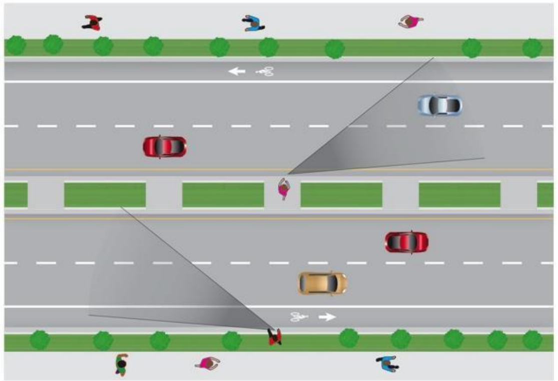


Medians and crossing islands allow pedestrians to complete the crossing in two stages.
(Credit: Michele Weisbart)

On streets with traffic speeds higher than 30 mph, it may be unsafe to cross without a median island. At 30 mph, motorists travel 44 feet each second, placing them 880 feet out when a pedestrian starts crossing an 80-foot wide multi-lane road.

In this situation, this pedestrian may still be in the last travel lane when the car arrives there; that car was not within view at the time he or she started crossing. With an island on multi-lane roadways, people would cross two or three lanes at a time instead of four or six. Having to wait for a gap in only one direction of travel at a time significantly reduces the wait time to cross. Medians and crossing islands have been shown to reduce crashes by 40 percent (Federal Highway Administration, Designing for Pedestrian Safety course).

As a general rule, crossing islands are preferable to signal-controlled crossings due to their lower installation and maintenance cost, reduced waiting times, and their safety benefits.

Curb Extensions

Curb extensions extend the sidewalk or curb line out into the parking lane, which reduces the effective street width. Curb extensions significantly improve pedestrian crossings by reducing the pedestrian crossing distance, visually and physically narrowing the roadway, improving the

Curb extensions
(Credit: Michele Weisbart)

ability of pedestrians and motorists to see each other, and reducing the time that pedestrians are in the street. Reducing street widths improves signal timing since pedestrians need less time to cross.

Motorists typically travel more slowly at intersections or mid-block locations with curb extensions, as the restricted street width sends a visual cue to slow down. Turning speeds are lower at intersections with curb extensions (curb radii should be as tight as is practicable). Curb extensions also prevent motorists from parking too close to the intersection.

Example of curb extensions
(Credit: Marcel Schmaedick)

Curb extensions also provide additional space for two curb ramps and for level sidewalks where existing space is limited, increase the pedestrian waiting space, and provide additional space for pedestrian push button poles, street furnishings, plantings, bike parking and other amenities. A benefit for drivers is that extensions allow for better placement of signs (e.g., stop signs and signals).

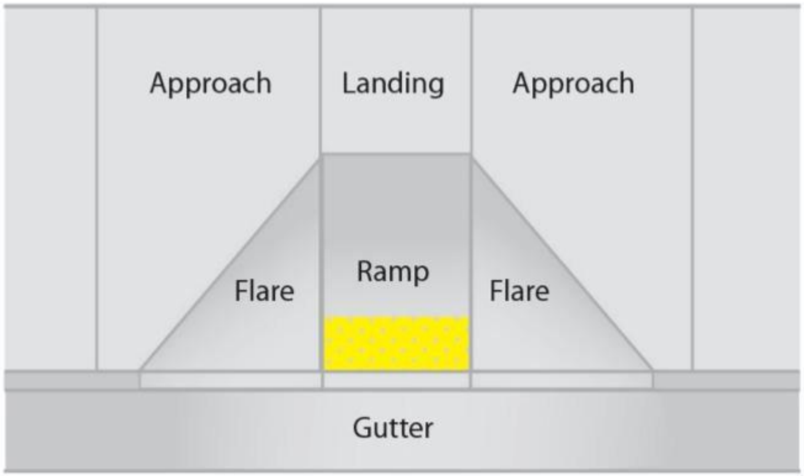
Curb extensions are generally only appropriate where there is an on-street parking lane. Where street width permits, a gently tapered curb extension can reduce crossing distance at an intersection along streets without on-street parking, without creating a hazard. Curb extensions must not extend into travel lanes or bicycle lanes.

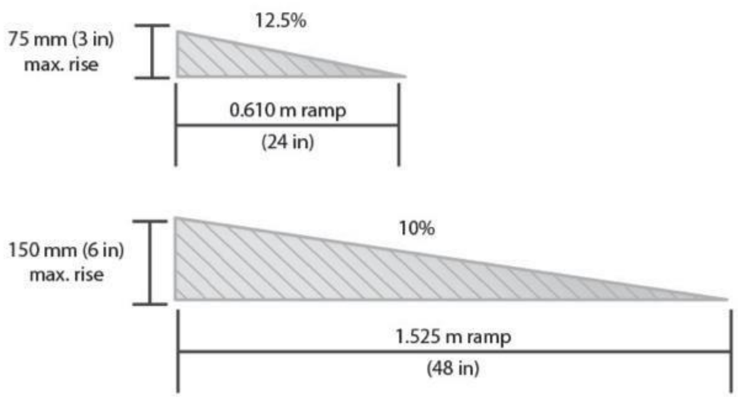
Curb extensions can impact other aspects of roadway design and operation as follows:

- May impact street drainage and require catch basin relocation
- May impact underground utilities
- May require loss of curbside parking, though careful planning often mitigates this potential loss, for example by relocating curbside fire hydrants, where no parking is allowed, to a curb extension
- May complicate delivery access and garbage removal
- May affect the turning movements of larger vehicles such as school buses and large fire trucks

Curb Ramps

Proper curb ramp design is essential to enable pedestrians using assistive mobility devices (e.g., scooters, walkers, and crutches) to transition between the street and the sidewalk. These design guidelines provide a basic overview of curb ramp design. The ADA requires installation of curb ramps in new sidewalks and whenever an alteration is made to an existing sidewalk or street. Curb ramps are typically installed at intersections, mid-block crossings (including trail connections), accessible on-street parking, and passenger loading zones and bus stops.





