Hennepin County 2040 Bicycle Transportation
Appendix C - Bikeway Design Toolkit

The Hennepin County Toolkit serves a dual function of providing definitions and reference guidance to local cities, agencies and partners through the design matrix and technical sheets as well as guidance used by county staff for typical county road retrofit striping plans and right of way needs for future bikeway development. The toolkit is intended to supplement local, state, national, and international bikeway planning and design guidelines. The toolkit includes the following elements to provide reference for local planning and design for bikeways in Hennepin County:

Bikeway Design Matrix: A quick-reference matrix of bikeway types and design treatments highlighting considerations for implementation based on roadway and land use context; and

Bikeway Design Technical Sheets: Technical sheets providing more detailed design guidance on specific bikeway types and treatments.

The toolkit provides information for communities in Hennepin County to understand some of the trade-offs and considerations associated with different bikeway types and treatments, and the most appropriate context where these design elements are best used, as well as to provide common language on what various treatments mean and entail.

The final design of a bikeway is a product of negotiation and evaluation of various trade-offs.

Bikeway design matrix

	Bikeways				Protected bikeways		
	On-street				*On- or off-street*		*Off-street*
Treatment	**Bicycle Boulevard**	**Shoulder**	**Bike lane**	**Buffered bike lane**	**Protected bike lane**	**Cycle track**	**Multi-use trail**
Land use context	Urban/ suburban	Suburban/ rural	Urban/ suburban	Urban/ suburban	Urban/ suburban	Urban/ suburban	Urban/ suburban/ rural
Level of separation from motor vehicle traffic	None	Low	Low to moderate	Moderate to high	High	High	High
Traffic volume (motor vehicles)	Low	Low to moderate	Moderate	Moderate to high	High	Moderate to high	N/A
Posted speed limit	25-30 mph	35-55 mph	Varies	Varies	Varies	Varies	N/A
Street type	Local or collector	All**	All**	All**	All**	All**	Independent right-of-way along minor or principal arterial
Minimum widths	N/A	5'-8' (width based on vehicle speed)	5' (with parking), 6' (curb adjacent)	5' (with parking) 6' (curb adjacent), 2' buffer	5' lane/3' buffer (one-way); 10' lane/3' buffer (two-way)	5' with 2' clear zone each side (one way); 10' with 2' clear zone each way (two-way)	8' with 2' clear zone each side (one-way); preferred 10' with 2' clear zone each side (two-way)
Construct new or as part of pavement maintenance (re-striping)	Both	Both	Pavement maintenance	Pavement maintenance	Both	New	New

* Traffic volume (average daily traffic): Low is less than 3,000 ADT; Moderate is 3,000-15,000 ADT; High is above 15,000 ADT

**All=Streets where bicycle use is not prohibited. Bikeway types will vary based on roadway and land use context

A buffer is a delineated space between the bikeway and travel lane. A clear zone is a space free of obstructions.


Emergency
ARIZONA - SONORA
DESERT MUSEUM
GO

Bicycle boulevard

Lower volume, lower speed residential streets designed to prioritize bicycle through travel while discouraging motor vehicle traffic and maintaining relatively low motor vehicle speeds.

(Note: bicycle boulevards are not appropriate on county roads, but could be appropriate on local streets identified as part of the county bicycle system)

Benefits:

- Suitable for all ages and abilities
- Calms traffic speeds; slower speeds are safer and help reduce crash injuries
- Typically retrofitted within existing right-of-way
- Reduces cut-through traffic

Challenges:

- Impacts to traffic patterns
- Traffic diversion management
- Emergency, transit and maintenance vehicle access
- Developing appropriate treatments at major intersections
- Wayfinding to community destinations on major roadways

Application Criteria:

- To create a lower stress, bicycle-prioritized route or network
- For lower volume and low-speed roadways
- Transit and heavy vehicle routes are discouraged as bicycle boulevards

Design Criteria:

- Target speeds are typically around 20 mph; there should be a maximum 15 mph speed differential between bicyclists and motor vehicles
- Preferred ADT: up to 1,500 vpd
- Recommended Maximum ADT: 3,000 vpd
- Traffic control at intersections should prioritize the bicycle movement and minimize stops, whenever possible.
- Traffic calming measures including:
    - Speed humps or tables
    - Visual narrowing of street (e.g., street trees)
    - Neighborhood traffic circles
    - Chicanes
- Additional treatments for major street crossings may be needed, such as:
    - Bicycle and pedestrians crosswalks
    - Median refuge islands
    - Curb extensions
    - Rapid flash beacons
    - HAWK/half signals
    - Full traffic signals
    - Bicycle detection and signals

References:

AASHTO Guide for the Development of Bicycle Facilities (2012)

NACTO Urban Bikeway Design Guide (2012)

Manual on Uniform Traffic Control Devices (2009)

Fundamentals of Bicycle Boulevard Planning & Design (2009)

Bikeable shoulders

Bikeable shoulders are the paved portion of the roadway adjacent to the travel way. Paved shoulders provide for the accommodation of bicycles as well as disabled vehicles, delivery vehicles (ex: postal, garbage, etc.), and in the absence of sidewalks — pedestrian walkways. Shoulders differ from bike lanes since they typically have fluid dimensions. Shoulders frequently disappear in constrained areas or where traffic bypass or turn lanes are required. In contrast, bike lanes are continuous and have special designs so as to maintain dedicated bikeway space especially through right turn lanes and intersections.

Benefits:

- Flexible space that provides for multiple uses
- Generally more compatible with rural roadway designs
- Wide rural shoulders (8 feet) allow separation from passing "truck blasts" for people biking

Challenges:

