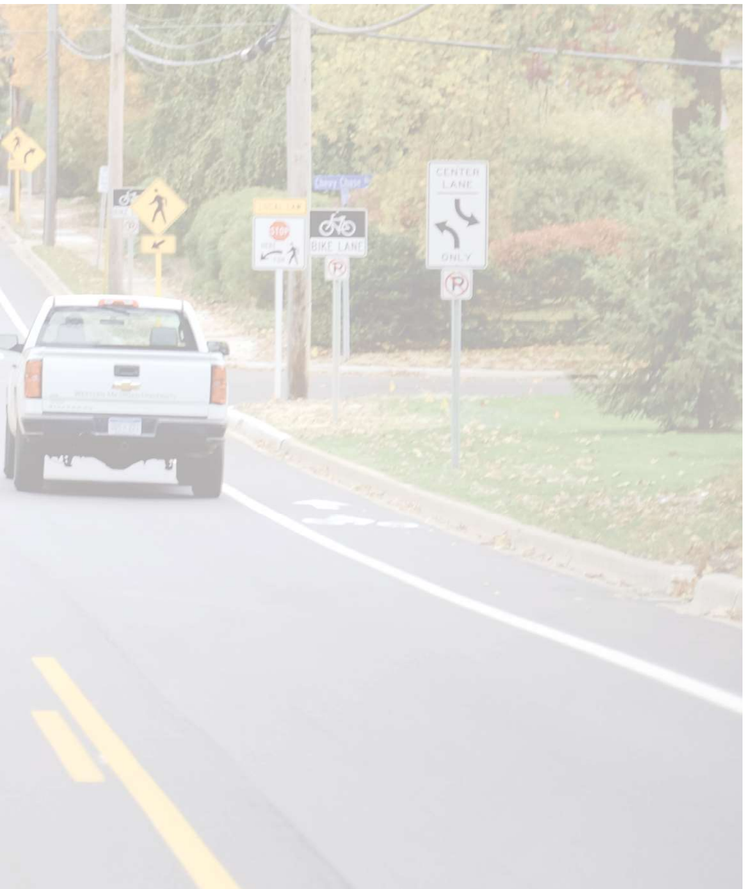


4.5

ROADWAY ELEMENTS

STREET TYPOLOGY								
UC	E/F	MS	NB	CB	CC	NN	EN	LN
Req.	Req.	Req.	Req.	Req.	Req.	Req.	Req.	Req.

ROADWAY ELEMENTS

TRAVEL LANES

DESCRIPTION & INTENT

Travel lanes are the portion of the roadway marked for the movement of vehicles. The width of travel lanes is a critical dimension that affects many aspects of the street including vehicle speed, pedestrian crossing distances, signal cycles, and the amount of roadway impervious surface.

Travel lanes may be used by both motorized vehicles and bicycles. Lanes intended for travel are not to be used for loading or parking.

The width of travel lanes has a direct relationship to the speed of vehicles. Research has shown that narrower lane widths reduce traffic speeds without decreasing safety, and that wider lanes are not correlated with safer streets. In general, travel lanes should be as narrow as possible, while still accommodating the roadway's design vehicle, in order to encourage slower speeds and improve safety for all users.

Turn lanes provide a space for vehicles to move out of the general flow of traffic into a dedicated space from which to turn. Turn lanes, particularly center-turn lanes, can significantly improve vehicle flow.

USE & APPLICATION

Location

- Travel lanes are required on all public streets.

Related Design Elements

- Travel lanes and turn lanes must be assembled together with other roadway elements such as parking lanes, bicycle facilities, transit lanes, and other curbside uses.
- The assemblage of travel lanes can have a substantial effect on the street experience, especially for pedestrians. Although a "typical section" taken at a mid-block location may result in a relatively narrow cross section, inclusion of right- and/or left turn lanes at intersections can dramatically increase the total roadway width and pedestrian crossing distances.

DESIGN & OPERATIONS

Design Requirements

A **Marked Travel Lane Width** [(1)]**:** The default width for all travel lanes on marked roads should be 10-feet wide, with the following exceptions:

» On streets with frequent and/or priority transit service, one 11-foot wide lane in each direction may be used where transit vehicles need to be accommodated and need additional room for clearance or operations.

» On streets with frequent, heavy truck traffic, 11-foot lanes may be used to provide additional maneuvering space.

» Wider lanes for transit or truck accommodations should be located in the outermost lane.

» **Centerline Markings:** On streets with lane markings, solid double-yellow (do not pass) lane markings should be used. Dashed yellow lines, which enable passing, are not recommended as it can encourage speeding and unpredictable driver behavior.

B **Turn Lane Widths:** Turn lanes (both center and right turn) should be 10-feet wide.

» Turn lanes used as part of a truck or transit route may be increased up to 11-feet.

» On lower volume or speed streets, and/or under constrained conditions, travel lanes or turn lanes may be reduced to 9-feet wide.

- **Unmarked Lanes:** Road typologies with unmarked travel lanes (enhanced neighborhood and local neighborhood) typically accommodate two-way traffic in a travel way that is narrower than it would otherwise be with marked lanes. Such roads usually include curbside zones for on-street parking.

  » For one-way roads, the travel way should be at least 10-feet wide where a curbside zone is present, or 12-feet wide when adjacent to curbing on both sides.

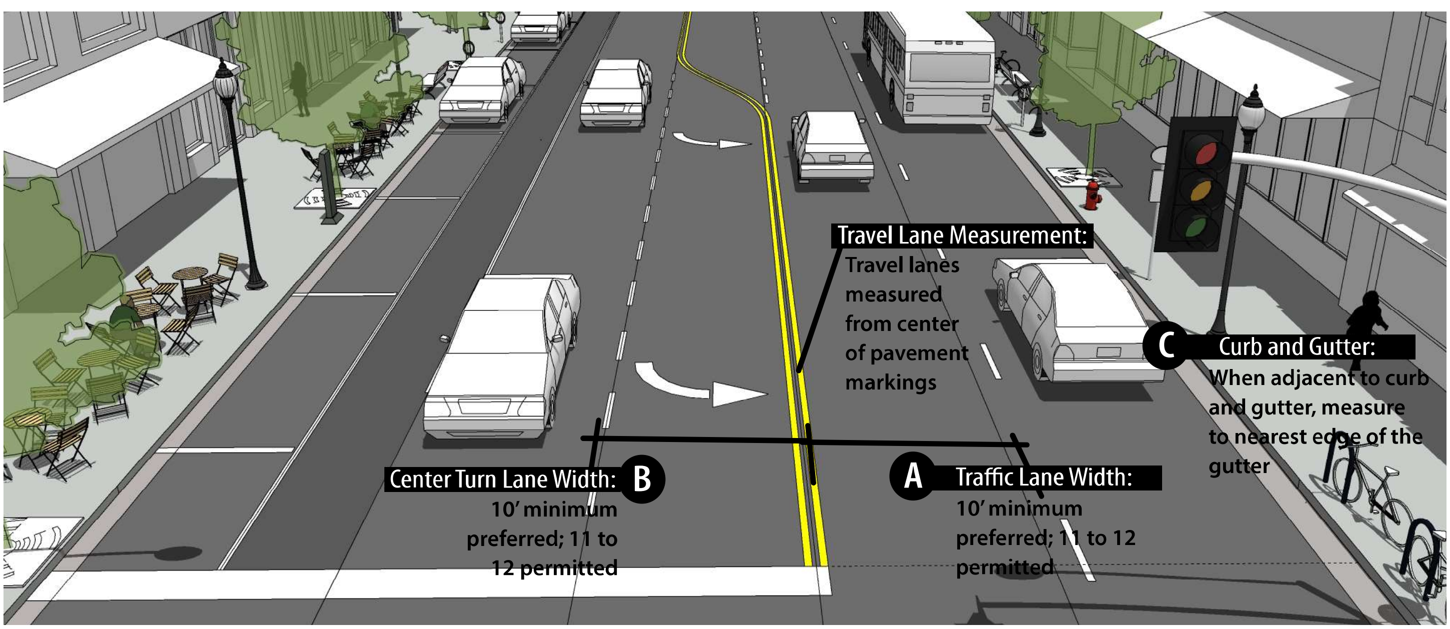
  » For two-way roads, the travel way should be a minimum of 16-feet wide up to a maximum of 20-feet wide.