Curb ramp components, and alternate ramp slopes (Credit: Michele Weisbart).

The following define the curb ramp components along with minimum dimensions:

- **Landing** – the level area at the top of a curb ramp facing the ramp path. Landings allow wheelchairs to enter and exit a curb ramp, as well as travel along the sidewalk without tipping or tilting. This landing must be the width of the ramp and measure at least 4 feet by 4 feet. There should also be a level (not exceeding a 2 percent grade) 4 foot by 4 foot bottom landing of clear space outside of vehicle travel lanes.
- **Approach** – the portion of the sidewalk on either side of the landing. Approaches provide space for wheelchairs to prepare to enter landings.
- **Flare** – the transition between the curb and sidewalk. Flares provide a sloped transition (10 percent maximum slope) between the sidewalk and curb ramp to help prevent pedestrians from tripping over an abrupt change in level. Flares can be replaced with curb where the furniture zone is landscaped.
- **Ramp** – the sloped transition between the sidewalk and street where the grade is constant and cross slope at a minimum. Curb ramps are the main pathway between the sidewalk and street.
- **Gutter** – the trough that runs between the curb or curb ramp and the street. The slope parallel to the curb should not exceed 2 percent at the curb ramp.
- **Detectable Warning** – surface with distinct raised areas to alert pedestrians with visual impairments of the sidewalk-to-street transition.

There are several different types of curb ramps. Selection should be based on local conditions. The most common types are diagonal, perpendicular, parallel, and blended transition.

Diagonal Curb Ramps

Diagonal curb ramps are single curb ramps at the apex of the corner. These have been commonly installed by many jurisdictions to address the requirements of the ADA, but have since been identified as a non-preferred design type as they introduce dangers to wheelchair users. Diagonal curb ramps send wheelchair users and people with strollers or carts toward the middle of the intersection and make the trip across longer.

Perpendicular Curb Ramps

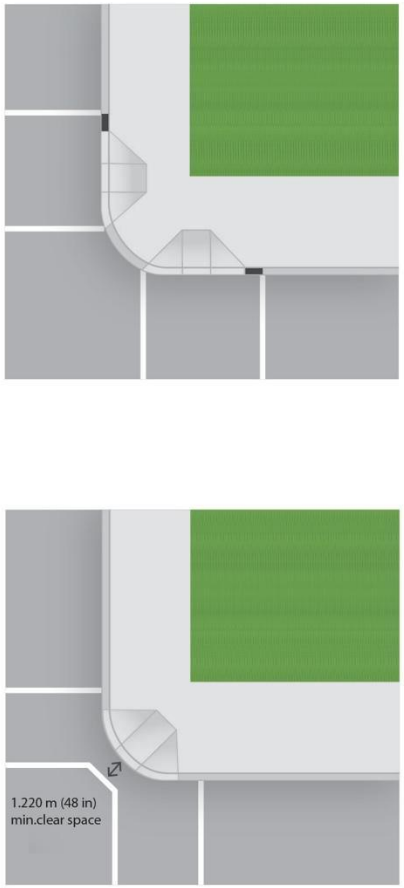
Perpendicular curb ramps are placed at a 90-degree angle to the curb. They must include a level landing at the top to allow wheelchair users to turn 90 degrees to access the ramp, or to bypass the ramp if they are proceeding straight. Perpendicular ramps work best where there is a wide sidewalk, curb extension, or planter strip. Perpendicular curb ramps provide a direct, short trip across the intersection.

Parallel Curb Ramps

Parallel curb ramps are oriented parallel to the street; the sidewalk itself ramps down. They are used on narrow sidewalks where there isn't enough room to install perpendicular ramps. Parallel curb ramps require pedestrians who are continuing along the sidewalk to ramp down and up. Where space exists in a planting strip, parallel curb ramps can be designed in combination with perpendicular ramps to reduce the ramping for through pedestrians. Careful attention must be paid to the construction of the bottom landing to limit accumulation of water and/or debris.

Curb Ramp Placement

One ramp should be provided for each crosswalk, which usually translates to 2 per corner. This maximizes access by placing ramps in line with the sidewalk and crosswalk, and by reducing the distance required to cross the street, compared with a single ramp on the apex.



One ramp per crosswalk vs. single ramp at the apex (Credit: Michele Weisbart)

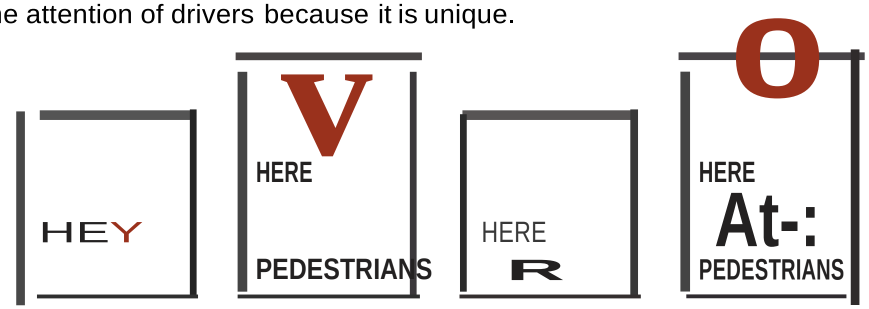
A single ramp at the apex requires users to take a longer, more circuitous travel path to the other side and causes users to travel towards the center of the intersection where they may be in danger of getting hit by turning cars; being in the intersection longer exposes the user to greater risk of being hit by vehicles. A single ramp at the apex should be avoided in new construction and may be used only for alterations where a design exception is granted because of existing utilities and other significant barriers. In all cases, reducing the curb radius makes ramp placement easier.

Signs

Signs can provide important information to improve road safety by letting people know what to expect, so they can react and behave appropriately. Sign use and placement should be done judiciously, as overuse breeds noncompliance and disrespect. Too many signs create visual clutter.

Regulatory signs, such as STOP, YIELD, orturn restrictions, require driver actions and can be enforced. Warning signs provide information, especially to motorists and pedestrians unfamiliar with an area.