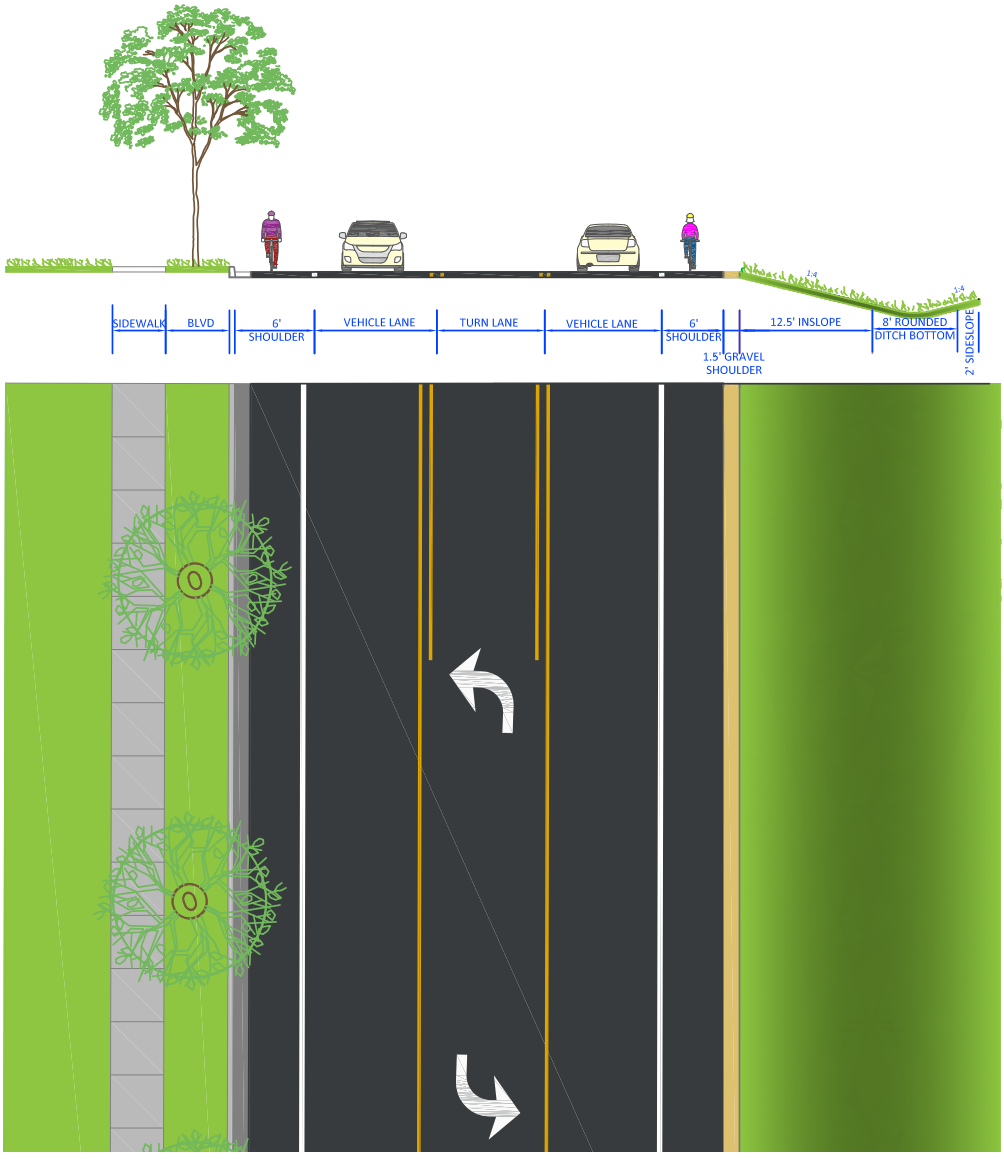
- Undesignated nature of the space may introduce conflicts with other uses
- Maintenance and sweeping may be relatively infrequent presenting road hazards to bicycling
- Illegal traffic bypassing on shoulders
- Areas where shoulders drop for turn lanes can present weave and safety problems for people biking

Application Criteria:

- Posted speed varies 35-55 mph
- For use on arterials and collectors
- Parking should be prohibited to avoid user conflict
- Generally used in a rural or suburban context where multiple uses are desired
- Often used in conjunction with 3-lane retrofit projects

Design Criteria:

- Desired width of 8 feet in rural context with speeds greater than 35 mph
- Minimum width of 6 feet — from fog line to edge of bituminous (rural) or fog line to edge of gutter seam or curb face if no gutter (suburban or urban)



References:

AASHTO Guide for the Development of Bicycle Facilities (2012)

MnDOT Bikeway Facility Design Manual (March 2007)

MnDOT Roadway Design Manual (May 2012)

Bicycle lanes

On-road facilities designated for exclusive use by bicyclists through pavement markings and signs (optional).

Benefits:

- Designated space for bicyclists
- Visually narrows the street to calm traffic; slower speeds are safer and help reduce risks of crash injuries

Challenges:

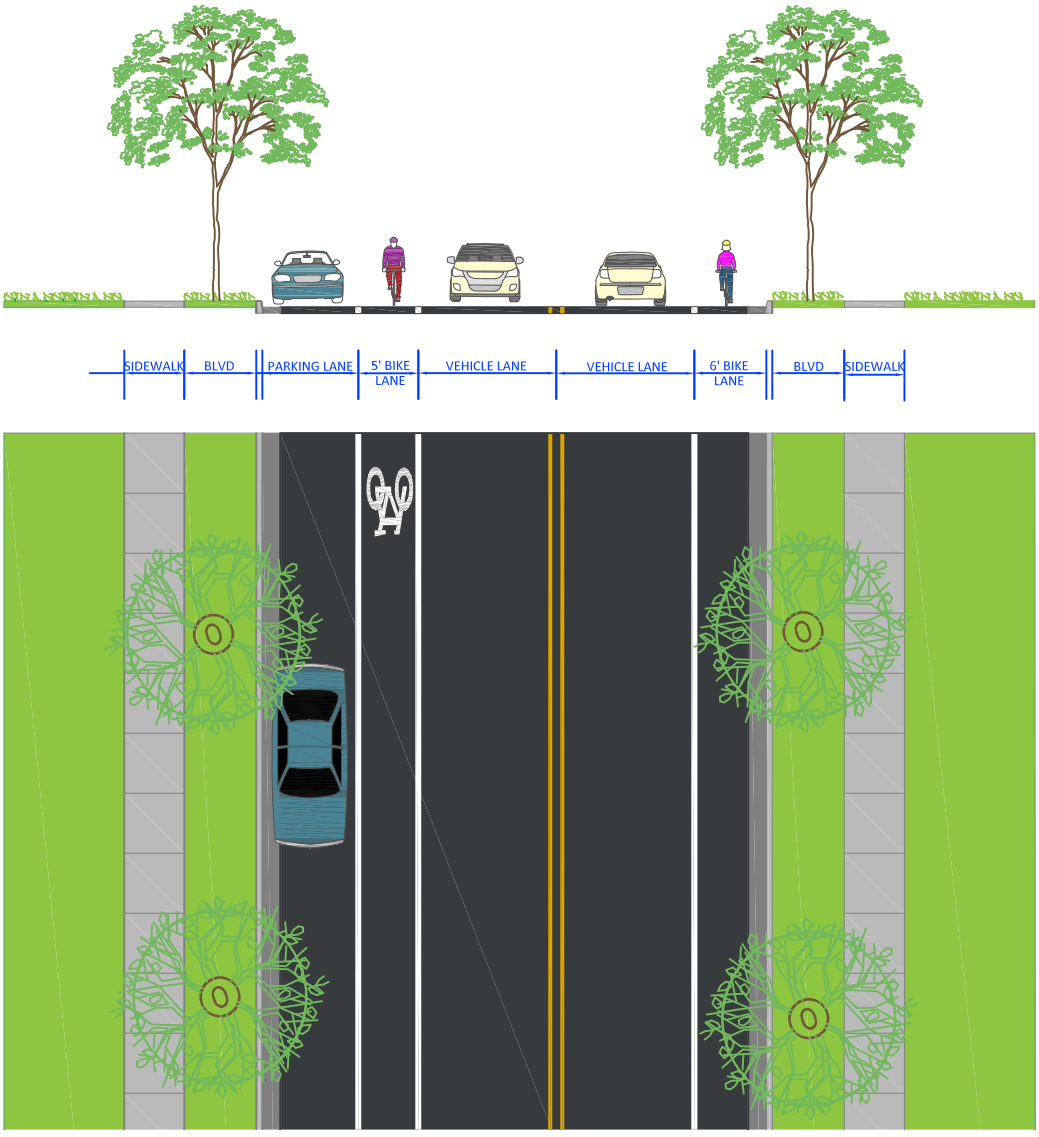
- May not be appropriate for all people biking because lack of physical separation
- People biking may have to operate as a vehicle in mixed traffic (i.e., to make turns, avoid obstacles, etc.)
- Potential risk of dooring

Application Criteria:

- Where protected bicycle facilities are not feasible or appropriate
- Left or right side of roadway
- In the uphill direction if space is only available for one bike lane (climbing lanes)
- In the contra-flow direction on one-way streets (contra-flow bike lanes)
- For use on arterials and collectors intended for major motor vehicle traffic movements

Design Criteria:

- Minimum bike lane width: 5 feet from parked car or 6 feet from curb edge
- Preferred bicycle pavement marking is a bike symbol with no rider
- A solid white 6 to 8 inch line should be used to demarcate the motor vehicle lane from the bike lane
- If the bike lane includes a gutter pan, a minimum of 4 feet must be outside of the gutter pan or the gutter pan must encompass the full bike lane



References:

AASHTO Guide for the Development of Bicycle Facilities (2012)

NACTO Urban Bikeway Design Guide (2012)

Manual on Uniform Traffic Control Devices (2009)

Buffered bicycle lanes

A bicycle lane with pavement marking buffers to provide separation from motor vehicle travel lane and/or parking lane.