  » Unmarked lanes may require passing cars to yield and slow down when passing each other, particularly in residential areas. Adequate overall roadway width should be present to allow cars to pull partially into parking lanes in order to facilitate passing (see ***Advisory Bicycle Lanes***).

- **Measuring Lane Widths:**

  » Travel lanes should be measured from the center of lane markings on either side of the travel lane (including where on-street parking is present).

C **Curb and Gutter:** When a travel or turn lane is adjacent to a curb and gutter, measure to the nearest edge of the gutter (i.e. "edge of metal"). If no gutter is present, measure to the face of curb, adding 18 inches to required lane width to account for drainage inlets and clearance from the curb.



Additional Design Considerations

- **Assembly:** The overall roadway cross section (all travel and turn lanes plus in-road bicycle facilities and curbside lanes) should avoid having absolute minimum dimensions for each incorporated street element. For example, narrower travel lanes (e.g. 9-feet) combined with absolute minimum bicycle lane widths (e.g. 4-feet) results in a constrained roadway for all users, and a different design approach should be considered.
- Locations where travel lanes are currently above the desired width should be considered for pavement marking treatments that stripe-off the areas outside of the travel lane and/or establish other street uses to make use of extra space (e.g. a paved shoulder, bicycle lanes, or parking areas). Street reconstruction projects are an opportunity to relocate curb lines and achieve a narrower pavement area.
- Travel lane widths need to be considered within the assemblage of the full street. Narrow travel lanes adjacent to minimally dimensioned bicycle or parking lanes may introduce some friction between uses.
- Wider travel lanes may be necessary approaching existing intersections depending on the design vehicle and curb configuration. Tight turning vehicles require more horizontal space while turning than while traveling straight (see ***Curb Radii***).
- **Road Diets:** Road diets can be used to reduce the number of travel lanes in the roadway and free up space for other uses, while improving safety for all users.
    - » Four lane roads (no center turn lane) typically pose the greatest safety concerns and can often be dieted to three lanes. Roadways with Average Annual Daily Trips (AADT) of 21,000 should be analyzed to assess the feasibility of a road diet.
    - » Vehicle lanes can typically accommodate approximately 1,900 cars per lane per hour. This can be used in consideration of peak hour volumes to understand the number of travel lanes that may be needed.

Utility Considerations

- Utilities will often be located under travel lanes. Manholes and access portals must be flush with the roadway surface. Utility work in a travel lane should resurface the whole of the travel lane for a smooth travel surface.

Sustainability Considerations

- Minimizing lane widths minimizes overall paved and impervious surfaces, which contribute to stormwater runoff and water quality.

Design References

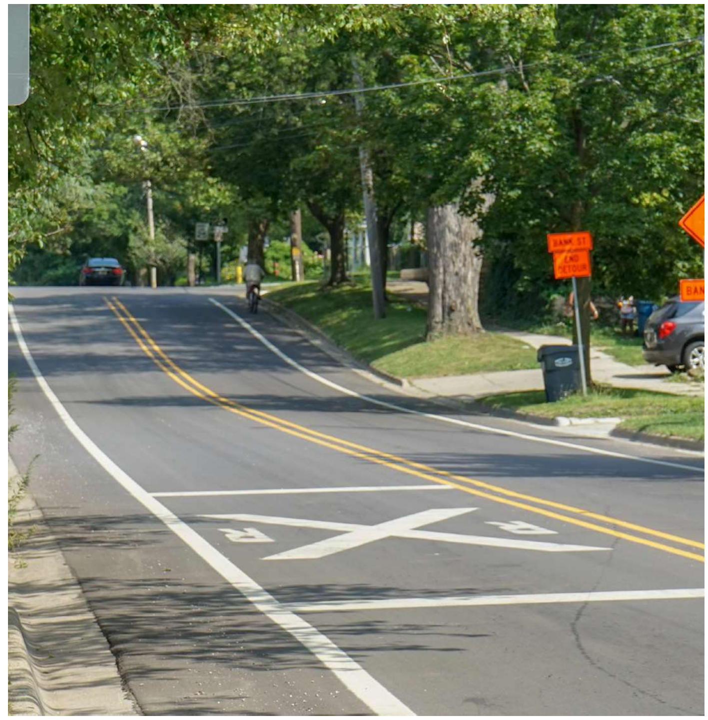
- NACTO Urban Street Design Guide (2013) provides guidance on travel lane widths.
- The AASHTO Green Book recommends 10- to 12-foot travel lanes and 10- to 12-foot turn lanes.
- A number of states have endorsed narrower lanes. The Florida Department of Transportation found that narrower lane widths do not impact street capacity "So long as all other geometric and traffic signalization conditions remain constant, there is no measurable decrease in urban street capacity when through lane widths are narrowed from 12 feet to 10 feet."
- The Institute of Transportation Engineers "Designing Walkable Urban Thoroughfares: A Context Sensitive Approach" recommends a range of 10- to 12-feet for travel lanes on urban arterial and collector streets. Narrower travel lane widths (down to 10-feet) are recommended on lower volume and speed on streets.
- The Michigan MUTCD provides standards and specifications on travel lane signage (Part 2) and markings (Part 3).

MAINTENANCE & MANAGEMENT

- Travel lanes require periodic sweeping and pavement marking re-striping.

Seasonal Use and Maintenance

- **Snow Removal:** Efficiently clearing snow and ice from travel lanes is a vital safety operation. Black ice and other dangerous conditions are common in Michigan. Snow should be cleared all the way to the curb, ensuring that drain inlets are able to take in melting snow.
- **Special Events:** Travel lanes may be closed to vehicle traffic and designated as a pedestrian, special event or play street by the city.



STREET TYPOLOGY								
UC	E/F	MS	NB	CB	CC	NN	EN	LN
Req.	Req.	Req.	Req.	Req.	Req.	Req.	Req.	Req.

ROADWAY ELEMENTS

CORNER GEOMETRY & DESIGN VEHICLE

DESCRIPTION & INTENT

The geometry of corners and turns at roadway intersections is critical for safe and comfortable operations of the street, and has an impact on all street users.

Larger corner radii can accommodate bigger vehicles making turns, but also allow for high speed turns from smaller vehicles, which may not be desired. Larger radii may also cut into pedestrian space at corners and make crossing distances longer, less comfortable, and requiring longer pedestrian crossing signal phases.

Conversely, smaller corner radii may preclude or inhibit larger vehicles from turning, but can promote slower turning speeds for all users while preserving more pedestrian space and narrowing crossing distances.

Two factors play the greatest role in determining the geometry of corner curb radii:

- **Intersection Angle:** Where two streets meet at an angle, the acute angle corners of the intersection commonly have very tight curb radii, while the obtuse angle corners have much larger curb radii. Angled intersections may result in very long pedestrian crossing distances.
- **Vehicle Type:** Larger vehicles make wider turns. Large vehicles include municipal and school buses, tractor trailers, and larger fire trucks.

- There are two measures of curb radius—the actual curb radius and the effective curb radius (see ***Figure*** on next page).

A **Actual Curb Radius:** Refers to the physical radius of the built curb at an intersection.

B **Effective Curb Radius:** Refers to the smallest inside arc that is possible for a vehicle to follow from the departing travel lane to the receiving lane. Because vehicles may begin their arc from a travel lane located outside of a bicycle facility and/or a lane of parking, it is common that the effective curb radius is significantly larger than the actual curb radius.

USE & APPLICATION

Location

- Corner geometries exist wherever two streets intersect.