Advance pedestrian warning signs should be used where motorists may not expect pedestrian crossings, especially if there are many motorists who are unfamiliar with the area. The fluorescent yellow/green color is designated specifically for pedestrian, bicycle, and school warning signs (Section 2A.10 of the 2009 MUTCD) and should be used for all new and replacement installations. This bright color attracts the attention of drivers because it is unique.



RI·S RI·Sa RI·Sb R1·

Sign RI-5 should be used in conjunction with advance yield lines, as described below. Sign RI-6 may be used on median islands, where they will be more visible to motorists than signs placed on the side of the street, especially where there is on-street parking.

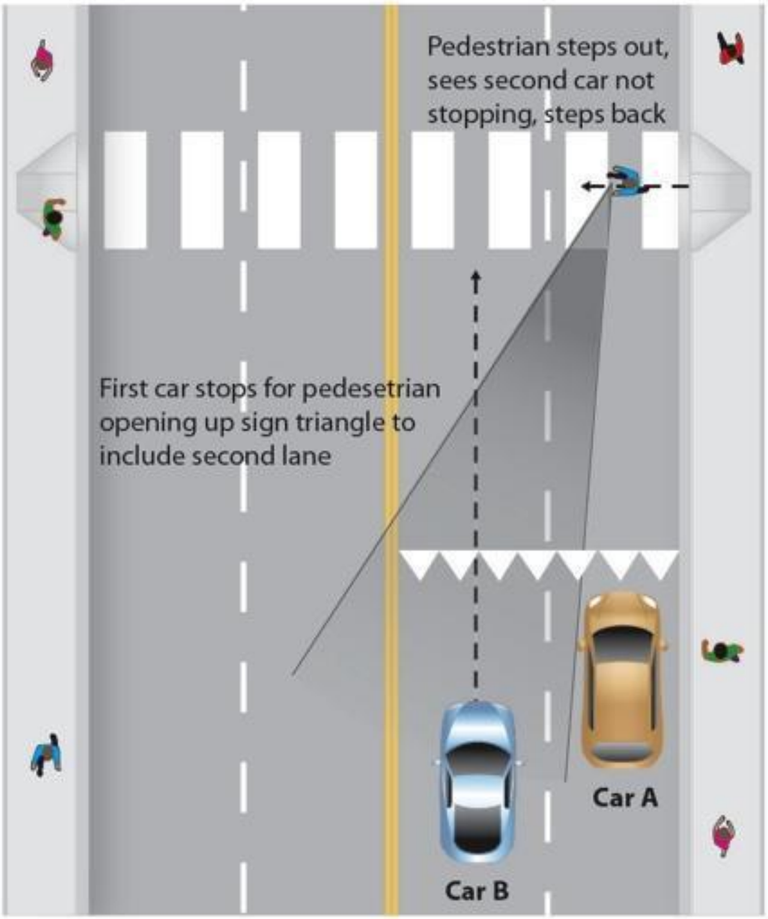
All signs should be periodically checked to make sure that they are in good condition, free from graffiti, reflective at night, and continue to serve a purpose.

All sign installations need to comply with the provisions ofthe MUTCD.

Advanced Yield/Stop Lines

Stop lines are solid white lines 12 to 24 inches wide, extending across all approach lanes to indicate where vehicles must stop in compliance with a stop sign or signal. Advance stop lines reduce vehicle encroachment into the crosswalk and improve drivers' view of pedestrians. At signalized intersections, a stop line is typically set back between 4 and 6 feet.

At uncontrolled crossings of multi-lane roads, advance yield lines can be an effective tool for preventing multiple threat vehicle and pedestrian collisions. Section 38.16 of the MUTCD specifies placing advanced yield markings 20 to 50 feet in advance of crosswalks, depending upon location-specific variables such as vehicle speeds, traffic control, street width, on-street parking, potential for visual confusion, nearby land uses with vulnerable populations, and demand for queuing space. Thirty feet is the preferred setback for effectiveness at many locations. This setback allows a pedestrian to see if a car in the second (or third) lane is stopping after a driver in the first lane has stopped.



Bicycle Facilities

ESSENTIAL PRINCIPLES OF BIKEWAY DESIGN

The following principles should be followed when designing facilities for bicyclists:

- Bicyclists should have safe, convenient, and comfortable access to all destinations.
- Every street is a bicycle street, regardless of bikeway designation.
- Street design should accommodate all types, levels, and ages of bicyclists.
- Bicyclists should be separated from pedestrians.
- Bikeway facilities should take into account vehicle speeds and volumes, with
  - Shared use on low volume, low-speed roads.
  - Separation on higher volume, higher-speed roads.
- Bikeway treatments should provide clear guidance to enhance safety for all users.
- Since most bicycle trips are short, a complete network of designated bikeways has a grid of roughly ½ mile.

Bicycle Lanes

Bike lanes are a portion of the traveled way designated for preferential use by bicyclists; they are most suitable on avenues and boulevards. Bike lanes may also be provided on rural roads where there is high bicycle use. Bike lanes are generally not recommended on local streets with relatively low traffic volumes and speeds, where a shared roadway is the appropriate facility. There are no hard and fast mandates for providing bike lanes, but as a general rule, most jurisdictions consider bike lanes on roads with traffic volumes in excess of 3,000-5,000 ADT or traffic speeds of 30 mph or greater.