Benefits:

- Designated space for biking
- Additional buffer space for separation from motor vehicles or parking
- Space for passing other people biking
- Visually narrows the street to calm traffic; slower speeds are safer and help reduce risks of crash injuries

Challenges:

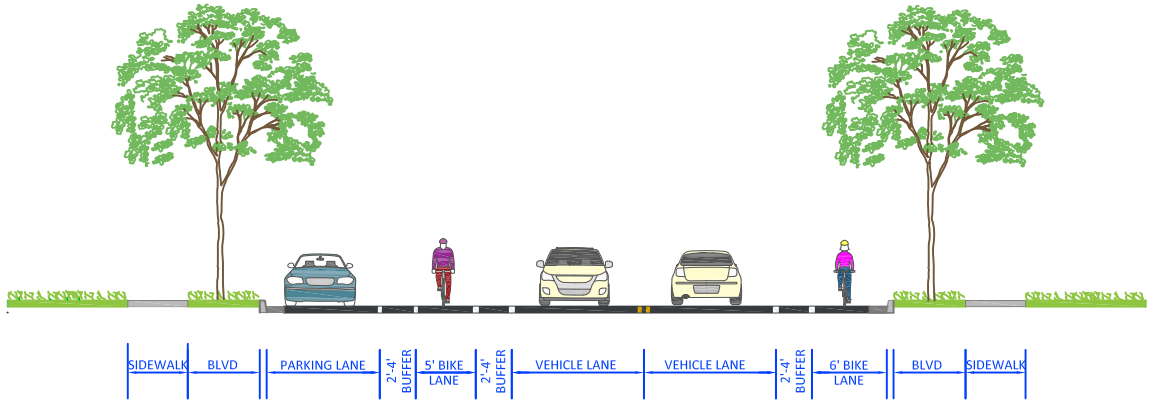
- May not be appropriate for all people biking because lack of physical separation
- People biking may have to operate as a vehicle in mixed traffic (i.e., to make turns, avoid obstacles, etc.)
- Vehicles driving or parking in the bicycle lane may be increased with additional width

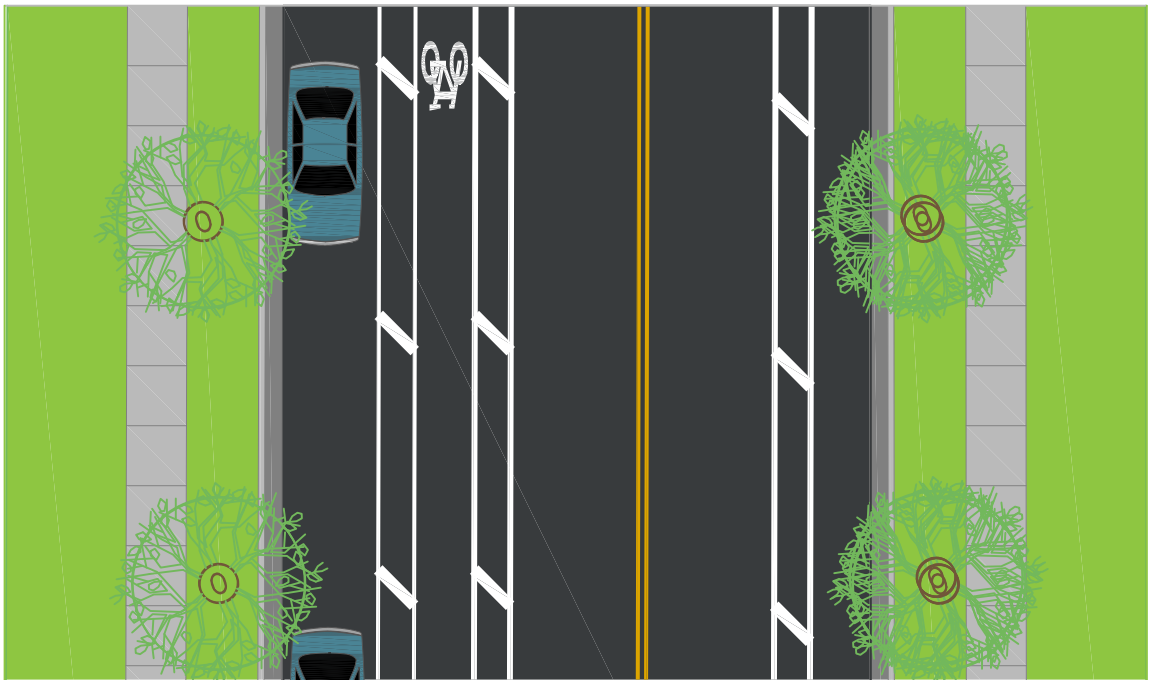
Application Criteria:

- Posted speed is greater than 25 mph
- For use on arterials and collectors intended for major motor vehicle traffic movements
- Where protected bicycle facilities are not feasible or appropriate
- Where separation from moving traffic or parking is desired
- Along the contra-flow direction on one-way streets (contra-flow bike lanes)

Design Criteria:

- Minimum bike lane width: 6 feet (from curb edge or parked vehicle)
- Minimum buffer width: 18 inches
- For buffers greater than 3 feet: provide chevron or crosshatch markings
- Width of buffer plus bicycle lane should be considered the total bicycle lane width
- The location of the buffer on the interior or exterior of the lane should be determined by parking turnover rates, vehicle speeds & volumes, and percent heavy vehicles





References:

AASHTO Guide for the Development of Bicycle Facilities (2012)

NACTO Urban Bikeway Design Guide (2012)

Manual on Uniform Traffic Control Devices (2009)

Protected bicycle lanes

A bike lane on street level protected from traffic by bollards, planters, parked cars or other barriers from moving traffic.

