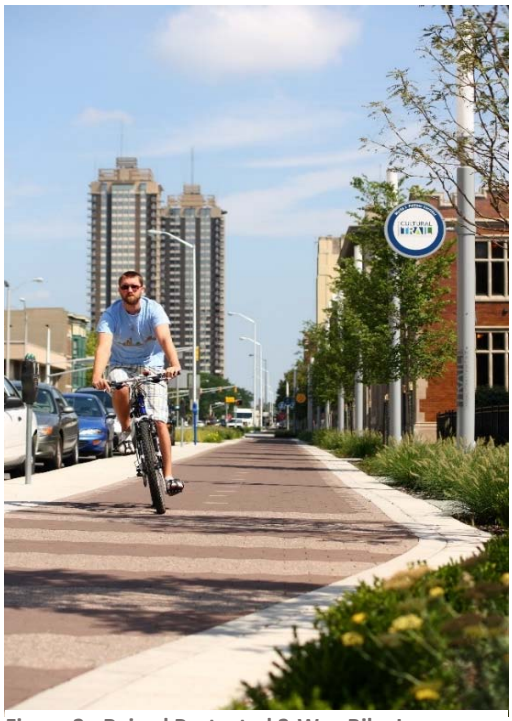

Figure 2 - Raised Protected 2-Way Bike Lane: Indianapolis Cultural Trail (Source: Toole Design Group)

Protected bikeways provide an extra level of comfort to bicyclists along the roadway by providing physical separation from motor vehicle traffic. Standards are still being refined for protected bike lanes, particularly at intersection crossings.

The minimum width of a two-way protected bike lane is 8-feet to allow enough space for opposing bicyclists to pass each other, though 10 to 12-feet is desired. One-way protected bikeways typically range in width from 5 to 7-feet. (City of Saint Paul, 2014)

Separation methods factor into the cross-section width; vertical separation elements require shy distance and adjacent parking lanes require additional space to allow motorists to enter and exit their cars without encroaching into the protected bikeway. Buffer space is the width between the protected bike lane and motor vehicle lanes. On a curbed roadway with a speed limit of 30 miles per hour (MPH) or less, a 2-foot minimum separation is recommended, but a desirable width of 5-foot or greater is appropriate as vehicle speeds increase. The buffer between the bike lane and an on-street parking lane should be a minimum of 3-feet (MnDOT, 2007).

Where two-way protected bike lanes are placed on one-way roads, intersections, alleys, and driveways with existing ONE WAY signs should be replaced with Turn Restriction signs with EXCEPT BIKES plaques. Other signing and pavement marking should meet Minnesota Manual on Uniform Traffic Control Devices (MN MUTCD) standards. (City of Saint Paul, 2014)

If cross slopes transition, a minimum transition length of 5-feet per one percent cross slope should be used. Protected bike lanes adjacent to roadways are allowed to exceed five percent in grade, but should be equal or less than the roadway grade. (AASHTO, 2012)

Parking should not be allowed within 40 feet of each intersection. Street or sidewalk furnishings should not be within 20-feet of minor street crossings and 10-feet of driveway crossings. (City of Saint Paul, 2014)

On-Street Bike Facilities

On-street bike facilities are included in almost all bike design manuals. They may include bike lanes, buffered bike lanes or shared lanes with motor vehicles.

Figure 3 - Buffered Bike Lane
(Source: Toole Design Group)

For roadways where the bike lane is immediately adjacent to curb, guardrails, on-street parking, or other vertical surfaces, a minimum width of 5-feet should be provided (NACTO, 2011). For bike lanes adjacent to a gutter pan, a usable minimum width of 4-feet measured from the longitudinal joint should be provided (NACTO, 2011). On MSA roads where 10-foot lanes are allowed, the bike and parking lanes shall be 1-foot greater than the minimum requirements (City of Saint Paul, 2014). Greater widths of 6 or 7-feet are recommended in locations with high volumes of bicyclists, parking turnover, vehicle speeds, traffic volumes, or heavy trucks or buses (City of Saint Paul, 2014). In constrained locations with speeds less than 45 MPH, bike lane width may be reduced to 4-feet (AASHTO, 2012).