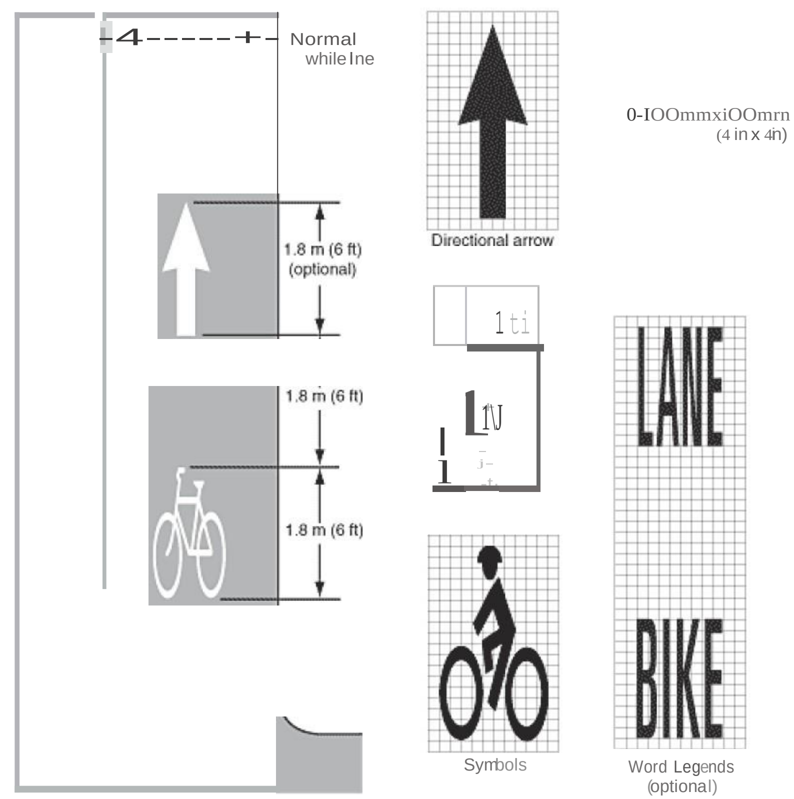
Bike lanes have the following advantages:

- They enable cyclists to ride at a constant speed, especially when traffic in the adjacent travel lanes speeds up or slows down (stop- and-go).
- They enable bicyclists to position themselves where they will be visible to motorists.
- They encourage cyclists to ride on the traveled way rather than the sidewalk.

Bike lanes are created with a solid stripe and stencils. Motorists are prohibited from using bike lanes for driving and parking, but may use them for emergency avoidance maneuvers or breakdowns. Bike lanes are one-way facilities that carry bicycle traffic in the same direction as adjacent motor-vehicle traffic. Bike lanes should always be provided on both sides of a two-way street. One exception is on hills where topographical constraints limit the width to a bike lane on one side only; the bike lane should be provided in the uphill direction as cyclists ride slower uphill, and they can ride in a shared lane in the downhill direction.

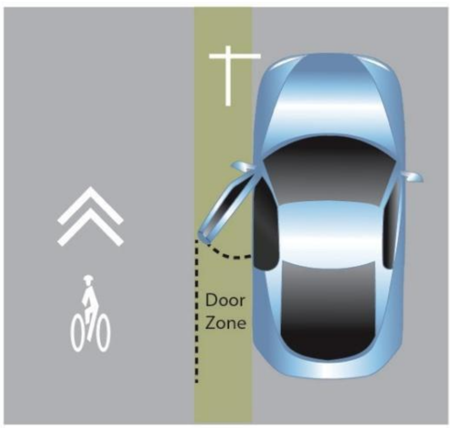
The minimum bike lane width is 5 feet from the face of a curb, or 4 feet on open shoulders. If on-street parking is permitted, the bike lane should be placed between parking and the travel lane with a preferred width of 6 feet so cyclists can ride outside the door zone. Streets with high volumes of traffic and/or higher speeds need wider bike lanes (6 feet to 8 feet) than those with less traffic or slow speeds. On curbed sections, a 4-foot (minimum 3 feet) wide smooth surface should be provided between the gutter pan and stripe. This minimum width enables cyclists to ride far enough from the curb to avoid debris and drainage grates and far enough from other vehicles to avoid conflicts. By riding away from the curb, cyclists are more visible to motorists than when hugging the curb. Where on-street parking is permitted, delineating the bike lane with two stripes, one on the street side and one on the parking side, is preferable to a single stripe.

Figure 9C-6. Example of Optional Word and Symbol Pavement Markings for Bicycle Lanes



Shared Lanes (sharrow)

Shared-lane marking stencils ("SLMs," also commonly called "sharrows") may be used as an additional treatment for shared roadways. The stencils can serve a number of purposes: they remind bicyclists to ride further from parked cars to prevent "dooring" collisions, they make motorists aware of bicycles potentially in the travel lane, and they show bicyclists the correct direction of travel. Sharrows installed next to parallel parking should be a minimum distance of 11 feet from the curb. Installing farther than 11 feet from the curb may be desired in areas with wider parking lanes or in situations where the sharrow is best situated in the center of the shared travel lane to promote cyclists taking the lane. Placing the sharrow between vehicle tire tracks increases the life of the markings and decreases long-term maintenance costs.



Sharrow
(Credit: Michele Weisbart)

Example of a sharrow: (Credit: Ryan Snyder)

Bicycle Parking

Secure bicycle parking at likely destinations is an integral part of a bikeway network. Bicycle thefts are common and lack of secure parking is often cited as a reason people hesitate to ride a bicycle. The same consideration should be given to bicyclists as to motorists, who expect convenient and secure parking at all destinations. Bicycle parking should be located in well-lit, secure locations close to the main entrance of a building, no further from the entrance than the closest automobile parking space. Bike parking should not interfere with pedestrian movement.

Bike racks along sidewalks should support the bicycle well, and make it easy to lock a U-shaped lock to the frame of the bike and the rack. The sample below shows an "inverted –U" rack.

Inverted U Bike Rack (Credit: Sky Yim)

Maintenance

Maintenance is a critical part of safe and comfortable bicycle access. Two areas that are of particular importance to bicyclists are pavement quality and drainage grates. Rough surfaces, potholes, and imperfections, such as joints, can cause a rider to lose control and fall. Care must be taken to ensure that drainage grates are bicycle-safe; otherwise a bicycle wheel may fall into the slots of the grate, causing the cyclist to fall. The grate and inlet box must be flush with the adjacent surface. Inlets should be raised after a pavement overlay to the new surface. If this is not possible or practical, the new pavement should taper into drainage inlets so the inlet edge is not abrupt.

The most effective way to avoid drainage-grate problems is to eliminate them entirely with the use of inlets in the curb face. This may require more grates to handle bypass flow, but is the most bicycle-friendly design.