Benefits:

- Provides physically protected, exclusive space for bicyclists separate from motor vehicles and pedestrians
- Suitable for, and more attractive to, bicyclists of all ages and abilities
- Prevents vehicles from driving and parking in facility
- Eliminates dooring issues
- Can visually narrow the street to calm traffic

Challenges:

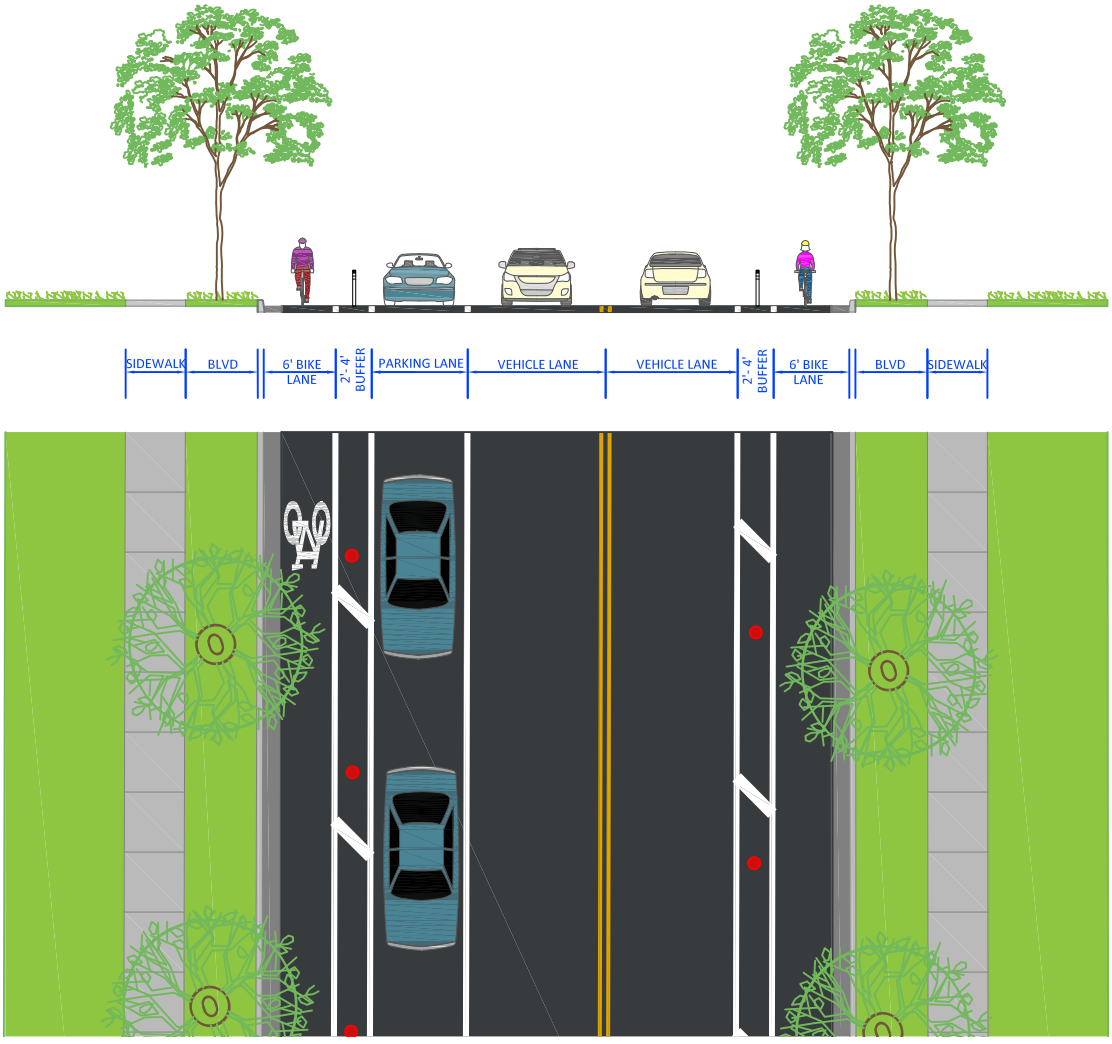
- Intersection and entrance sight distance requirements
- Managing conflicts at intersections and driveways
- Developing a year-round maintenance plan; may require specialized maintenance equipment
- Maintain pedestrian accessibility at intersections and transit stops

Application Criteria:

- To create a lower stress, protected bicycle facility route or network
- For higher volume and speed roadways
- Where protection from moving traffic is desired
- Street level
- One-way facility on both sides of the street or two-way facility on one side of the street
- Connections and transitions to other bicycle facilities
- Maintenance strategies necessary
- Frequency of, and treatments for, driveways and intersections

Design Criteria:

- One-way dimensions:
  - 7′ preferred (5′ min.) bikeway
  - 1′ to 3′ minimum (> 3′ preferred) buffer
- Two-way dimensions:
  - 12′ preferred (8′ in constrained spaces) bikeway
  - 1′ to 3′ minimum (> 3′ preferred) buffer



References:

AASHTO Guide for the Development of Bicycle Facilities (2012)

NACTO Urban Bikeway Design Guide (2012)

Manual on Uniform Traffic Control Devices (2009)

Green Lanes Project

ITE Pedestrian and Bicycle Council, Separated Bikeways, March 2013.

Cycle tracks

A cycle track is a high-priority protected bikeway that is separated from adjacent motor vehicle travel lanes by a curb.

Benefits:

- Provides physically protected, exclusive space for bicyclists separate from motor vehicles and pedestrians
- Suitable for, and more attractive to, bicyclists of all ages and abilities
- Prevents vehicles from driving and parking in facility
- Eliminates dooring issues
- Can visually narrow the street to calm traffic

Challenges:

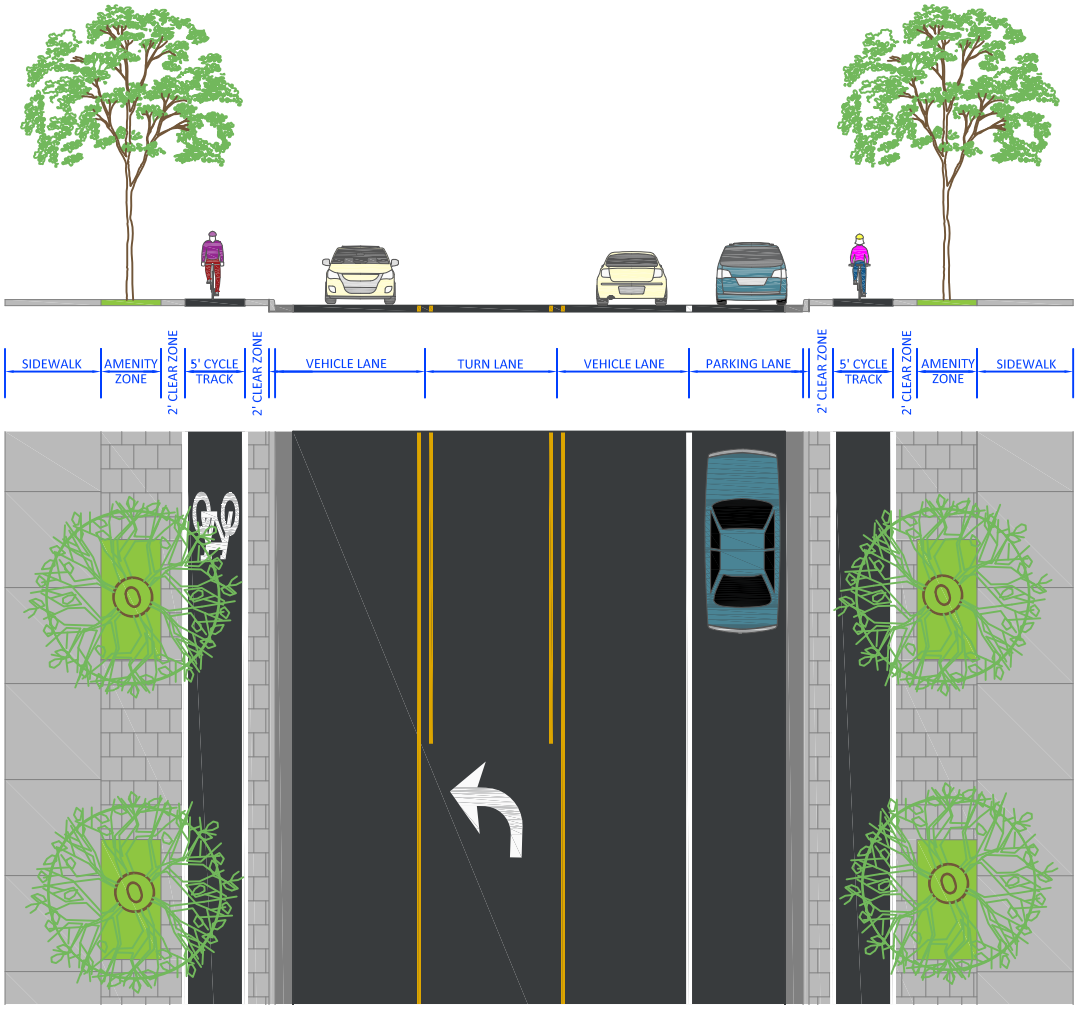
- Intersection and entrance sight distance requirements
- Managing conflicts at intersections and driveways
- Developing a year-round maintenance plan; may require specialized maintenance equipment
- Deterring pedestrians walking in cycle track
- Maintain pedestrian accessibility at intersections and transit stops