Related Design Elements

- **Intersections:** Curb radii and corner geometries are critical in the assemblage of intersections. Radii affect pedestrian crossing distances, traffic turning speeds, and overall safety and operation of the intersection.
- **Crosswalks and Curb Ramps:** The size of the actual curb radius directly affect pedestrian crossing distances and visibility relative to the roadway. It also affects the placement of curb ramps. Larger radii make it more difficult to install curb ramps that are in parallel and directly aligned with the crosswalk and approaching sidewalk.

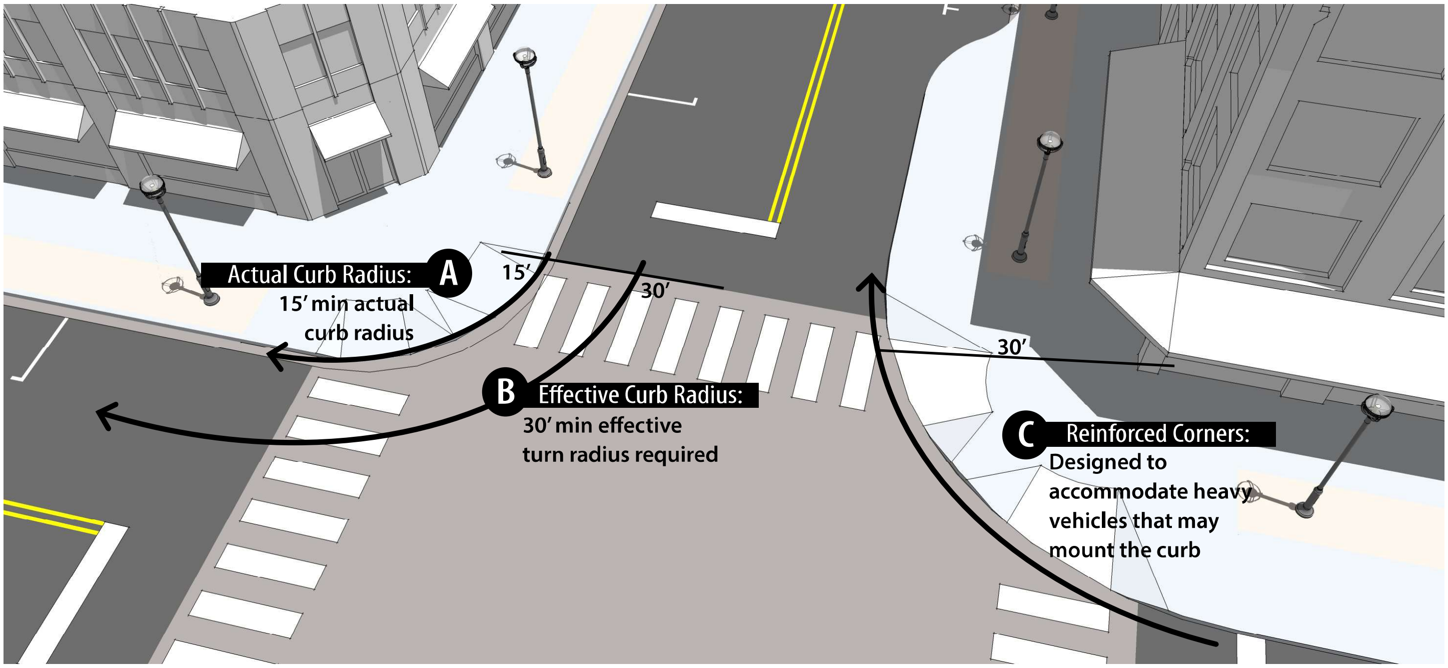
- **Bumpouts:** Although corner bumpouts typically have larger curb radii than the underlying natural curb, they nonetheless help to manage vehicle turning speeds by establishing a tighter effective radius. Actual corner bump out radii are typically equal to the effective curb radii.

DESIGN & OPERATIONS

Design Requirements

- **Corner Radius:** Corner curbs shall be designed using the smallest radius possible to accommodate the necessary design vehicle(s) (see ***Design Vehicles*** below).
- On most streets, the effective turn radius should be a minimum of 30-feet in order to accommodate an SU-30 vehicle (which has an inside radius of 28-feet). This may be narrower or larger depending on the selected design vehicle of the roadway (see ***Design Vehicle***).
  - » Actual curb radii should be as small as possible while still achieving the target effective radius. Corner radii may be assembled using a single simple curve, multiple curves, or complex curves.
- **Design Vehicle:** The target design vehicle that needs to be accommodated along the street and must be accommodated for each specific turning movement should be identified early in the design process.
  - » **Target Design Vehicle:** This is the vehicles routinely expected to navigate a corner.
  - » **Accommodation Vehicle:** This is a vehicle that may occasionally be required to navigate the turn, but may require more finessed turning behaviors and/or may result in minor encroachments outside of the normal vehicle path.
  - » **Transit and Trucks:** For transit and truck routes, larger design vehicles may be used at corner locations where these vehicles are regularly making turns as part of the designated routes (i.e. only those corners where trucks or transit vehicles are turning).

Design Vehicle	Target Design Vehicle	Acommod. Vehicle	Transit Route	Truck Route
Primary Roads UC, E/F, MS, NB, CB, CC, NN	SU-30	WB-40	CITYBUS	WB-50
Local Roads EN, LN	DL-23	SU-30	CITYBUS	n/a



- At signalized intersections, larger vehicles may be permitted to use all available receiving lanes to complete their turn. This should be reflected in turn modeling.
- **No-Turn Corners:** Corners where no legal turn is possible, such as from a one-way street onto another one-way street, can have a minimal actual curb radius (5-feet).
- **Parking Lane:** On-street parking permits tighter actual curb radii as no vehicle will be turning directly from curb lane to curb lane along the actual curb radius, vehicles will be turning from outside the parking lane to outside the parking lane. Where permanent on-street parking exists on both streets, bumpouts may be utilized.

C **Reinforced Corners:** Corners can be designed to accommodate heavier vehicle loads where transit vehicles or trucks may occasionally mount the curb.

- "Sneckdowns" are tracks in fresh snow that reveal the actual turn radii and frequency of turning vehicles and may be used to inform locations where tighter curb radii and/or bumpouts are viable.

Utility Considerations

- Keep utility cabinets, hand holes, and other fixtures off corner curb areas to the extent possible. Where utility cabinets are necessary, they should be in subsurface vaults or in nearby locations clear from the intersection.
- Locate stormwater inlets to effectively drain the street while not precluding curb ramps and corner bumpouts.

Design References

- The NACTO Urban Street Design Guide provides additional guidance on corner geometries (see ***Corner Radii*** section).

MAINTENANCE & MANAGEMENT

Seasonal Use and Maintenance

- Snow should be removed all the way to the vertical curb face of a corner.

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STREET TYPOLOGY								
UC	E/F	MS	NB	CB	CC	NN	EN	LN
Lim.	Lim.	Lim.	Lim.	Opt.	Opt.	Opt.	Opt.	Opt.

DRIVEWAYS & CURB CUTS

DESCRIPTION & INTENT

Driveways provide access in and out of adjacent property for vehicles. "Curb cuts" refers specifically to the break in the street curb and associated ramp (also called a driveway apron) that links to the driveway.

While driveways are an important part of the public realm, too many driveways create an unpleasant pedestrian environment and increase conflicts between motorists and other street users. They also take away space that may otherwise support planting, street furniture, and curbside parking. Coordinating the design of driveways together with the sidewalk contributes to a higher-quality pedestrian experience and reduces dangerous conflicts.

USE & APPLICATION

Location

- Driveways and curb cuts are generally undesirable in denser pedestrian oriented commercial areas (urban center, event/festival, main streets, neighborhood business). In these areas, building services should be accessed via alleys or side streets whenever possible.
- Driveways and curb cuts in more auto-oriented commercial street types (commercial business, city connector) should be minimized to the extent possible, with property owners sharing curb cuts where feasible.
- Regardless of context, the number of driveways should be minimized. Use of a single common curb cut to provide access to several businesses or properties is preferred. City code allows for one driveway per lot and a second driveway on lots wider than 200-feet.