Greenways/Multi-Use Path

Width and Clearance

Ten feet is the recommended minimum width for a two-way, shared use path on a separate right- of-way. Other critical measurements include:

- 8 feet (2.4m) may be used where bicycle traffic is expected to be low at all times, pedestrian use is only occasional, sightlines are good, passing opportunities are provided, and maintenance vehicles will not destroy the edge of the trail.
- 12 feet is recommended where substantial use by bicycles, joggers, skaters, and pedestrians is expected, and where grades are steep (see later).
- 2 feet of graded area should be maintained adjacent to both sides of the path.
- 3 feet of clear distance should be maintained between the edge of the trail and trees, poles, walls, fences, guardrails or other lateral obstructions.
- 8 feet of vertical clearance to obstructions should be maintained; rising to 10 feet in tunnels and where maintenance and emergency vehicles must operate.

Design Speed, Horizontal and Vertical Alignment

The design of a shared use path should take into account the likely speed of users, the ability of bicyclists to turn corners without falling over, skidding, or hitting their pedal on the ground as they lean over. The AASHTO Guide for the Design of Bicycle Facilities has a number of tables, and equations to help designers meet the tolerances of a bicyclist based on the following key numbers:

- 20 miles per hour (30 km/h) is the minimum design speed to use in designing a trail
- 30 miles per hour (50 km/h) should be used where downgrades exceed 4 percent
- 15 miles per hour (25 km/h) should be used on unpaved paths where bicyclists tend to ride more slowly (and cannot stop as fast without skidding or sliding on a loose surface)

The result is a series of recommended desirable minimum curve radii for corners that should be safe for bicyclists.

Grade

Another critical factor in trail design is the grade or slope of the path. Generally, grades greater than 5 percent (one feet of climbing for every 20 feet traveled forward) are undesirable as they are hard for bicyclists to climb and may cause riders to travel downhill at a speed where they cannot control their bicycle. However, recognizing that trails cannot always remain quite flat, the AASHTO Guide offers the following suggested lengths for certain grades:

- 5-6 percent is acceptable for up to 800 feet (240m)
- 7 percent is acceptable for up to 400 feet (120 m)
- 8 percent is acceptable for up to 300 feet (90m)
- 9 percent is acceptable for up to 200 feet (60m)
- 10 percent is acceptable for up to 100 feet (90m)
- 11 percent plus is acceptable for up to 50 feet (15m)

However, slopes with 9 percent grade are not acceptable for inexperienced bicyclists and are not compliant with Americans with Disabilities Act (ADA) guidelines. Consider the ADA grade guidelines as a guide to better meet the needs of pedestrians or bicyclists with disabilities and inexperienced bicyclists.

And, suggestions are offered for ways to mitigate the impact of steeper slopes, such as:

- adding 4-6 feet of additional width to the trail to allow sufficient space for a cyclist to dismount and walk their bicycle without blocking the trail, or to allow cyclists to pass each other,
- alerting cyclists to the approaching grade with appropriate signs and markings posting a recommended descent speed
- exceeding the usual minimum stopping sight distances to allow for the higher speeds
- exceeding the usual minimum thresholds for providing recovery areas, railings etc
- using a series of short switchbacks to contain the speed of descending riders

Sight Distances

The ability of a cyclist to stop or slow down to avoid a collision or crash is affected by many things. The rider must have time to identify a potential problem and react accordingly, which means that they must be able to see approaching intersections or corners in plenty of time even when they are traveling at the design speed of the trail. The bicycle itself must be able to be stopped or brought under control in time, which is affected by the braking ability of the bike, the surface material (a loose surface requires greater stopping distance), and the weather (wet conditions require greater stopping distances than dry). Once again, the AASHTO Guide and state/local manuals have tables and charts to enable the designer to calculate the appropriate sight distances in a range of situations.

Drainage

In response to a message about trail maintenance posted recently to an e-mail listserv, one trail manager identified the three most important issues: drainage, drainage and drainage. Poor drainage can ruin a good trail.

The AASHTO Guide recommends a minimum cross slope of 1 percent and the need to make trails accessible to people using wheelchairs demands a maximum cross slope of 2 percent. Other considerations to ensure adequate drainage include:

- slope the trail in one direction rather than having a crown in the middle of the trail
- ensure a smooth surface to prevent ponding and ice formation
- place a ditch on the upside of a trail constructed on the side of a hill (where needed)
- place drainage grates, utility covers etc out of the travel path of bicyclists, unless they can be made fully bicycle-friendly.
- preserve natural ground cover adjacent to the trail to inhibit erosion

Surface

Another important consideration in trail design is the type of surface that will be provided. A hard surface, such as cement or asphalt, will generally see cyclists operating at a faster speed than a soft surface, but may not be as popular with joggers and is more expensive to install. A soft surface trail (i.e. crushed granite) will discourage or prevent in-line skating but may be less expensive to install (although it will require more maintenance than concrete). Factors such as weather conditions and soil types can affect the choice of asphalt, concrete, or crushed rock. Choices in surface will affect requirements for periodic monitoring of the path surface and appropriate levels of maintenance.

Structures

One of the great advantages and unique features of trails along former railroad corridors is that they often have grade separated intersections with the highway system, and have bridges to carry them over rivers or stream valleys. However, not all corridors have this asset and structures of all kinds are needed to carry trail users under or over obstacles such as highways, rivers, freeways etc. The critical dimensions to use in designing underpasses, overpasses, bridges and tunnels, include:

a. the minimum width of the trail (usually 10 feet) should be maintained through the structure

b. the clear distance of two feet on either side of the trail surface should also be maintained through the structure — otherwise, riders will tend to ride in the center of the trail to stay away from the wall or railing of the structure

c. an overhead clearance of 10 feet (8 feet with good horizontal and vertical clearance, good sightlines etc) should be maintained through an underpass or tunnel

d. railings, fences, or barriers on both sides of a path on a structure should be at least 42 inches (1.1m) high, and where they are higher than this a rub rail should be provided at the approximate handlebar height of 42 inches.

e. clearances should allow for maintenance and emergency vehicles, as should the strength of the bridge (live loading)

Under-crossings are generally less expensive than overpasses and require less change in grade as a clearance height of only 10 feet is required. However, they may present security problems due to reduced visibility and drainage problems, both of which can be expensive to fix.