Application Criteria:

- To create a lower stress, protected bicycle facility route or network
- For higher volume and speed roadways
- Where protection from moving traffic is desired
- Street level
- One-way facility on both sides of the street or two-way facility on one side of the street
- Pedestrian accessibility at intersections and transit stops
- Connections and transitions to other bicycle facilities
- Maintenance and drainage strategies
- Frequency of, and treatments for, driveways and intersections

Design Criteria:

- One-way dimensions:
  - 7′ preferred (5′ min.) cycle track
  - 1′ to 3′ minimum* (> 3′ preferred) buffer
- Two-way dimensions:
  - 12′ preferred min. (8′ in constrained spaces) cycle track
  - 1′ to 3′ minimum* (> 3′ preferred) buffer



References:

AASHTO Guide for the Development of Bicycle Facilities (2012)

NACTO Urban Bikeway Design Guide (2012)

Manual on Uniform Traffic Control Devices (2009)

Green Lanes Project

ITE Pedestrian and Bicycle Council, Separated Bikeways, March 2013.

Dutch "Design Manual for Bicycle Traffic" (CROW)

Multi-use trails

A multi-use trail is a two-way bikeway physically separated from motor vehicle traffic and for use by bicyclists, pedestrians, and other nonmotorized users. Wider multi-use trails and separating users onto parallel trails can support differing user volumes and types.

Benefits:

- Provides physically protected, exclusive space for bicyclists and pedestrians separate from motor vehicles
- Suitable for, and more attractive to, bicyclists of all ages and abilities
- Prevents vehicles from driving and parking in facility
- Eliminates dooring issues

Challenges:

- Intersection and entrance sight distance requirements
- Managing conflicts at intersections and driveways
- Developing a year-round maintenance plan; may require specialized maintenance equipment
- Potential conflicts between pedestrians and bicyclists

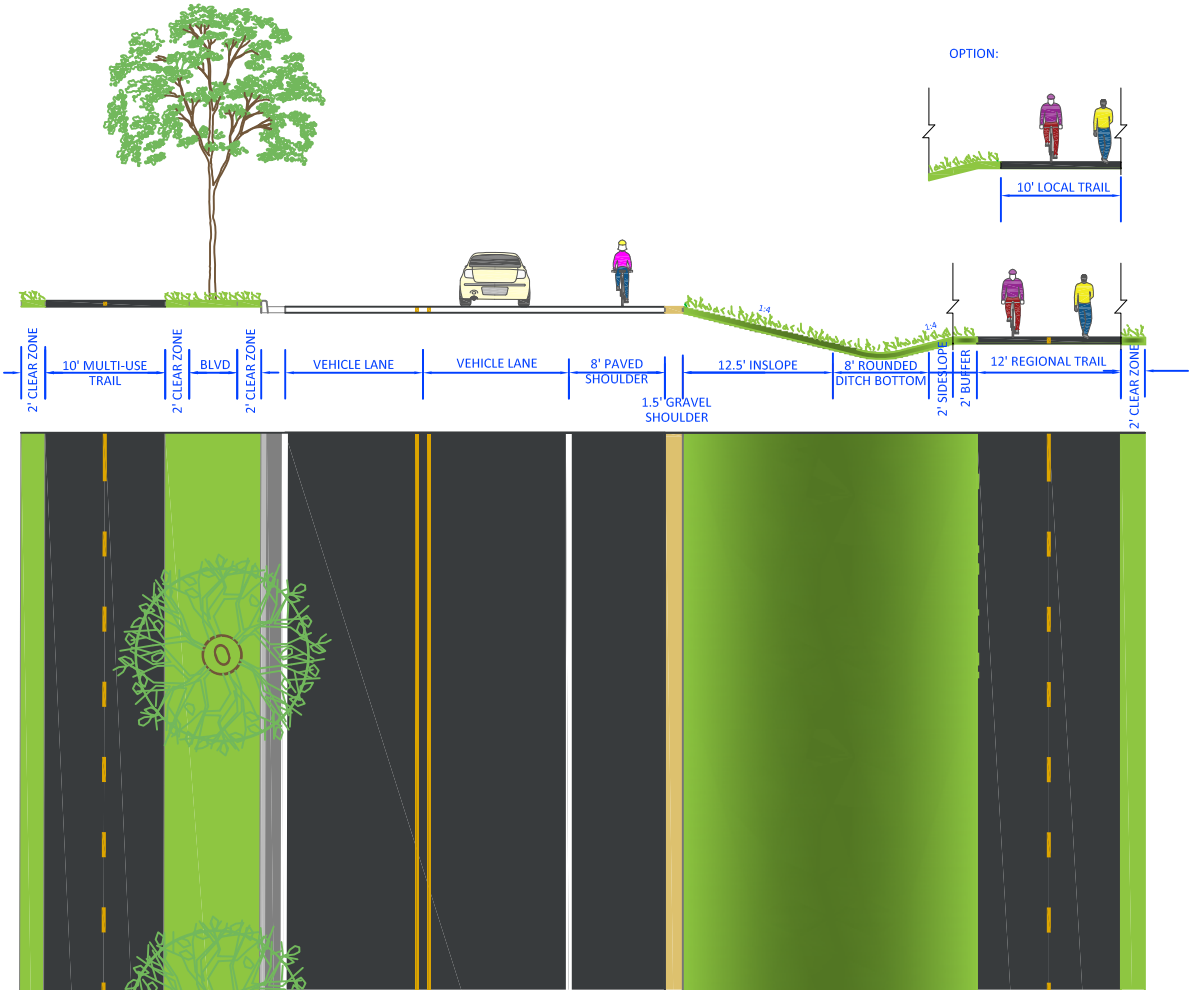
Application Criteria:

A multi-use trail should be designed to suit the characteristics of cyclists. To accommodate high volumes and reduce conflicts between different user types, a trail wider than the minimum can be provided or modes can be separated by adding one of the following facilities:

- Soft-surface gravel (2-4 feet) pedestrian walking path, which can be separated by a buffer
- Paved pedestrian walking path, separated by a buffer or stripe
- Parallel soft-surface trail for pedestrians, mountain bikers, and/or equestrians. This trail should be 6-10 feet in width and may follow the natural or more scenic terrain, with more hills and curves, if necessary.
- Parallel hard-surface walking trail for pedestrians along shared-use path corridors following a scenic route. This trail should provide additional facilities such as benches for the recreational users it attracts.