A buffered bike lane has a minimum required buffer width of 2-feet utilizing pavement marking and a 5-foot bike lane width (NACTO, 2011). The City of Saint Paul Street Design Manual recommends using a buffered bike lane where vehicle travel speeds are 35 MPH or greater, or the average daily traffic (ADT) is greater than 10,000 vehicles per day (vpd).

If a shared-lane is proposed, a 14-foot minimum lane width is required for use by bicyclists and off-peak vehicle parking (City of Saint Paul, 2014). Shared use lane markings should be placed a minimum of 4-feet from the face of curb or 11-feet from the face of curb if on-street parking is present (NACTO, 2011).

When contra-flow bike lanes are located on a one-way road, they should be placed on the right hand side of the road from the bicyclist's perspective. Turn Restriction signs with EXCEPT BIKES signs should be posted at intersections, alleys and driveways. DO NOT ENTER with EXCEPT BIKES may also be posted along the facility. Contra-flow bike lanes must be separated by a solid, double yellow lane line marking from opposing vehicles. If medians or traffic separators are used, a minimum 7-foot bike lane width is recommended. It is recommended that on-street parking not be provided adjacent to contra-flow bike lanes. In order to install a contra-flow bike lane, a similar bicycle facility (bike lane or shared-lane marking) should be installed in the direction of motor vehicle traffic. (City of Saint Paul, 2014)

Figure 4 - Counter-flow Bike Lane (Source: Urban Bikeway Design Guide)

Bike lane marking and signing should follow MN MUTCD standards. A solid white line should delineate bike lanes from travel lanes. Bike lane symbols should be placed at every intersection or signalized driveway, as well as the beginning and end of bike lane pockets turn lanes to indicate to cyclists and motor vehicles that there is a bike lane. Additional bike lane symbols may be appropriate based on driveway density. (AASHTO, 2012)

Pedestrian Zone (City of Saint Paul, 2014)

Sidewalks in the City of Saint Paul are composed of frontage, pedestrian, and boulevard/furnishing zones. The frontage zone is located between the building face and pedestrian zone and has a minimum of 0-feet and 2-feet desired. Where there is no frontage zone, pedestrians will shy away from the building front and the effective pedestrian zone is reduced by 1-foot. The pedestrian zone is the area in which pedestrians are most comfortable walking and has a desirable minimum of 8-feet and absolute minimum of 3-feet for ADA compliance, though 5-feet is typical in the Twin Cities. Between the curb and pedestrian zone is the boulevard and furnishings zone with a desirable minimum of 5-feet.

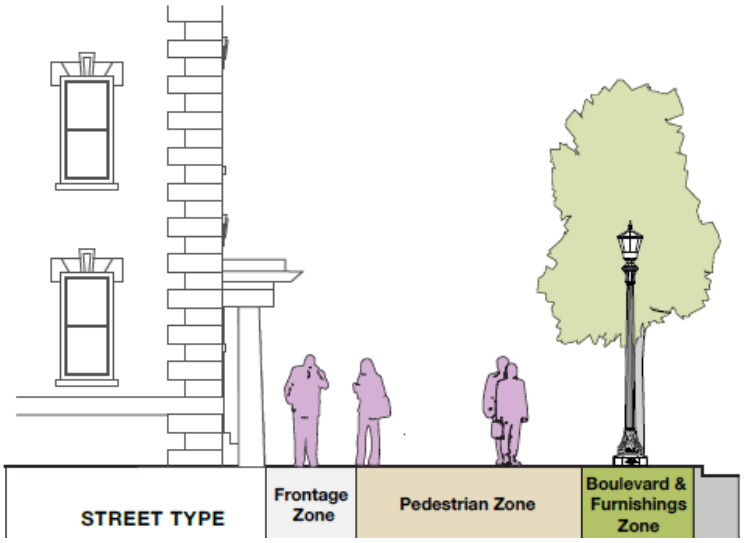

Figure 5 - City of Saint Paul Sidewalk Zones (Source: City of Saint Paul Draft Street Design Manual)

In the City of Saint Paul, the area within 2-feet of the face of curb should be free of obstructions. To accommodate a sidewalk café, the minimum frontage zone is 6-feet wide and the minimum boulevard/furnished zone is 8-feet wide.