Related Design Elements

- **Traffic Calming:** At a location where vehicles frequently enter and exit a street, driveways are excellent opportunities to introduce traffic calming elements to the street (e.g. mid-block bumpouts) to ensure that motorists are aware of their surroundings and do not drive in a way that endangers other road users.
- **Bumpouts:** Driveways can be used in conjunction with bumpouts. Move the driveway apron out to the bumpout and make it flush with the sidewalk level.
- **Intersection Proximity:**
  - » On residential streets, driveways should be restricted within 20-feet of unsignalized intersections, and at least 40-feet from signalized intersections as measured from the leading edge of the crosswalks.
  - » On commercial streets, driveways should always be at least 100-feet from intersections as measured from the leading edge of the crosswalks.
- **Bus stops:** Bus stops and driveways should be positioned relative to each other such that an unbroken curb line can be accessed by the full length of the bus to allow curb height boarding.

DESIGN & OPERATIONS

Design Requirements

While driveways are often necessary for building access and loading, their design should indicate to motorists that pedestrians and cyclists, and through vehicle traffic have the right-of-way across a driveway. Driveway entrances and curb cuts are an opportunity to provide traffic calming to reduce the potential for conflicts.

A **Driveway Width:**

- » Single-lane driveways shall be between 8-feet and 12-feet wide at the throat.
- » Bi-directional driveways shall be at least 20-feet wide and no wider than 24-feet. Exceptions may be made for driveways that must accommodate frequent large trucks.

B **Driveway aprons** shall be placed in the amenity zone. The apron should not encroach on the clear sidewalk zone. If there is a bumpout or parking lane planter, the apron should lie within the bumpout. Bumpouts should be used if the sidewalk is too narrow to accommodate a safe driveway intersection.

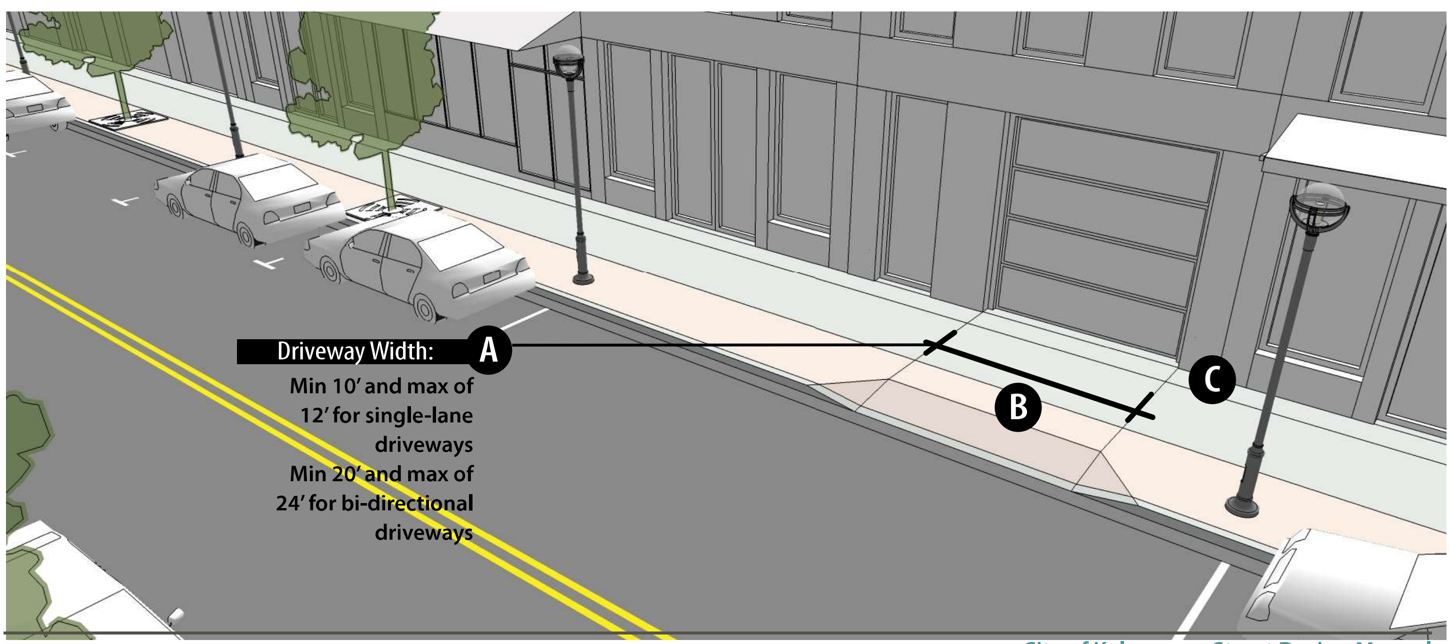
- **Materials:** Driveways shall be of concrete, asphalt, concrete pavers, brick or stone. Curb cuts and associated ramps must be made of concrete.

C **Sidewalk Interface:** Driveways shall be flush with the sidewalk level to maintain a comfortable walking environment and reduce conflicts. Continue sidewalk paving material across the driveway to indicate that pedestrians will be crossing this space.

- **Visibility Sight Lines:** Curb cuts shall provide adequate visibility to and from the sidewalk and street. Ideally, vehicles should not need to block the sidewalk while gaining clear lines of sight, but this may not be unavoidable.
  - » Where sight lines are limited, include appropriate signage indicating where the driver is to stop and wait.
  - » Mirrors, audible signals, or other devices to assist with visibility of pedestrians are encouraged at high volume locations where visibility is limited (e.g. parking garage exits).

Additional Design Considerations

- **Alley Access:** Curb cuts are not appropriate where alleys can provide rear access to residences and businesses. Where large new development occurs along a significant portion of a block face, provide a central alley to reduce the need for multiple driveways and curb cuts.
- **Bicycle Lane Markings:** Where a driveway crosses a bicycle facility, pavement markings should be dashed across the driveway so that cyclists and drivers are alerted to the potential conflict area.



- **Major Driveways:** Ensure driveways that function as an intersection, such as onto private alleys or circulation drives, contain all of the features of a conventional intersection, including crosswalks, tight corner radii, and a signal (if deemed necessary).

Utility Considerations

- Design new curb cuts as to not impede drainage from the street. A curb gutter shall be provided where necessary to continue the flow of street drainage across the driveway.

Sustainability Considerations

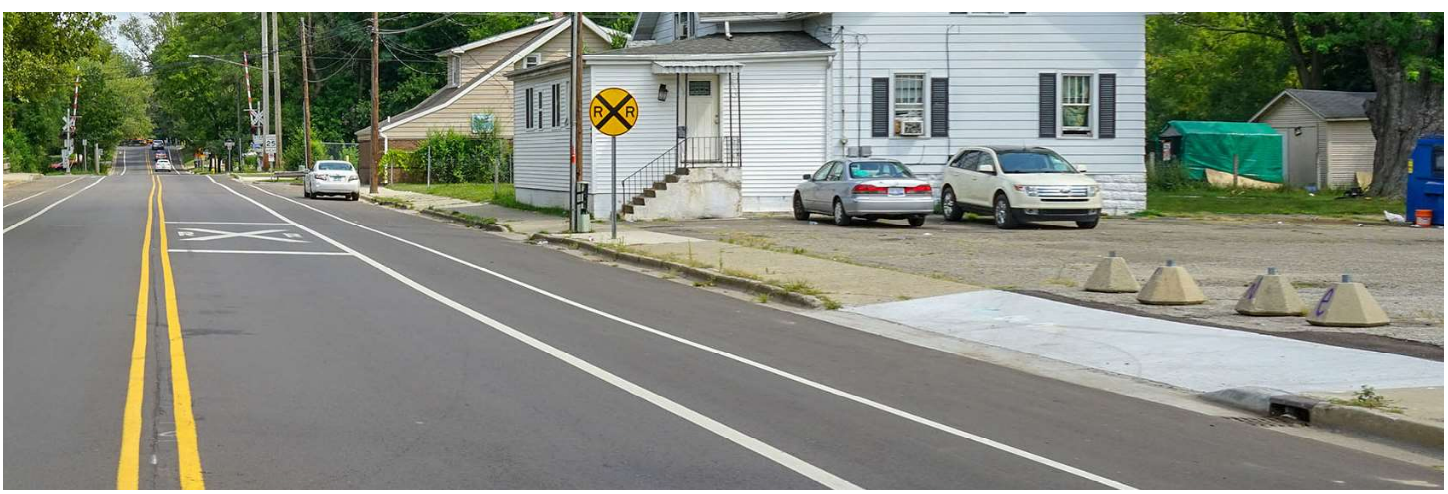
- Consider using pervious materials for driveways, which can reduce stormwater runoff and improve water quality. Double-track driveways are also permitted in areas of low vehicle volume and may reduce imperviousness.