Design Criteria:

- The Federal Highway Administration's Shared-Use Path Level of Service Calculator is an additional tool for determining appropriate trail width given the quantity and breakdown of users on the trail.
- The trail purpose should also be considered when determining appropriate trail width. On a trail that is shared by both utilitarian and recreational bicyclists, additional trail width is desirable to allow users to pass.
- On wider trails, signage to remind users to keep right except to pass should be provided.
- Minimum 10-foot trail width
    - 8-foot widths are acceptable for short distances under physical constraint. Warning signs should be considered at these locations.
    - Greater than 10-foot widths are recommended at locations with heavy volumes or a high proportion of pedestrians. A minimum of 11 feet is required for users to pass with a user traveling in the other direction.



References:

AASHTO Guide for the Development of Bicycle Facilities (2012)

FHWA Shared-Use Path Level of Service Calculator (2006)

Pavement marking through intersections

Intersection pavement markings designed to improve visibility, alert all roadway users of expected behaviors, and to reduce conflicts with turning vehicles.

Benefits:

- Warns users of potential conflict locations
- Helps to define expected behaviors
- Designs encourage turning motorists to yield to people biking

Challenges:

- Potential confusion or clutter with additional pavement markings

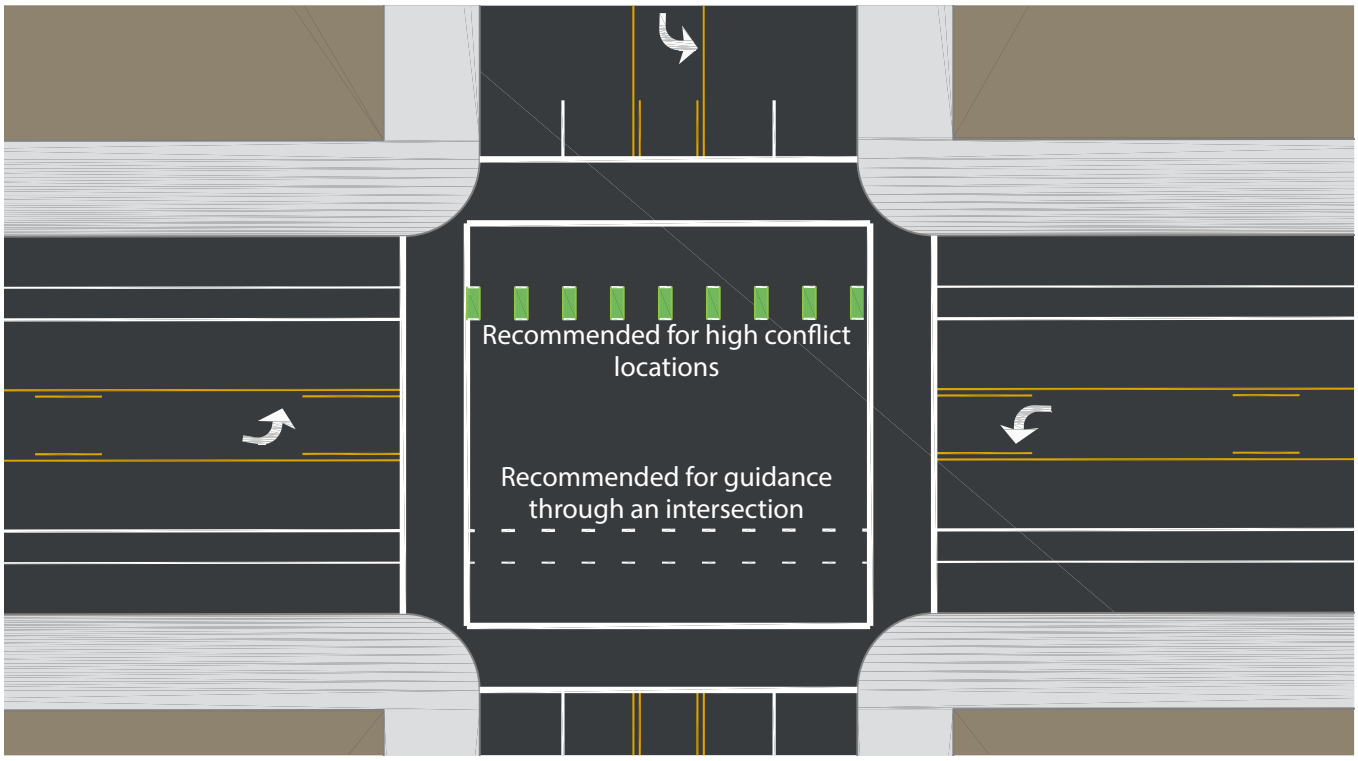
Application Criteria:

These treatments should be used guide bicyclists to the safest place to ride and warn of potential conflicts. Pavement marking treatments will vary depending on the context and character of each intersection based on engineering judgment.

- Pavement marking treatments used at intersections can include:
    - Dashed white lines
    - Symbols including chevrons or bicycle symbols
    - Green paint or pavement

Design Criteria:

- Dashed white lane lines should conform to the latest edition of the MUTCD. These can be used through different types of intersections based on engineering judgment.
- A variety of pavement marking symbols can enhance intersection treatments to guide people biking and warn of potential conflicts.
- Green pavement markings can be used along the length of a corridor or in select conflict locations.
- The level of emphasis and visibility: dashed lane lines may be sufficient for guiding people biking through intersections; however, consider providing enhanced markings with green pavement and/or symbols at complex intersections or at intersections with documented conflicts and safety concerns.
- Symbol placement within intersections should consider wheel paths for maintenance.
- Driveways with higher volumes may require additional pavement markings and signage.
- Consideration should be given to using intersection pavement markings as spot treatments or standard intersection treatments. A corridorwide treatment can maintain consistency; however, spot treatments can be used to highlight conflict locations.
- Additional treatments can help facilitate transitions between facilities (See Transitions between Facilities Technical Sheet for more information)



References:

AASHTO Guide for the Development of Bicycle Facilities (2012)

NACTO Urban Bikeway Design Guide (2012)

Manual on Uniform Traffic Control Devices (2009)

Cycle track driveway and intersection treatments

Treatments that help reduce and manage conflicts at intersection and driveways with turning vehicles and pedestrians; the overall goals are to reduce conflicts, speeds and delay, and maximize safety and comfort for all modes.