Parking Lanes (City of Saint Paul, 2014)

Where parking is adjacent to travel lanes, a combined parking and travel width of 18-feet is the recommended minimum width required. Recommended parking lane widths are in **Table 4**. Minimum parking lane widths for MSA routes are discussed below in the Vehicle Travel Lanes section.

Table 1 - Recommended Parking Lane Widths

Low Parking Turnover	7-foot parking
High parking turnover and high bike volumes	8 or 9-foot parking
10,000 vpd and high mix of trucks or parking turnover	10-foot lanes

Vehicle Travel Lanes

The City of Saint Paul Draft Street Design Manual recommends avoiding multiple minimum widths on roadways, however, if multiples must be used, the mode for the most vulnerable user should not be minimized. (City of Saint Paul, 2014)

On MSA routes, vehicle travel lane widths must be a minimum of 11-feet wide. In addition, on arterial routes or roads with ADT of 10,000 vehicles per day or more, a curb reaction distance of 4-feet is required where parking is not provided and a parking lane must be 10-feet wide. On collectors or local roads with less than 10,000 ADT, a curb reaction distance of 2 feet is required where parking is not present and a minimum parking lane width of 8-feet if parking is allowed. Turn lanes must be 10-feet minimum width on MSA routes plus curb reaction. If bike lanes are on the roadway, the width of the bike lane is included in the curb reaction distance. (MnDOT, 2013)

If a road will be designed to include an on-road bike facility, minimum MSA standards for different types of vehicle facilities are provided based on roadway functional classification and projected traffic volumes. The minimum requirements are presented in **Figure 6** on the following page. (MnDOT, 2013)

On one-way MSA routes, a minimum of two through lanes must be maintained. MSA routes with projected volumes of 15,000 ADT or greater are required to have at least four through lanes unless level of service D or better can be shown through a capacity analysis. (MnDOT, 2013)

Intersections

Sight lines for both motor vehicles and bicyclists must be maintained at all intersections to provide all users with sufficient time to react and stop or yield as appropriate.

Approaching intersections, bike lanes should be installed on the right side of a shared through/right-turn or left-turn lane. Dotted lines may be installed 50 to 200-feet prior to a crosswalk or intersection edge to drop a bike lane or carry it through the intersection (City of Saint Paul, 2014). Bike lanes adjacent to right-turn only lanes should be on the left side of the turn lane and dotted lane markings should start 80 to 200-feet prior to the crosswalk or intersection and become solid 50 to 80-feet from the crosswalk or stop bar (City of Saint Paul, 2014). The recommended minimum bike lane width at an intersection is 5-feet, however, MSA routes should follow State Aid standards (AASHTO, 2012).

Within an intersection, pavement marking should be a minimum of 6-inches in width when adjacent to motor vehicle traffic. In locations where bikes have a two-turn stage queue, the queue location should have a bike stencil and turn arrow in the protected area. In addition, NO TURN ON RED signs are required for motorists where there is a two-stage turn queue for bicyclists within the roadway. (NACTO, 2011)

Figure 7 - Intersection Design in Rotterdam, ND (Source: Toole Design Group)

Marked crosswalks should be a minimum of 6-feet wide, but have a desired minimum of 10-feet wide with stop lanes marked no less than 4-feet and no more than 30-feet from the crosswalk edge. (City of Saint Paul, 2014)

Functional Classification and Projected Traffic Volume	Design Speed	Lane Width (a)	Curb Reaction Distance (d)	Parking Lane Width (f)	Bikeway Design Roadways with Two Travel Lanes Urban Curb and Gutter		Bikeway Design Roadways with Four or more Travel Lanes Urban Curb and Gutter
	(mph)	(feet)	(feet)	(feet)	(ADT)	(feet)	(feet)
Collectors or Locals with ADT <2,000	25-30	10-12 (e)	2	7-10	<500	SL	N/A
					500-2,000	WOL 14-16 or BL 5-6	
	35-40	11-12	2	8-10	<500	SL	BL 5-6
					500-2,000	WOL 14-16 or BL 5-6	
	over 40	12	2	10		BL 5-6	BL 5-6
Collectors or Locals With ADT 2,000-5,000	25-30	10-12 (e)	2	7-10		WOL 14-16 or BL 5-6	WOL 14-16 or BL 5-6
	35-40	11-12	2	8-10		BL 5-6	BL 5-6
	over 40	12	2	10		BL-6	BL 6
Collectors or Locals with ADT 5,000-10,000	25-30	10-12 (e)	2	7-10		BL 5-6	BL 5-6
	35-40	11-12	2	8-10		BL 5-6	BL 5-6
	over 40	12	2	10		BL 6 or PS 8 or SUP	BL 6 or PS 8 or SUP
Collectors or Locals with ADT >10,000 and Arterials	30-40	11-12	4 (b)	10		BL 6 or PS 8 or SUP	BL 6 or PS 8 or SUP
	over 40	12	4 (b)	10 (c)		BL 6 or PS 8 or SUP	PS 8 or SUP