MAINTENANCE & MANAGEMENT

- Driveway aprons with special paving materials may need additional maintenance from property owners.

Seasonal Use and Maintenance

- Snow should be removed from the curb line to the back of sidewalk to provide access for vehicles and sidewalk users. Do not clear snow into bicycle lanes.



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STREET TYPOLOGY								
UC	E/F	MS	NB	CB	CC	NN	EN	LN
Rec.	Opt.	Opt.	Opt.	Rec.	Rec.	Rec.	Opt.	Opt.

ROADWAY ELEMENTS

MEDIANS

DESCRIPTION & INTENT

A median divides lanes of traffic. Medians are generally located in the center of the right-of-way and divide opposing directions of travel. They may also be located on the side, separating local access or special purpose lanes such as dedicated travel ways.

Medians increase safety and enhance roadway operations by reducing vehicular movement conflicts, preventing undesired turning movements, and providing a refuge for pedestrians crossing the street. Medians also help visually break down the scale of the street, narrowing the perceived width of the roadway and thereby encouraging slower travel speeds.

Medians take on many forms. They may be flush with the pavement and consist of painted markings, a space protected with bollards, or a raised curb. Striped or painted medians may precede more permanent improvements, providing localities an opportunity to test travel behaviors before making a significant capital investment. Raised medians within the travel zone provide opportunities for landscaping, street trees, and two-stage pedestrian crossings.

USE & APPLICATION

Location

- Medians are recommended on larger vehicle oriented streets, especially where there is a center turn lane and/or multiple travel lanes in each direction. Breaks in medians should be provided where essential vehicle turns must be accommodated.
- Medians are an access management tool, providing a means to limit superfluous vehicle turns in a corridor to facilitate traffic flow and safety.
- Medians planted with taller trees and vegetation can impede visibility of businesses, and such landscaping may be less suited to these areas. Medians can make commercial support activities (e.g. deliveries) more challenging.

Related Design Elements

- **Traffic Calming:** While medians can slow travel speeds on their own, for the purpose of significant speed management, medians are generally used in conjunction with other traffic calming measures, such as bumpouts, lane narrowing, or vertical speed controls (*see **Traffic Calming***).
- **Pedestrian Crossings:** Medians can provide a pedestrian refuge, but add to the overall width of the crossing. For especially large crossings, wider medians can allow pedestrians to comfortably wait and cross the street in two separate movements (*see **Pedestrian Refuge Islands** and **Mid-block Crossings***).
- **Sidewalks and Bicycle Lanes:** Do not remove or narrow sidewalks or bicycle facilities to provide medians or pedestrian refuges.

DESIGN & OPERATIONS

Design Requirements

A **Median Width:** The width of medians can vary depending on site conditions.

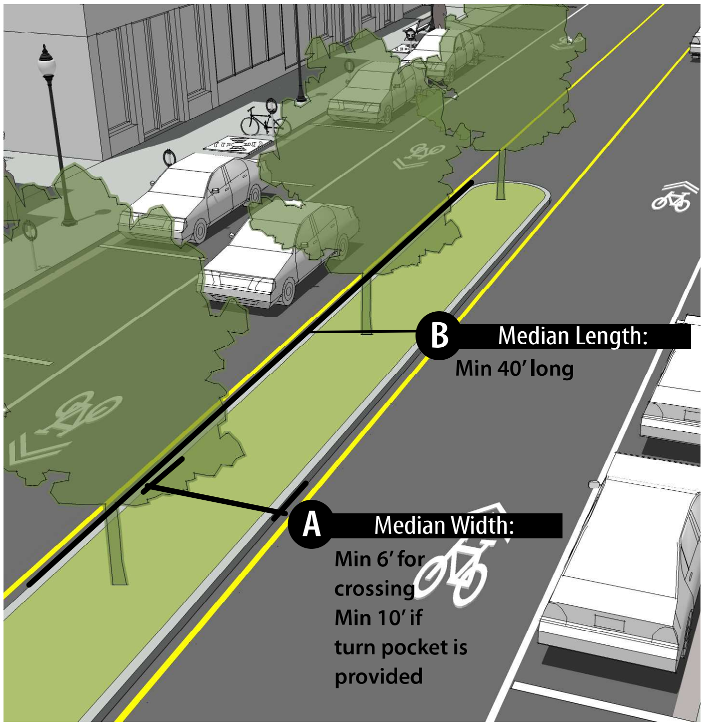
» Narrow medians with a full curb and gutter may be as little as 3-feet wide (two 12-inch gutters and a 12-inch flat surface). Narrower medians can be constructed, but should be at least 2-feet wide for durability and visibility.

» Medians incorporating a pedestrian refuge island should be a minimum of 6-feet wide to provide a level landing area and detectable warning within the median.

» Medians should be at least 10-feet wide if they are to provide turn pockets for vehicle turning.

B **Median Length:** The length of a median is variable. Medians are more impactful the longer and more unbroken they are, and provide more space for landscape or other site features. However, this must be balanced by providing gaps for turning, crossings, stormwater drainage, and meeting other site needs.

- **Intersection Crosswalks:** Crosswalks should cross medians at street level. The width of the crosswalk opening should be 1-foot wider than the crosswalk width on both sides (see ***Pedestrian Refuge Island***).



- **Median End Cap:** Medians should use a rounded end cap to facilitate snow clearing and better maintain the durability of the median. Angled corners are more prone to damage.

- **Planting:** Plants can help drivers identify medians and also help break down the visual scale of the street, which can have a traffic calming effect. However, plantings should be designed to avoid blocking sight lines for pedestrian, cyclists, and motorists near intersections and crossings.

Utility Considerations

- Access points to utilities below medians must be maintained. Provide manholes or hand holes as needed. Avoid planting trees in medians if the trees would end up planted above utility lines.

Sustainability Considerations

- Landscaping medians reduce the impervious surface area in the roadway, allowing stormwater infiltration or retention in the exposed soil. A minimum of 3-feet of width should be provided for planting areas in medians when using perennials and other hardy ground covers.

- Trees planted in medians should have sufficient surface area and soil volume for healthy growth (see ***Street Trees***).

Design References

- The NACTO Urban Street Design Guide (2016) provides further information on the design of medians and pedestrian crossing islands in urban environments.

MAINTENANCE & MANAGEMENT

Seasonal Use and Maintenance

- **Snow Removal:** Medians should be designed with snow removal in mind. Medians can be used for snow storage when necessary, although this may negatively impact planted materials, can block sight lines along the roadway, and can trap pedestrians trying to cross at unmarked locations.

  » Medians should allow adequate width in the adjacent travel lane to accommodate snow removal vehicles, as well as turn radii that facilitates snow clearing and removal.