Benefits:

- Improved safety by minimizing and/or separating conflicts, and providing adequate sight lines
- Helps to define expected behaviors for all modes
- Provides connections to adjacent facilities

Challenges:

- Impacts to signal cycle lengths/phases
- Enforcing yielding behaviors
- Accommodating sight distance requirements may have impacts to parking
- Intersection safety

Application Criteria:

Where cycle tracks cross driveways and intersections, possible treatments can include:

- Pavement markings including green pavement markings and symbols; and signage (See Pavement Markings through Intersections Technical Sheet)
- Geometric changes to reduce speeds and improve sight lines (e.g. restricting parking, chicane cycle tracks, channelize vehicles to create vehicle/ bicycle mixing zones)
- Signalization that provides separate bicycle and vehicle phases (See Through Bicycle Facilities and Turn Lanes Technical Sheet)

Design Criteria:

- For cycle tracks with parking, restrictions between 20 feet and 40 feet may be sufficient to provide proper sight distances at the near and far-side of intersections and driveways; however additional space may be needed based on geometry, volumes, and other operational characteristics. Sight and stopping distance requirements should be calculated for motor vehicles and bicycles per the AASHTO Green Book and the AASHTO Guide for the Development of Bicycle Facilities, respectively.
- Chicanes in cycle tracks can slow bicyclists speeds to meet sight distance requirements and help retain more on-street parking. Chicanes can be designed to reduce bicycle approach speeds to 8 to 11 mph corresponding to a bicycle stopping distance of 35 feet to 65' feet.
- Motor vehicle/bicycle mixing zones transition cycle tracks to a shared curbside bicycle and motor vehicle lane. Turning vehicles should be angled into the mixing zone to reinforce yielding, reduce speeds, and maximize visibility of oncoming bicyclists. Yield markings should be provided for motorists at the approach to the mixing zone and can be accompanied by "Turning Vehicles Yield to Bikes" or "Begin Turn Lane Yield to Bikes" signs to denote bicycle prioritization.
- Stopping and sight distance requirements should allow sufficient time for both a person biking to react prior to the intersection if a vehicle turns in front of the person biking, and for a motorist to yield to the straight-traveling bicyclist.
- Major driveways should be treated similarly to intersections; minor driveways will still need to provide adequate stopping sight distances.
- Raised cycle tracks should remain raised across driveways to reinforce that motor vehicles must yield to people biking.
- Additional traffic calming measures to slow speeds should be considered.
- Providing separated signal phasing to eliminate conflicts must balance delay with safety.
- Mixing zones may not be appropriate at intersections with high volumes of right turning vehicles or higher speeds, and further studies are needed to determine their effectiveness in reducing crashes compared to alternative treatments such as signalization.
- At midblock pedestrian crossings, cycle track designs should provide indications, including pavement markings and signage, for people biking to yield to pedestrians.
- Transitions and connections to other facilities should be provided (See Transitions between Facilities Technical Sheet)
- Wayfinding signs should consider the types of users and facilities to provide a lower stress network of bicycle routes.

References:

AASHTO Guide for the Development of Bicycle Facilities (2012) - 5.2.8 Stopping Sight Distance

NACTO Urban Bikeway Design Guide (2012) - "Intersection Crossing Markings," "Cycle Track Intersection Approach"

Manual on Uniform Traffic Control Devices (2009)

Transitions between facilities

Facility types may vary along a roadway corridor given land use, parking needs, right-of-way constraints and other characteristics. Additionally, a common or logical route for bicyclists may turn at an intersection. It is important to provide transitions between different types of facilities (e.g. wayfinding signage, pavement markings, turn-queue boxes).

Benefits:

- Helps to define expected behaviors for all modes
- Provides advanced warning of changes in the roadway/facility
- Provides opportunities for turning movements onto adjacent facilities
- Helps manage potential conflicts

Challenges:

- Maintaining consistent, comfortable, and appropriate facilities
- Enforcing yielding behaviors
- Vehicle delay with signalization for bicycles
- Managing potential conflicts between modes

Application Criteria:

When transitioning between facilities, treatments can include:

- Warning and educational signs
- Pavement markings
- Bicycle Boxes/Turn-Queue Boxes
- "Jug-handles" or curb cuts to facilitate turning movements
- Signalization
- Wayfinding
- For off-road facilities, providing queuing areas and areas for modes to mix.

References:

NACTO Urban Bikeway Design Guide (2012), "Intersection Treatments"

AASHTO Guide for the Development of Bicycle Facilities (2012) , 2.5.2 Practical (Opportunistic) Approach to Network Planning

Manual on Uniform Traffic Control Devices (2009)

Design Criteria:

- Always carry bicycle facilities to a logical terminus. Specifically designers should avoid abruptly ending facilities without considering transitions and interactions with vehicles.
- At locations where bicycle lanes transition to shared lanes, it may be desirable to provide a transition to a short segment of shared lane markings, even if the shared lane markings will not continue.
- Signage should be provided per recommendations in the latest edition of the MUTCD and AASHTO Bike Guide. Pavement markings should alert motorists of the change in facility and intended shared use of travel lanes.
- Taper lengths for lane drops and transitions should follow the MUTCD and AASHTO Green Book recommendations.
- Bicycle boxes and turn-queue boxes should be placed out of vehicle paths and be wide/long enough to support multiple bicyclists queuing at intersections. Bicycle boxes should only be used where a dedicated facility is provided prior to the intersection (bicycle lane or cycle track); however, queue boxes may be used at a variety of locations with or without dedicated facilities.
- Appropriate connections and transitions between facility types should be conducted as a part of network plans. It is important that facilities have logical termini and a network is planned that serves a range of users.
- Enhance visibility with green pavement markings and/or bicycle symbols at conflict locations.
- Two-stage left turn movements are common practice in the Netherlands and other European countries, and can be easier for some bicyclists to execute, and may be more comfortable because it does not require waiting for gaps to merge laterally across multiple lanes of traffic.

Through bikeways and motor vehicle turn lanes

Strategies to manage conflicts at intersection between through bicycles and turning motor vehicles; the overall goals are to reduce conflicts, speeds, and delay, as well as maximize safety and comfort for all modes.

Benefits:

- Improved safety by minimizing and/or separating conflicts
- Helps to define expected behaviors for all modes
- Designs encourage turning motorists to yield to people biking

Challenges:

- Maintaining a consistent, comfortable, and appropriate facility
- Enforcing yielding behaviors
- Vehicle delay with signalization or bicycles
- Managing potential conflicts between modes

Application Criteria:

Where a through bike facility and turn lanes exist, treatments can include:

- Maintain bicycle through lane approaching the intersection and use pavement markings, green pavement and/or symbols in the area where turning vehicles have to cross the bike lane.
- Transitioning to shared lanes with pavement markings and signs prior to the intersection; shared lanes may transition back to a bicycle lane and can be supplemented with green pavement
- Combined bicycle lanes/right turn lanes, or mixing zones
- Signalization to separate turns from through bicyclists

Design Criteria:

- Separate signal phases is the only strategy that will eliminate conflicts between turning vehicles and through bicyclists. However, signalization may increase delay for all users so trade-offs should be weighed based on constraints, needs and safety concerns at the intersection.
- Merging areas should be located prior to the intersection.
- A combination of bicycle lanes and shared lanes can be provided to accommodate both through and turning bicyclists.
- Combined through bicycle lanes and motor vehicle turn lanes should only be used where there is not enough space to provided separate facilities.
- Transitions from dedicated bicycle facilities to shared lanes should alert all users of the change in the roadway.