(SL = shared lane; BL = bicycle lane; WOL = wide outside lane; PS = paved shoulder; SUP = shared use path)

Engineering judgment should be used to choose a lane-width, on-road bicycle facility, or shoulder width dimension other than the widths indicated in the chart. Factors to consider include safety, speed, population/land use, benefit/cost analysis, traffic mix, peak hourly traffic, farm equipment, environmental impacts, terrain limitations, bicycle traffic, pedestrian traffic, on-street parking, intersection and driveway spacing, rights-of-way constraints, vehicle turn lane configuration, sight distance, sight lines, bus routes, other nonmotorized uses, functional classification, or other factors. Dimensions less than those indicated in the chart require a variance in accordance with parts 8820.3300 and 8820.3400.

(a) One-way turn lanes must be at least ten feet wide, except 11 feet is required if the design speed is over 40 mph.

(b) Curb reaction distance may be reduced to two feet if there are four or more traffic lanes and on one-way streets.

(c) No parking is allowed on streets with six or more traffic lanes or when the posted speed limit exceeds 45 mph.

(d) Curb reaction shall be provided unless on-street parking, a bicycle facility, or a wide outside lane are provided adjacent to the curb. The dimensions for wide outside lanes include the curb reaction distance.

(e) When creating a multimodal design with a combination of vehicle lane, parking lane, and bikeway lane widths, if a vehicle lane width of less than 11 feet is used, the parking and bikeway lanes shall be at least one foot wider than the minimum widths. Engineering judgment should be used to choose a vehicle lane width of less than 11 feet. Additional factors to consider include the types of vehicles (buses, trucks, etc.), peak hour counts, turning movements, population/land use, crash history/analysis, terrain limitations, bicycle traffic, pedestrian traffic, other nonmotorized uses, and snow storage.

(f) In determining the parking lane width, the roadway ADT and the vehicle mix shall be taken into consideration for residential, commercial and/or industrial areas, or for a mixed use thereof.

Figure 6 - Minimum Design Standards for On-Road Bike Facilities for Urban, New, or Reconstruction Projects (Source: MnDOT State Aid Operations Chapter 8820)

The City of Saint Paul is installing accessible pedestrian signals at all new signal installations. Pedestrian crossing times should be based on the MN MUTCD and leading pedestrian intervals should be at least 3-seconds (City of Saint Paul, 2014). The minimum green signal timing should allow for a bicyclist to clear the intersection from a stopped position (AASHTO, 2012).

The City of Saint Paul uses curb radii of 20-feet or smaller where possible. Downtown curb radii should accommodate a WB-40 design vehicle at City owned intersections, and turning vehicles may utilize adjacent lanes, preferably in the same travel direction. At MnDOT owned intersections, larger design vehicles may need accommodation. If curb bump outs are in place, the minimum extension width is 6-feet and the minimum length of the bump out shall be the width of the crosswalk. The angled portion of the bump out should be 30-degrees from the main curb line with 5-foot radii for snow plows to navigate around the bump out. The roadway must be a minimum width of 26-feet in order for bump outs to be installed. (City of Saint Paul, 2014)

Driveways should be a minimum of 100-feet from intersections in commercial corridors. Each driveway should have a 4-foot flare on each side. (City of Saint Paul, 2014)

Landscaping (City of Saint Paul, 2014)

The Saint Paul Draft Street Design Manual provides information for minimum landscaping design standards. Plants may not exceed 12-inches in height within 30-feet (40-feet on corridors with protected bike lanes) of intersections and corners per the Saint Paul manual, but sight distance requirements from above must also be considered. Outside of the intersection and corner zones, plant heights must not exceed 3-feet. In addition, structures, such as raised planters, will require an obstruction permit.