STREET TYPOLOGY								
UC	E/F	MS	NB	CB	CC	NN	EN	LN
Rec.	Req.	Rec.	Rec.	Lim.	Lim.	Rec.	Rec.	Rec.

VOLUME & SPEED MANAGEMENT

DESCRIPTION & INTENT

Volume and speed management are tools used to improve safety and comfort for all street users by creating a calming street environment.

Speed Management refers to physical design techniques used to reduce the speeds of vehicles on the roadway and encourage vehicles to operate at or below the posted speed limit. These techniques include the following:

» Speed tables and speed humps

» Lane shifts and chicanes

» Traffic circles and mini-roundabouts

» Medians, bumpouts, and lane narrowing

Volume Management refers to techniques used to manage the routing of vehicles. Typically these are used to discourage "cut thru" vehicle trips on quieter streets where lower traffic volumes are desired. Speed management techniques (above) can support volume management, as reduced travel speeds increase travel time and can make such routes relatively less attractive. Additionally, speed management techniques deliberately create navigation obstacles that are less conducive to through trips. Specific volume management techniques include the following:

» Traffic Diverters

This design element section provides general guidance on the use and applicability of specific treatments listed above.

USE & APPLICATION

Location

- Speed management techniques should be explored on all street types in order to ensure that roadway design aligns with the desired travel speed of the road. At a minimum, this includes using the narrowest viable travel lanes (see ***Travel Lanes***), bumpouts, medians, and other treatments to manage road speeds.
- More intense speed management techniques (speed tables/humps, lane shifts, etc.) are important to consider on pedestrian focused streets, such as downtown streets, neighborhood business streets, and quieter residential streets where target design speeds can not be achieved through normal treatments and/or where there known cases of regular, excessive speeding.
- Specific volume management techniques (i.e. traffic diverters) should typically only be used as part of a comprehensive strategy for managing traffic flows in the city, and is often associated with the creation of bicycle boulevards or neighborhood greenways (see ***Bicycle Facility Selection***).

DESIGN GUIDANCE

- FHWA Traffic Calming ePrimer- Module 3: Toolbox of Individual Traffic Calming Measures.
- NACTO Urban Bikeway: Volume Management & Speed Management Sections.

SPEED TABLES

Speed tables are raised areas of the roadway surface, typically the length of a passenger vehicle that passing vehicles must traverse over. Gradual ramps are located on both approaches to the table. The raised area creates a vertical shift in the road, inciting drivers to slow down.

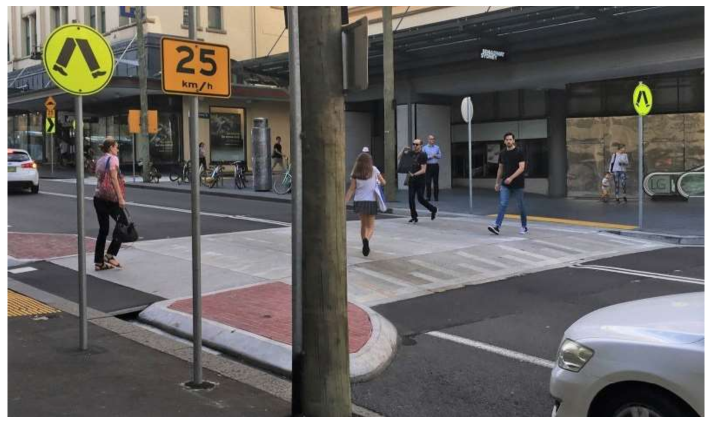
Applicability

- Speed tables should be considered on lower volume roads where there are concerns about speeding traffic and where there are relatively large gaps between stop or signal controlled intersections.
- Speed tables are often built in conjunction with a mid-block crossing, creating a raised crossing. This can be beneficial near schools or other high pedestrian crossing areas.
- Speed tables provide less jarring and abrupt experience compared to speed humps, and can be more suitable than humps in locations where transit service occurs.
- Speed tables cannot be placed in a manner that blocks driveway or alley access.

Design and Operations

- **Height:** Speed tables are typically a minimum of 3 inches high up to the height of the curb.
- **Width:** The flat tabletop surface should be 10- to 20-feet long.
- **Ramps:** The approach ramps should be sloped no more than 1:10 and no less than 1:25.
- **Signage:** Signage must be installed warning drivers of the presence of the speed table.
- **Markings:** Pavement arrow markings may be used on the ramps to increase their visibility and guide the vehicle.
- **Materials:** Speed tables and ramps should be constructed of concrete. Special concrete finishes may be used on the flat tabletop surface. Asphalt may be used as a lower cost substitute and/or for rapid deployment.
- **Utilities:** Understanding roadway drainage and providing additional inlets or other drainage structures around the speed table is essential.

Speed Table (in asphalt) with Mid-block crossing
Source: FHWA / R. Goldberg



Speed Table (concrete) with Mid-block crossing and gutter trench drain
Source: Web

Speed Table with Cushions: *Source: FHWA / Jeff Gulden*

Cushions

Speed tables or speed humps can be designed with “cut outs” that match the track of wider vehicles to allow emergency vehicles and/or transit vehicles to pass through the speed table more easily. .

SPEED HUMPS

Speed humps are a curving raised area of the roadway designed to slow traffic on lower volume and lower speed roadways. Speed humps typically reduce speeds to 15 to 20 MPH and are a lower cost treatment than speed tables.

Applicability

- Speed humps should be considered on lower volume roads where there are concerns about speeding traffic and where there are relatively large gaps between stop or signal controlled intersections.
- Speed humps provide a more pronounced vertical obstacle compared to speed tables, and are less suitable than speed tables for use along transit routes.
- Speed humps cannot be placed in a manner that blocks driveway or alley access.

Design and Operations

- **Height:** The the highpoint (crown) of a speed hump should be 3 to 4 inches above the roadway.
- **Width and Ramps:** The overall dimension of the speed hump should be 12- to 14-feet wide. Curving slopes should be no steeper than 1:10.
- **Signage:** Signage must be installed warning drivers of the presence of the speed hump.
- **Markings:** Pavement arrow markings may be used on the ramps to increase their visibility and guide the vehicle.
- **Materials:** Speed humps are constructed from asphalt.

Speed Hump (in asphalt) *Source: FHWA / Lucy Gibson*

LANE SHIFTS & CHICANES

Lane shifts, also known as chicanes, is a treatment where the travel lanes of the road is deliberately shifted left or right. These shifts incite drivers to slow down as they navigate the transition. Multiple chicanes can be strung together in order to manage the speed of the roadway along the length of the block.

Applicability

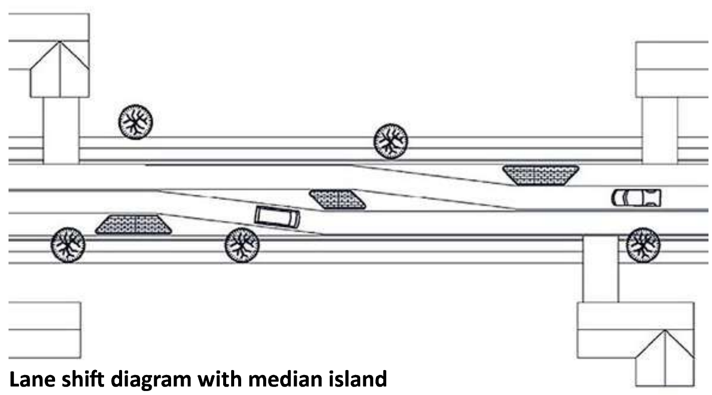
- Chicanes can be used on most street types where speed management is desired. They can be especially beneficial on main streets (in the downtown area) and neighborhood business streets where speed tables or humps could interfere with curbside zones and other vehicle operations.
- Chicanes should be used and designed alongside a comprehensive street design that considers the arrangement of curbside zones (parking, loading, etc.), streetscape, mid-block crossings, and medians.