Over-crossings are more open and present fewer security problems but they require much longer approaches to achieve the minimum 17 feet of clearance from a roadway, and they are often more expensive. Overpasses also may result in complaints from nearby residences due to a loss of privacy or due to aesthetic concerns.

Another issue is when retrofitting a shared use path onto an existing highway bridge, should a separate path on one side, both sides, or an on-street facility be recommended?

The Florida DOT's Bicycle Facilities Planning and Design Handbook discusses the various options and recommends that:

- the shared use path should be carried across the bridge on one side where:
    - the bridge facility connects to a shared use path at both ends
    - sufficient width exists on one side of the bridge, or can be obtained by widening or restriping lanes
- provisions are made to physically separate bicycle and pedestrian traffic from motor vehicle traffic on-street facilities such as bike lanes may be advisable where:
    - the shared use path transitions into bicycle lanes at one end of the bridge
    - sufficient width exists or can be obtained by widening or restriping.

The AASHTO Guide also warns that this latter option must only be used if the transition from bike lanes to shared use path can be achieved without increasing the potential for wrong way riding or inappropriate crossing movements.

Lighting

Shared use paths in urban and suburban areas often serve travel needs both day and night, for example, commuter routes and trails accessing college campuses. Fixed source lighting improves visibility along trails and at intersections, and is critical for lighting tunnels and underpasses. The AASHTO guide recommends using average maintained illumination levels of between 5 and 22 lux.

Preventing Motor Vehicle Use of Paths

In some locations, shared use paths may be mistaken for motor vehicle roads or may suffer from illegal or unauthorized motorized use. At intersections with roadways, therefore, the path should be clearly signed, marked and/or designed to discourage or prevent unauthorized motorized access. A variety of alternatives exist to achieve this:

a. Bollards. Probably the most common device is the bollard, often lockable, collapsible or removable to allow for authorized access to the trail. Great care should be used in locating the bollard to ensure that they are visible, allow trail users through, and are not placed so as to channel both directions of trail users towards the same point in the trail. If bollards are to be used, they should be retro-reflective, brightly colored, and have pavement markings around them. On a ten foot trail, one bollard should be used in the center of the trail. If more than one bollard is necessary, there should be five feet between them.

b. Splitting the trail in two. Many manuals suggest the option of splitting a ten foot trail into two five foot approaches to an intersection, with a planted triangle between them. This may increase maintenance costs.

c. Medians. The Florida DOT manual notes that "curbing with tight radii leading up to the roadway can often prevent motorists from attempting to enter the path. Medians should be set back from the intersection 25 feet (8m) to allow bicyclists to exit the roadway fully before navigating the reduced pathway width."

Signing and marking

While fewer signs may be needed on paths compared to on-street facilities, adequate signing and marking are essential on shared use paths, just as they are on streets and highways. Trail users need to know about potential conflicts, regulatory information, destinations, cross streets etc. The Manual on Uniform Traffic Control Devices (MUTCD) provides some minimum traffic control measures that should be applied and a range of options.

Striping: a yellow center line stripe is recommended where trails are busy, where sight distances are restricted, and on some unlit trails where night time riding is expected. The line should be dashed when adequate passing sight distance exists, and solid when no passing is recommended.

A solid white line may be used to separate pedestrians from bicycle/blading traffic, and solid white edge stripes may also be useful where nighttime riding is expected.

Warning signs: a range of warning signs can be used to inform users that recommended design criteria cannot be met, for example curve radii or grades or where unexpected conditions may exist.

Informational signs: trail users need to know where they are, where they are going, what cross streets they are crossing, how far destinations are away, and what services are available close to the trail. The MUTCD has information on the appropriate signs to use in these instances. Although not in the MUTCD, many trails post signs encouraging uniform trail user etiquette (e.g. "give audible signal when passing" or which type of trail user has the right-of-way).

Intersection markings and signs: pavement marking and signs at intersections should channel users to cross at clearly defined locations and indicate that crossing traffic is to be expected. Similar devices to those used on roadways (STOP and YIELD signs, stop bars, etc) should be used on trails as appropriate.

The AASHTO Guide notes that in addition to traditional warning signs in advance of intersections, motorists can be alerted to the presence of a trail crossing through flashing warning lights, zebra-style or colored pavement crosswalks, raised crosswalks, signals, and neck-downs/curb-bulbs. However, some devices such as flashing warning lights are expensive to install and maintain and should be kept to a minimum.

Streetscape

Urban Forestry

The urban forest includes all trees, shrubs, and other understory plantings on both public and private lands. Street trees and landscaping are essential parts of the urban forest, as they contribute positively to the urban environment—to climate control, stormwater collection, and the comfort and safety of people who live or travel along the street. A street lined with trees and other plantings looks and feels narrower and more enclosed, which encourages drivers to slow down and to pay more attention to their surroundings. Trees provide a physical and a psychological barrier between pedestrians and motorized traffic, increasing safety as well as making walking more enjoyable.

A healthy urban forest is also a powerful stormwater management tool. Leaves and branches catch and slow rain as it falls, helping it to soak into the ground. The plants themselves take up and store large quantities of water that would otherwise contribute to surface runoff. Part of this moisture is then returned to the air through evaporation to further cool the town.

As an important element along sidewalks, street trees must be provided with conditions that allow them to thrive, including adequate uncompacted soil, water, and air. This section provides guidance for appropriate conditions and selecting, planting, and caring for street trees, as well as for other landscaping along streets.

Street Trees

Goals and Benefits of Street Trees

The goal of adding street trees is to increase the canopy cover of the street, the percentage of its surface either covered by or shaded by vegetation, not simply to increase the overall number of trees. The selection, placement, and management of all elements in the street should enhance the longevity of a town's street trees and healthy, mature plantings should be retained and protected whenever possible.