Figure 8 - Landscaping along the Indianapolis Cultural Trail (Source: Toole Design Group)

Trees must be installed to have the lowest tree branch a minimum of 8-feet above the sidewalk. Adjustable tree grates are not recommended. It is a recommended best practice to provide 1.25 to 2 cubic feet of soil for every 1 square foot of mature canopy cover to allow trees to grow. Some best practices to encourage growth include engineered or structural soils, permeable paving, enhanced soil preparation and amendments, or stormwater infiltration practices. Existing subsurface conditions should be evaluated prior to installing bio-infiltration systems and a right-of-way permit is required. Minimum spacing for trees is provided in **Table 5**.

Table 2 - Minimum Tree Spacing in Urban Areas

Ornamental Trees	Canopy Trees	Street Lights	Stop Sign or Traffic Control	Hydrants, Driveways, or Utility Poles
20 – 30 feet minimum on center	30 – 40 feet on center	15 feet between street lights and tree trunks	30 feet from corner[1]	10 feet from object

[1] – 40 feet from corner on blocks with protected bike lanes.

Lighting

The City of Saint Paul lighting standard is the single lantern style. Light design should be in accordance with AASHTO's *An International Guide for Roadway Lighting and ANSI/IES Recommended Practices* (MnDOT, 2007). It is recommended that average horizontal illumination levels should be maintained between 0.5 to 2-foot candles (AASHTO, 2012).

Wayfinding/Art (City of Saint Paul, 2014)

Sign installations should follow the MN MUTCD standards. A best practice for bike routes is to use the D11-1c series instead of the M1-8 to call out a specific bike route name. Signs for wayfinding or route identification should be posted at all major decision points for bicyclists. Opportunities for bicycle route branding can be considered as part of the design process.

Other Features

Roadway medians should be a minimum of 6-feet (4-foot island plus a 1-foot reaction distance on each side) and up to 10-feet if there will be a high volume of pedestrians or bicyclist (City of Saint Paul, 2014)s. Reflective delineators should also be placed on the median refuge island (NACTO, 2011).

A single bike has a parking footprint of 6x2x4-feet. Where bike racks are in place, they must support bikes in at least 2 places, be securely anchored to the ground, and resist cutting, rusting, and bending, or deformation. A minimum 2-foot clearance around the rack should be provided. Racks perpendicular to a curb should be a minimum of 3-feet from the back of curb and 2-feet when parallel. Bike racks should be placed a minimum of 6-feet from street furniture and 15-feet from fire hydrants, bus shelters, etc. Bike racks should be installed a minimum of 3-feet from a parallel or 4-feet from a perpendicular wall. A 5-foot aisle (3-foot minimum) should be provided between adjacent bike racks and 8-feet between racks aligned end to end. The overhead clearance for bike rack locations is 8-feet. (MnDOT, 2007)

In urban areas, minimum vertical clearances for underpasses on MSA routes are presented in **Table 6** (MnDOT, 2013).

Table 3 - Minimum MSA Route Vertical Clearances

Location	Vertical Clearance (feet-inches)
Highway under Roadway Bridge	14-6
Highway under Railroad Bridge	14-6
Highway under Pedestrian Bridge	15-6
Highway under Sign Structure	15-6
Railroad under Roadway Bridge	22-0

The minimum width for a shared bike and pedestrian path over a structure is 12-feet or the approach path width plus 2-feet (City of Saint Paul, 2014). Under a structure, a minimum width of 8-feet for short segments may be used, though a desirable minimum of 10-feet or greater is preferred. The minimum vertical clearance is 8-feet, however, if emergency vehicle access is needed, a minimum of 10-feet clearance is required. Bike and pedestrian railings must be a minimum height of 4.5 feet. If a bridge is over a street or railroad, 6 to 8-feet of protective screening is required. (MnDOT, 2007)

Bikes and railroad crossings should preferably cross at angles between 60 and 90 degrees so that bike tires do not get caught in the tracks. Bike compatible drain grates should also be used along bike facilities to prevent bike tires from getting caught in the grates. (AASHTO, 2012)

Figure 9 shows the maximum acceptable surface irregularities on bikeways (MnDOT, 2007).