Design and Operations

- **Shift Length:** The horizontal shift of the travel lane should be at least 4-feet. Shifts less than 4-feet may be less visible or may not produce the desired speed reduction.
- **Deflection Angle and Taper Length:** The angle of the lane shift and taper length approaching the shifted area will depend on the design speed of the roadway. The taper length can be determined using the following formula for roadways under 45 MPH:
  - » ***$L = WS^2 / 60$***. L is the taper length, W is the width of the lane shift, S is the speed (MPH).
  - » For example, the taper length for a 6-foot lane shift designed for 20 MPH equals 40-feet.
  - » Chicanes can be designed with more abrupt angled tapers or curbing/parabolic lines.
- **Median Island:** Offsetting the opposing flows of traffic as their respective lanes shift can allow the creation of smaller medians within the roadway that can further reinforce slower traffic.

Lane shift (angled) *Source: FHWA / Google Street Capture*

Lane shift (curving) *Source: NACTO*



Lane shift diagram with median island
Source: Delaware Department of Transportation

TRAFFIC CIRCLES

Traffic circles are small circular areas of raised paving, curbing, and/or landscape placed at the center of an intersection. Traffic circles manage the speed of vehicles in the intersection by requiring through and left turning traffic to maneuver around them carefully, typically reducing speeds through the intersection to 5 to 15 MPH.

Traffic Circle. *Source: FHWA / Scott Batson*

Applicability

- Traffic circles are typically used at minor intersections on residential and local streets to slow traffic and address speeding concerns.
- Traffic circles can be used at uncontrolled intersections and/or where stop sign controls are present.
- Traffic circles are generally used in locations where reconstruction of intersection corners and approaches is not required, i.e. the traffic circle can be installed with little modification of the existing intersection.
- Treatment is more effective when multiple sequential intersections utilize traffic circles.

Traffic Circle. *Source: FHWA / Dan Burden*

Design and Operations

- Traffic circles should be designed such that the desired distance at each corner radius from the point closest to the intersection center to the edge of the traffic circle is 15-feet.
- Traffic circles should be curbed and raised at least 3 inches above the roadway.
- The surface of the traffic circle can be hardscape (concrete, decorative brick, pavers, etc.) or landscaped. Landscape should not impede visibility through the traffic circle, and should be kept to 36 inches or less in height above the roadway.
- To accommodate larger vehicles, the traffic circle can be reduced in size with a flared mountable collar added around the traffic circle that allow larger vehicles to pass over it.

Traffic Circle. *Source: NACTO*

Mini-Roundabouts

Mini-roundabouts can also be used as a traffic management and speed control device, while allowing for a free-flow of traffic. Mini-roundabouts typically require more substantial intersection design and should only be considered as part of a larger project (see ***Intersections***).

TRAFFIC DIVERTERS

Traffic diverters are treatments used within a roadway or intersection that prevent motor vehicles from traveling in certain directions but allow cyclists and other smaller vehicles to pass through them. Diverters are used to discourage and limit through vehicle movements in order to create a lower traffic and calmer street environment for non-motorized travel.

Applicability

- Diverters should be used as part of a comprehensive neighborhood greenway or bicycle boulevard treatments intended to provide an all ages and abilities accessible route for cyclists. Broader traffic patterns and where diversions will relocate traffic are important to consider.
- Preferred to be used on roadways with less than 1,500 AADT, but may be used on roadways with up to 3,000 AADT if feasibility can be verified through a more extensive analysis effort.
- Understanding local residential needs and obtaining public support for the project from local residents is important for success.

Design and Operations

- Traffic diverters can be utilized in the following way:
    - » Within an intersection to prevent certain movements. Typically diverters are setup up force right turn only operations for vehicles.
    - » Mid-block to prevent through vehicle movement. Typically must provide turn around space for vehicles and appropriate signage at the start of the block indicating no thru-traffic.
    - » At the receiving lane of an intersection to prevent vehicles from traveling down the road in certain directions.
- Openings in the diverters should be 5- to 6-feet wide to provide room for bicycles to pass but prevent motor vehicles.
- Appropriate signage (e.g. DO NOT ENTER- EXCEPT BIKES) should be used to inform drivers of safe operations and allowed turning movements.

T-Intersection Diverter. *Source: NACTO / Richard Drdul*


Intersection Right Only Diverter. *Source: NACTO*

Full Roadway Diverter. *Source: NACTO*


T-Intersection Diverter. *Source: NACTO*

STREET TYPOLOGY								
UC	E/F	MS	NB	CB	CC	NN	EN	LN
Req.	Req.	Req.	Req.	Req.	Req.	Req.	Req.	Req.

ROADWAY ELEMENTS

INTERSECTION STRATEGIES & TRAFFIC SIGNALS

DESCRIPTION & INTENT

Intersections occur wherever two or more roads intersect. Sometimes a driveway with significant vehicle volumes may also be treated as an intersecting road, such as at an entrance to a large shopping area, parking lot, or alley. Intersections come in all sizes and shapes, from simple T-intersections to complex multi-leg intersections and traffic circles.

Intersections are one of the most important components of roadway design. They are where all the modes intersect – pedestrians, bicyclists, transit and vehicles. Add to this turning movements, signals, crosswalks, sight lines considerations, lighting , and accessibility and intersections design quickly becomes a complex problem to solve. Not surprisingly, intersections are also where accidents are most likely to occur, especially for pedestrians and cyclists.

Intersections, and corners in particular, are also where people like to hang out. When William H. Whyte did his groundbreaking studies of public life in New York he found that when he mapped where people stopped to have a conversation of two minutes or more, over 50% of the time it was at the corner. People often like to sit near a corner too, as they can be great places to people watch, be seen, or wait for a friend. Intersections can function as gateways, welcoming people into a section of town, district, or corridor.

USE AND APPLICATIONS

The design and operations of intersections must be considered on all street types and street projects with the City.

At all intersections, it is important to prioritize the most vulnerable users, usually pedestrians and bicyclists, while maintaining a reasonable level of service for vehicles. In urban areas a level of service D or E should generally be acceptable in order to provide design flexibility in meeting the safety needs of all users.

Related Design Elements

- **Crosswalks:** Crosswalks allow pedestrians to traverse intersections, and their design and placement are critical to pedestrian safety. Whenever possible they should be perpendicular to the direction of vehicle travel (see ***Crosswalks***).
- **Pedestrian Refuge Islands:** Pedestrian refuge islands can greatly improve pedestrian safety at intersections but need to be coordinated carefully with left hand turning movements (see ***Refuge Islands***).
- **Bumpouts:** Bumpouts should be used whenever possible at intersections to shorten crossing distances and improve sight lines. They can also prevent parked vehicles and loading from creeping to close to the intersection and blocking crosswalks and sight lines, making them 40’ near side and 30’ far side at a minimum. They do require careful coordination with bus stops, protected bike lanes, and right turn lanes (see ***Bumpouts***).

- **Bicycle Boxes:** Bicycle boxes provide a place for bicyclists to wait at the intersection where they can be in front of traffic, and therefore more visible. They also can help cyclists safely make a left turn. Coordinating bike boxes with signals, crosswalks, stop bars and sight lines is important to ensure safety and visibility (see ***Bicycle Boxes***).
- **Two-stage Turn Queues:** Two-stage turn queues, much like bicycle boxes, can help bicyclists make left turns through intersections, and similarly, need to be coordinated with crosswalks, turning movements and signals. It is important to align these spaces to minimize conflicts with turning movements and use protected intersections where feasible (see ***Two-Stage Turn Queues***).
- **Protected Intersections:** Protected intersections greatly increase safety for pedestrians and cyclists at intersections, but they also require space and careful coordination with bus stops and turn lanes, and clear markings so that all users understand when they are to stop or yield to others (see ***Protected Intersections***).
- **Bus stops & Shelters:** Bus stops and their accompanying shelters, are often located at intersections. The general rule is that intersections function better when bus stops are far side, but this is not always feasible. When near side, they can be combined with right turn lanes. Ensuring the buses have enough clearance to prevent them from blocking crosswalks is also very important. Ideally bus stops are 100 foot in length to ensure buses can pull to the curb and that multiple buses can be accommodated if need be (see ***Bus Stops & Shelters***)
- **Bus Bulbs:** Bus bulbs can speed up boarding and alighting at bus stops which can help with traffic flow through intersections, but they usually mean that the bus will be stopping in the through lane, which can also back up traffic, so location and traffic patterns must be carefully considered. Also it is important that pedestrians can safely access them and that they do not compromise crosswalk sight lines (see ***Bus Bulbs***).
- **Corner Geometry & Design Vehicles:** Many of the elements listed above impact corner geometry and therefore what design vehicle can be accommodated. If large vehicle turning movements need to be accommodated this will need to be carefully coordinated, with a focus on protecting the most vulnerable users, pedestrians and cyclists (see C***orner Geometry and Design Vehicles***).