Principles for Street Trees

The following principles influence the selection of street trees and landscaping design:

- **Seek out and reclaim space for trees**. Streets have a surprising number of residual or left-over spaces between areas required for travel lanes and parking, once they are examined from this perspective. Traffic circles, medians, channelization islands, and curb extensions can provide space for trees and landscaping.

- **Create optimum conditions for growth.** Space for roots and above ground growth is the main constraint to the urban forest achieving its highest potential. Typically a 6 to 8-foot wide, continuous sidewalk furniture zone must be provided, with uncompacted soil to a minimum of a 3-foot depth. If space for trees is constrained, provisions should be made to connect these smaller areas below the surface to form larger effective areas for the movement of air, root systems, and water through the soil.

- **Select the right tree for the space**. In choosing a street tree, consider what canopy, form, and height will maximize benefits over the course of its life. Provide necessary clearances below overhead high-intensity electrical transmission lines and prevent limbs from overhanging potentially sensitive structures such as flat roofs. In commercial areas where the visibility of façade-mounted signs is a concern, choose species whose mature canopy allows for visibility, with the lowest branches at a height of 12 to 14 feet or more above the ground. Select trees with non-aggressive root systems to avoid damaging paving and sidewalks.

- **Start with good nursery stock and train it well.** When installing plant material, choose plants that have complete single leaders and are in good "form," and check that boxed trees are not root bound. Proper watering and pruning every three to four years will allow trees to mature and thrive for many years of service.
- **Do not subject plants to concentrated levels of pollutants.** Trees and other plants should be integrated within stormwater management practices whenever possible, but filtering of pollutants from "first flush" rain falls and street runoff will extend the life of trees and prevent toxic buildup of street pollutants in tree wells.

Guidelines

Climate and Soil

Selecting trees that are adapted to a site's climate and local rain cycles can create a more sustainable urban forest. The urban environment is harsh for many plants. Often plants native to an area are best adapted to that area's climate. Select plants that can tolerate the environmental elements, such as radiant heat from the sidewalk or street surface or 50 to 60 mph winds from passing traffic.

Urban soils have became highly compacted through construction activities and the passage of vehicle and even foot traffic. Compaction reduces the soil's capacity to hold and absorb water. Plants need healthy soil, air, and water to thrive.

Using planters in the urban forest can increase the biomass and canopy cover, but these plants and trees are still compromised and confined. At its bottom and sides, a barrier will exist as the prepared area meets the surrounding compacted soils. Covering the soil surface with some form of mulch can help as the shade, cooling, and retained moisture that mulch provides help support the biological activities close to the soil's surface. These activities open the pore structure of the soil over time, help keep it open, and cushion the impact of foot traffic. This process works better if the mulch material is organic, as opposed to stones. If planters have limited resources for soil preparation, they should have an extensive covering of mulch.

The generalized soil types map for a town can be used as a starting point when planning projects, but then the basic soil classifications should be identified on-site, especially when confronted by planting sites at the extreme ends of the spectrum: very fast-draining, nutrient-poor sands, and dense, often nutrient-rich, but oxygen-starved poorly drained clays.

Planting Sites

Traditionally, trees have been squeezed into whatever limited space is easily found, but this does not work well for either the tree or the street. The following guidelines provide recommended planting areas:

- Establish and maintain 6 to 8-foot wide sidewalk furniture zones, where possible. Many large trees need up to 12 feet in width, and are not suitable for placement in narrower furniture zones. In residential areas, sidewalk furniture zones within the root zone should be unpaved and planted/surfaced with low groundcover, mulch, or stabilized decomposed granite where these can be maintained. Where maintenance of such extensive sidewalk furniture zones is not feasible, provide 12-foot long tree wells with true permeable pavers (standard interlocking pavers are not permeable).

- If the above conditions are not feasible, provide for the tree's root system an adequate volume of uncompacted soil or structural or gap-graded soil (angular rock with soil-filled gaps) to a depth of 3 feet under the entire sidewalk (in the furniture, frontage, and pedestrian sidewalk zones).
- Spacing between trees will vary with species and site conditions. The spacing should be 10 percent less than the mature canopy spread. Closer spacing of large canopy trees is encouraged to create a lacing of canopy, as trees in groups or groves can create a more favorable microclimate for tree growth than is experienced by isolated trees exposed to heat and desiccation from all sides. On residential streets where lots are 40 or 50 feet wide, plant one tree minimum per lot between driveways. Where constraints prevent an even spacing of trees, it is preferable to place a tree slightly off the desired rhythm than to leave a gap in the pattern.
- Planting sites should be graded, but not overly compact, so that the soil surface slopes downward toward the center, forming a shallow swale to collect water. The crown of the tree should remain 2 inches above finished grade and not be in the center of a swale, but off to the side. The finished soil elevation after planting is held below that of the surrounding paving so 2 to 3 inches of mulch can be added. The mulch layer must be replenished as needed to maintain a nearly continuous level surface adjacent to paving.
- Generally tree grates and guards are best used along streets with heavy pedestrian traffic. Along streets without heavy foot traffic and in less urban environments, use mulch in lieu of tree grates.

Species Selection

- Select trees with non-aggressive root systems to avoid damaging paving and sidewalks.
- In general, street trees should be species that will achieve a height and spread of 50 feet on residential streets and 40 feet on commercial streets within 10 years of planting to provide reasonable benefits. Typically, trees on commercial streets will not achieve the same scale as they will on residential streets where greater effective root zone volumes may be achieved. On commercial streets with existing multi-story buildings and narrow sidewalks, select trees with a narrower canopy than can be accommodated on the limited sidewalk width.
- Cities and towns should establish a list of recommended tree species for use in the public street rights-of-way. On commercial streets with ground-floor retail, deciduous trees with a strong central leader, such as Ginkos and London Planes, are desirable as they grow rapidly above the ground floor business signs. A town's list of recommended tree species should specify minimum planting site widths for each and which trees may be planted below utility lines. Where there are overhead power lines that are less than 50 feet above grade, braided insulated electrical wire should be used so that trees do not have to be pruned to avoid the electrical lines. If braided insulated electrical wire cannot be provided, appropriate trees that will not grow tall enough to reach the power lines should be specified and planted.