Orientation of the Irregularity to Bike Traffic	Width of Cracks *	Height of Projections **
Parallel	13 mm (0.5 in)	10 mm (0.375 in)
Perpendicular	20 mm (0.75 in)	20 mm (0.75 in)

* Cracks/fissures are in the surface. Cracks are often found in hot-mix asphalt surfaces or between slabs of Portland cement concrete.

** Projections are abrupt changes in the surface of a traveled way. Sinking drainage grates, crude asphalt, pavement joints, pedestrian ramp transitions, or root growth under pavement may cause projections.

Figure 9 - Maximum Acceptable Surface Irregularities on Bikeways (Source: MnDOT Bikeway Facility Design Manual)

The use of permanent bollards is not recommended, but if they are used, they should be a minimum of 40-inches high, 4-inches in diameter and should be retroreflective (AASHTO, 2012).

If bike boxes are used, they should be a minimum of 10 to 16-feet deep and have the bike symbol or helmeted bike symbol between the crosswalk and stop line. Stop lines should be in place for motor vehicles, along with NO TURN ON RED signs (NACTO, 2011).

PART 2: Protected Intersection Design for Protected Bikeways

For an intersection to be considered protected for bicyclists it must either phase separate conflicts with signal control or manage the conflict with roadway geometry.

Separating conflicting turning movements across the protected bikeway by utilizing protected turn phasing at signals is recommended where there are high volumes of turning motor vehicles per hour. **Table 7** represents the MassDOT Separated Bike Lane Planning and Design Guide motor vehicle volume thresholds for separating bicycle and turning motor vehicle movements. This can be accomplished by allowing bicyclists to proceed with the through motor vehicle phase, stopping bicyclists, and then allowing turning movements to proceed through a protected signal phase.

Table 4 - MassDOT Protected Bikeway Thresholds for Time-Separated Bicycle Movements

Protected Bikeway Operation	Motor Vehicles per Hour Turning Across Protected Bikeway		
	Right Turn	Left Turn Across One Lane	Left Turn Across Two Lanes
One-way	150	100	50
Two-way	100	50	0

Geometric features may include:

- Extended corner protection islands, or corner protection islands which control turning vehicle speeds
- Mountable truck aprons which act as curb extensions for small cars while still providing the ability for trucks to navigate the corner (i.e. a similar concept as aprons at roundabouts).
- Raised crossings

A well-designed protected intersection will:

- Maximize safety and comfort of bicyclists, attracting more users
- Reduce and mitigate conflicts between pedestrians, bicycles, and motor vehicles
- Provide positive guidance to separate pedestrians and bicyclists continuously to the corner and across the intersection (via separate crosswalks)

Providing an extended bikeway nose on the street buffer will:

- Allow bicyclists to stop where they naturally will want to stop – as close to the cross street as practical to improve their visibility to turning motorists
    - Research and observations at Bike Box locations has proven this behavior is widespread – providing queuing space and advanced stop lines reduces pedestrian crosswalk blockages by bicyclists
- The advance stop will improve safety:

    - Placing bikes ahead of stopped cars waiting to turn reduces conflicts with turning motorists. Preliminary design shows bicyclists will be 20-30 feet further ahead of stopped cars in most places.
    - This encourages compliance at signals and creates a built-in head start which will reduce conflicts between motor vehicles and bicyclists.
    - If bikes are required to wait behind the crosswalk perpendicular to cars, and start at the same time when the light turns green, then the bicycle and motor vehicle travel paths are likely to conflict. These interactions will encourage bicyclists to pull forward into the pedestrian crosswalk over time to reduce the conflict.
- The corner protection islands are a critical design feature to slow the speed of turning motorists.
- A secondary purpose of extended corners is to create queuing space for turning bicyclists and waiting pedestrians. This is only feasible at locations where the street buffer is 6 feet in width or larger.

The use of protected intersections with median noses is starting to gain interest and use is advancing around North America. Cities include: Vancouver, Seattle, Portland, Davis, Austin, Boston, and Montreal among others.