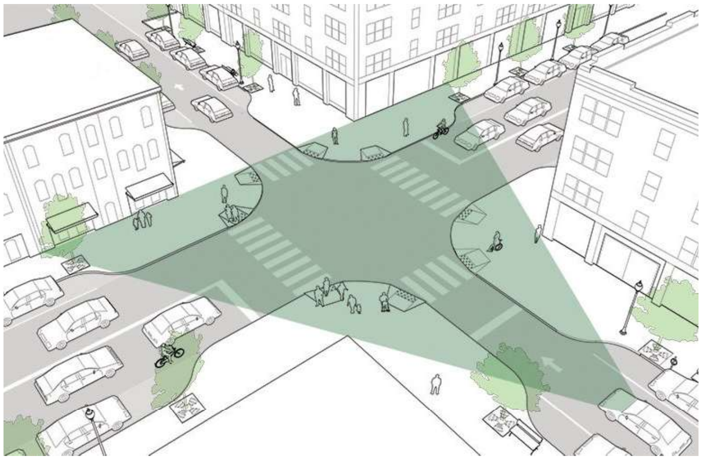
Design Guidance

- NACTO Urban Street Design Guide (2016)
- NACTO Don't Give Up at the Intersection Design Guide (2019)
- Signalized Intersection Informational Guide, Second Edition, Federal Highways Administration

INTERSECTION STRATEGIES

Overall Approaches:

- Be predictable and intuitive.
- Maximize visibility, especially of vulnerable users.
- Promote eye contact between all users.
- Be as compact as possible.
- Use signalization timing to minimize delay and queue lengths, modulate speed, and accommodate different use patterns during different times of the day and days of the week.
- Design intersections to function as part of the overall transportation network.



Sight Lines. *Source: NACTO*

Specific Strategies:

- **Traffic Control Warrants:** All established traffic signal warrants should be considered to determine whether a stop-controlled or signalized intersection is appropriate. Warrants may also be used to justify removal of signals and converting intersections back to stop control.
- **Corners:** Corner radii should be as tight as possible to allow for the design vehicle while safely accommodating pedestrians, reducing vehicle speeds should be prioritized over turning movements
- **Crossing distances** should be minimized and good sight lines should be maximized.
- **Waiting Space:** Corners should have plenty of space to wait and be fully accessible, with well-marked crosswalks.
- **Throat widening:** A widening of the roadway pavement at intersections to accommodate extra lanes (usually turn lanes), should be avoided when possible as this usually increases the pedestrian crossing distance and reduces the width of the sidewalks where it is needed most. However, if throat widening is determined to be beneficial so that mid-block roadway pavement widths can be minimized, reduce their impact with curb extensions that shadow right turn lanes, and/or pedestrian refuge islands where left turns are forbidden or when intersecting a one-way street whenever possible.
- **Intersection Size:** Extra-large intersections should be avoided. If they cannot consider using round abouts and traffic circles, and medians and pedestrian refuge islands. It is critical to ensure pedestrians have at least 3.5'/second to cross the road, and if that is not possible, proper refuge space to create a two-stage crossing should be present.
- **Parking & Driveways**: On-street parking and driveways should be setback from the intersection (30-feet and 100-feet respectively) to not conflict with intersection operations.
- Intersections should be well lit (see ***Street Lighting***)
- **Pork chop** islands and slip lanes should generally be avoided and only allowed in unique circumstances and where they can prioritize safety for vulnerable users.
- **Utilities:** Avoid crowding intersections with poles, signage, signal boxes and controllers.

NO TURN ON RED

Description and Intent

"Right on Red" permit vehicles to complete a right-hand turn even when the signal governing their leg is displaying red.

Right on Red operations are generally used to aid in progressing vehicle traffic, but can create conflicts between turning vehicles and pedestrian movements. Vehicles wishing to turn on red are inclined to "inch forward" over crosswalks, often blocking pedestrians wishing to cross.

Use and Application

- No Right on Red is typically employed at locations with relatively high pedestrian volumes, such as downtown street typologies and neighborhood commercial areas. It is also used when sight lines are poor for cross traffic or intersection geometry is complex, such as with 6 legged intersections.

Design Guidance

- No Turn on Red must be used at locations where turning movements cross separated bikeways and/ or where two-stage turn queue boxes for bicycle are present.
- Right on Red can be temporal, prohibiting right turns only during peak hours of pedestrian activity (for example 7AM to 7PM). Right on Red may be further qualified with signage that indicates "No Right on Red When Pedestrians Present."

SIGNAL TIMING

Traffic signals are an integral part of maintaining safe and efficient roadway operations on public streets. There are a number of specific signalization strategies described below that should be considered wherever signalized intersections are currently operating or proposed.

Signal timing should:

- Be designed to achieve the desired speed, not the existing travel speeds.
- Be adjusted for different times of the day and days of the week.
- Minimize signal phases
- Shorten signal cycle lengths to increase turnover balanced with providing ample signal time for pedestrians and bicyclists to safely navigate the intersection.
- Transit priority should be considered when transit is present.
- Provide fixed timing verses activated signals

Related Design Elements

- **Pedestrian Signals:** Pedestrian signalization and associated strategies must be considered alongside traffic signals. Leading Pedestrian Intervals (LPIs), recall, and other treatments must integrate with the overall signalization.
- **Bicycle Signals:** Bicycle signalization must be considered alongside traffic signals, and coordinated with left and right turn signalization similar to pedestrian signals.

Design Guidance

- The MMUTCD is the definitive guide for all signal operations and design.

LAGGING VS. LEADING LEFTS

Description and Intent

Designated signal phases for left turns are common in many locations. Left turns may be accommodated through an exclusive signal phase, where only opposing left turns are permitted, or as an early or elongated period for the through green time for one approach of the intersection. These left turns are known as "leading lefts" if they occur at the beginning of the through vehicle phase or "lagging lefts" if they occur at the end of the phase.

Leading lefts tend to be less intuitive to pedestrians accustomed to being given a walk phase at the conclusion of the red phase for opposing traffic. Pedestrians may jump the signal and find themselves in direct conflicts with left turning vehicles. Pedestrian/vehicle conflict have been found to be almost six times higher with leading lefts as compared to lagging left signal operations.

Use and Application

- Lagging lefts are preferred (over leading-lefts) and should be used as the default signal phasing, as they prioritize for pedestrian progression, allowing waiting pedestrians to clear the intersection before left turning vehicles make their turns.
- Leading or lagging lefts allow time for turning vehicles to clear the intersection with less conflicts. They should be used in locations that have a high volume of pedestrians or through traffic that inhibit the completion of the left turn.

Design and Operations

- Intersections with leading left phases should provide more generous sidewalk space to accommodate pedestrian queuing. Pedestrians are generally at their greatest concentration at the beginning of any signal cycle. Lagging lefts permit the majority of pedestrians to clear the intersection before left turns proceed.
- Leading Pedestrian Intervals (LPI) may not be used in conjunction with leading left signal operations, but may be combined with lagging left signals.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