- Consistent use of a single species helps reinforce the character of a street or district, but a diversity of species may help the urban canopy resist disease or insect infestations. New plantings added to streets with existing trees should be selected with the aim of meeting the same watering requirements and creating visual harmony with existing trees and plantings. Native species should be considered for inclusion whenever possible, but consideration should be first given to a species' adaptability to urban conditions.
- Consider evergreen species where it is desirable to maintain foliage through the winter months.
- Consider deciduous species where their ability to allow sunlight to penetrate into otherwise shaded areas (such as south facing windows of adjoining buildings) during the winter months will be a plus.

Tree Spacing and Other Considerations

- Most jurisdictions have spacing requirements between trees and street lights (typically about 30 feet high), which typically vary from 10 to 20 feet. The smaller setback provides greater flexibility in tree spacing and allows for a more complete tree canopy.
- Pedestrian lights, which are about 12 feet tall, generally do not conflict with the tree canopy, so spacing is less rigid. Some jurisdictions still require wide clearance for their convenience in maintaining the lights, but this wide spacing greatly reduces tree canopy and is therefore discouraged. Spacing of 10 feet away from trees is generally adequate.
- An 8-foot minimum clearance must be maintained between accessible parking spaces and trees.
- Adequate clear space should be provided between trees and awnings, canopies, balconies, and signs so they will not come into conflict through normal growth or require excessive pruning to remediate such conflicts.
- Trees may be planted in medians that are 4 feet or wider, but must have an adequate clear height between the surface of the median and the lowest branches so that pedestrians can be seen. Where trees hang over the street, the clear height should be 14 feet.

Understory Landscaping

Understory landscaping refers to landscape elements beneath the tree canopy in areas within the public right-of-way not required for vehicular or pedestrian movement, including

- Medians
- Curb extensions
- Furniture and frontage zones

Benefits of Understory Landscaping

- Complements and supports street trees, in particular by providing uncompacted, permeable areas that accommodate roots and provide air, water, and nutrients
- Reduces impervious area and surface runoff
- Treats stormwater, improving water quality
- Provides infiltration and groundwater recharge
- Provides habitat

- Reduces the perceived width of the street by breaking up wide expanses of paving, particularly when the understory is in medians and sidewalk furniture zones
- Contributes to traffic calming
- Provides a buffer between the walkway zone and the street, contributing to pedestrian comfort
- Improves the curb appeal of properties along the street, potentially increasing their value
- Enhances the visual quality of the community

Principles

- Trees take precedence: the understory landscape should support them. It should not compete with them.
- Only pave where necessary: keep as much of the right-of-way unpaved and planted as possible to maximize benefits
- Design understory areas to infiltrate water
- The entire understory area does not have to be covered with plants—composted mulch is a good groundcover (top of mulch should be below adjoining hardscape so that runoff will flow into planting areas)
- Make the understory sustainable: use drought-tolerant plants
- Replenish the soil with compost
- Design the understory to contribute to the sense of place

Guidelines

Soil

Provide good quality, uncompacted, permeable soil. Soil analyses should address the concentration of elements that may affect plant growth, such as pH, salinity, infiltration rate, etc. Remove and replace or amend soil as needed. Good preparation saves money in the long run because it reduces the need to replace plants, lowers water consumption, and reduces fertilizer applications.

Design

Generally, understory landscaped areas should be as wide as possible where there are trees: when feasible, at least 6 to 9 feet wide for parkways and 8 to 12 feet wide for medians. However, many existing parkways and medians are less wide. Narrower parkways can support understory plants and some tree species. A path or multiple paths should be added as needed across a parkway as a means of access from the curb to the sidewalk. For example, where there are striped curbside parking spaces, a path across the parkway should be provided at every one or two parking spaces.

Install plant species that:

- Do not require mowing more frequently than once every few months
- Are drought tolerant and can survive with minimal irrigation upon establishment
- Do not exceed a height of 2 feet within 5 feet of a driveway/curb cut and within 20 feet of a crosswalk, and, excluding trees, 3 feet elsewhere

- Do not have thorns or sharp edges adjacent to any walkway or curb
- Are located at least 4 feet from any tree trunk

Appendix 2: Capital Improvement Cost Estimates

Please note the figures below are estimates. Consultation with NCDOT, a professional engineer, or licensed landscape architect should be sought prior to the design or construction of any of the facilities listed below.

Cost Estimates

Item	Comments	Low End Estimates	High End Estimates	Unit
10' Asphalt Multi-use Path	Does not include right-of-way. Assumes no major drainage cost.	$25	$75	Per Linear Foot
Tree Plantings and Landscaping	Low end is trees only; High end is trees, sod, irrigation, & shrubs. Assumes sufficient right-of-way.	$10	$35	Per Linear Foot
Crosswalk Markings	Includes thermoplastic markings on pavement and on concrete portion of medians/sidewalks as necessary.	$1500	$2,000	Per Crossing
Crosswalk Signage	Simple neighborhood signs.	$250	$300	Each
Pedestrian Countdown Signals	Assumes traffic signals exist at the intersection. Also, on NCDOT streets there are strict warrants that must be met for pedestrian signals to be	$7,500	$12,000	Per Intersection
Sidewalk Installation	Does not include right-of-way. Assumes no major drainage cost.	$20	$50	Per Linear Foot
Curb Ramps	ADA compliant. Does not include right-of-way.	$400	$600	Each
Streetscape	Cost varies based on material, amenities, size, and drainage requirement.	$400	$1,000	Per Linear Foot
Curb Extensions	Cost varies based on material, amenities, size, and drainage requirement.	$5,000	$15,000	Each
Vegetated Roof	Cost varies depending on plant material, structural requirements, and roofing membrane.	$15	$50	Per Square Foot
Lighting	Cost varies depending on size, wattage, and material of lighting.	$500	$3,500	Each
Mast Arm Signal Pole	25 foot galvanized steel mast arm signal post. Cost does not include utility relocation.	$6,000	$10,000	Each