- Taper lengths for lane drops and transitions should follow the MUTCD and AASHTO Bike Guide recommendations.
- "Begin (Right or Left) Turn Lane Yield to Bikes" sign should be provided per the latest edition of the MUTCD.
- Enhance awareness with green pavement markings and/or bicycle symbols at conflict locations.
- Dual turn lanes on roadways with bicycle lanes should be avoided unless clearly needed for turning capacity.
- Left side bike lanes on one-way streets to avoid right turn conflicts of prevalent along the length of the corridor or dual turn lanes.
- Provide facilities and connections for turning bicyclists.

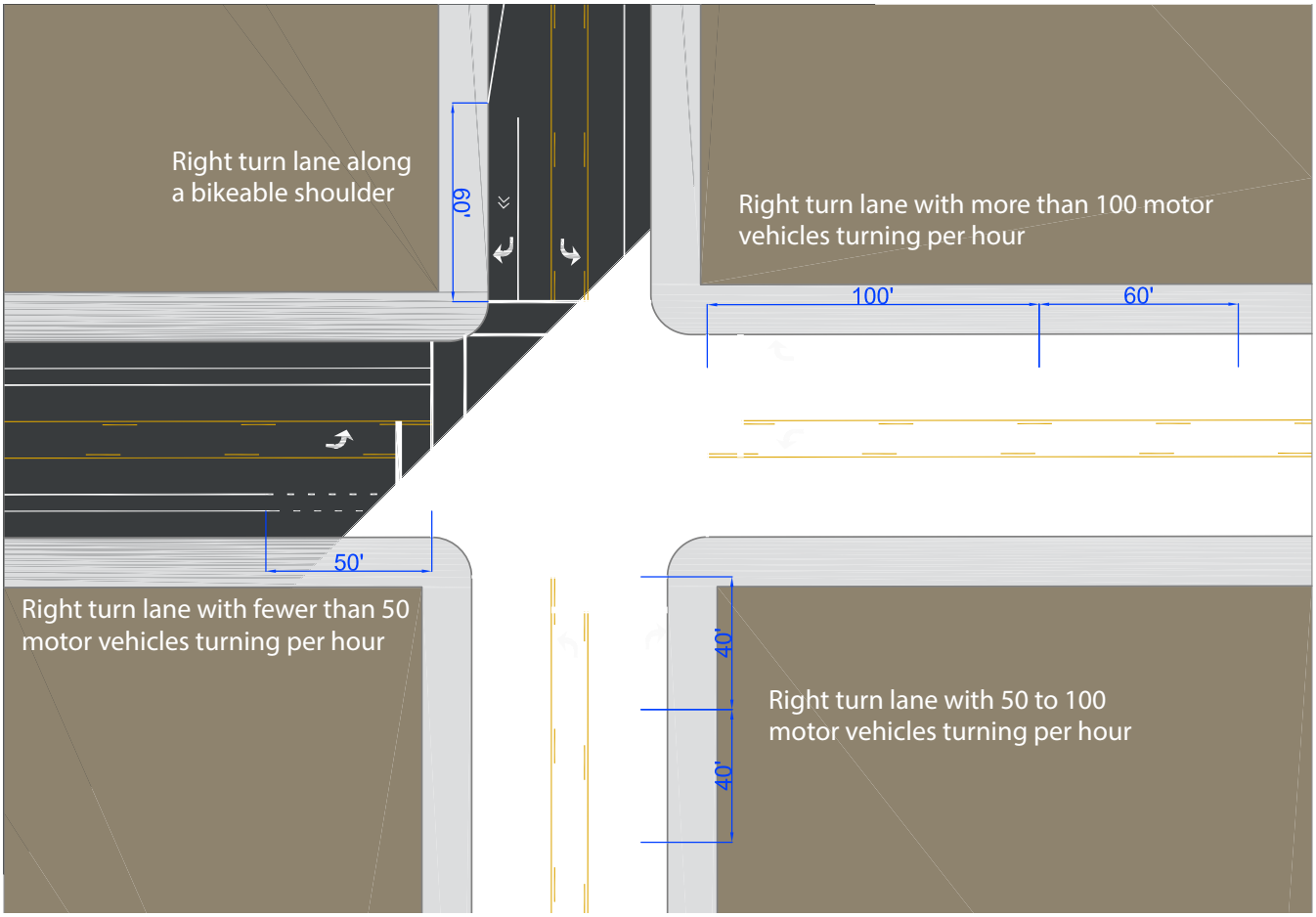
References:

AASHTO Guide for the Development of Bicycle Facilities (2012) - 4.8.1 Right Turn Considerations, 4.8.2 Left Turn Considerations

NACTO Urban Bikeway Design Guide (2012) - "Through Bicycle Lanes," "Combined Bike Lane/Turn Lane"

Manual on Uniform Traffic Control Devices (2009)

Bike lane and right turn lane treatment options:



Signal design for bicycles

Signalized intersections can be optimized to accommodate people biking, serving the unique operating characteristics of bicycling (i.e. size, speed, acceleration and deceleration).

Benefits:

- Provides adequate time for people biking to clear a signalized intersection
- Minimizes delay for people biking, reducing likelihood that people biking will disobey the signal

Challenges:

- May result in a slight loss of capacity at the intersection
- May increase red-light running

Application Criteria:

Accommodating people biking at signalized intersections includes three main components: (1) bicycle detection, (2) minimum green time for people biking, and (3) change and clearance times for people biking. These elements should be modified at signalized intersections in the bicycle network where people biking are expected to travel. Particular consideration should be given to signal timing at locations with high vehicular speeds and long crossing distances. Detection should be provided for people biking at signalized intersection approaches requiring actuation. It should not be expected that on-road bicyclists will be required to leave the roadway to actuate a signal.

Design Criteria:

- A stationary, or "standing," bicyclist entering the intersection at the beginning of the green indication can typically be accommodated by increasing the minimum green time on an approach per the 2012 AASHTO Guide for the Development of Bicycle Facilities.
- A moving, or "rolling," bicyclist approaching the intersection towards the end of the phase can typically be accommodated by increases to the red times (change and clearance intervals) per the 2012 AASHTO Guide for the Development of Bicycle Facilities.
- Set loop detectors to the highest sensitivity level possible without detecting vehicles in adjacent lanes and field check. Type D and type Q loops are preferred for detecting bicyclists. Install bicycle detector pavement markings and signs per the MUTCD, 2012 AASHTO Guide for the Development of Bicycle Facilities, and the NACTO Urban Bikeway Design Guide.
- Bicycle-specific signals may be appropriate to provide additional guidance or separate phasing for bicyclists per the 2012 AASHTO Guide for the Development of Bicycle Facilities.
- Video detection, microwave and infrared detection can be an alternate to loop detectors.
- It may be desirable to install advanced bicycle detection on the intersection approach to extend the phase, or to prompt the phase and allow for continuous bicycle through movements.
- Another strategy in signal timing is coordinating signals to provide a "green wave," such that bicycles will receive a green indication and not be required to stop. Several cities including Portland, OR and San Francisco, CA have implemented "green waves" for people biking.

References:

AASHTO Guide for the Development of Bicycle Facilities (2012)

NACTO Urban Bikeway Design Guide (2012)

Manual on Uniform Traffic Control Devices (2009)