Cross-section and Roadside Elements

3.1 Introduction

The basic design controls described in Chapter 1-2 influence the width, functional areas of the cross-section, and accommodation for different users. The careful selection of roadway cross-section elements (sidewalks, bicycle accommodation, motor vehicle lanes, etc.) is needed to achieve a context-sensitive design that accommodates all users safely. This chapter describes the various components of roadway cross-section, including ranges of recommended dimensions for different' area and roadway types. This chapter also describes basic elements of roadside design.

3.1.1 Multimodal Accommodation and Context Sensitivity

The goals of selecting an appropriate roadway cross-section and the design of roadside elements are:

- To develop a transportation infrastructure that provides access for all, a real choice of modes, and safety in equal measure for each mode of travel.
- To ensure that transportation facilities fit their physical setting and preserve scenic, historic, aesthetic, community, and environmental resources to the extent possible.

In some cases, these design objectives can be achieved within the available right-of-way. In other cases, additional right-of-way needs to be acquired. Sometimes, tradeoffs in user accommodation need to be made to preserve environmental or community resources located within or adjacent to the right-of-way. In these situations, the challenge is to provide access and safety for each mode of travel. In other situations, it will be necessary to modify environmental characteristics in order to provide safe accommodation.

To assist designers, this Plan provides options and recommendations for safe accommodation of pedestrians, bicycles, vehicular traffic, and public transit operations.

General approaches to cross-section formulation are discussed in Section 3.2.

Approaches to cross-section formulation are presented from right-of-way edge to edge, rather than the more traditional method from center line out. Through this approach, accommodation of pedestrians and bicyclists is positively encouraged, made safer, and included in every transportation project.

The challenge is to balance the competing interests of different users in a limited amount of right-of-way and to provide access for all, a real choice of modes, and safety in equal measure for each mode of travel.

Detailed description of the following cross-section elements associated with different roadway users are described in Section 3.3:

- **Pedestrians including people requiring mobility aids**
  - Sidewalks
  - Shoulder use
  - Shared lanes
  - Shared use paths
- **Bicycles**
  - Bicycle lanes
  - Shoulder use
  - Shared lanes
  - Shared use paths
- **Motor Vehicles including transit**
  - Usable shoulders
  - On-street parking
  - Travel lanes

Once the elements associated with roadway user groups are described, guidance for assembling cross-sections is provided. This guidance describes the elements typically encountered for the roadway and area types defined in Chapter 1-2.

3.1.2 Additional Topics Covered

In addition to cross-section elements specifically associated with the movement of pedestrians, bicycles, and motor vehicles, there are several other cross-section elements included in this chapter as described below.

3.1.2.1 Public Transit Elements

Public transit often operates as a motor vehicle within the public right-of-way. There are several design features, both within the roadway and on the sidewalk, that should be considered in cross-section design. These are discussed in Section 3.4 and include:

- Bus stops, and
- Dedicated lanes.

3.1.2.2 Other Cross-section Design Features

Section 3.5 describes the application of the following features:

- Medians and auxiliary lanes,
- Curbs, berms, and edging, and
- Cross-slopes.

The relationship of these aspects of cross-section design to multimodal accommodation are also described.

3.1.2.3 Utilities and Signage

Utilities are frequently located within the roadway right-of-way. Considerations for the placement of utilities and roadside signage is discussed in Section 3.6.

3.1.2.4 Right-of-Way

Section 3.7 describes how cross-section elements translate into right-of-way requirements. The necessary right-of-way is the summation of all desired cross-section elements (sidewalks, buffer strips, curbs and berms, shoulders and on-street parking, bicycle lanes, travel lanes, and medians) and roadside elements (clear zones, barriers, drainage ditches, utility poles, signage, snow storage area and maintenance areas).

3.2 Multimodal Accommodation

Once the purpose and need for a project is defined, the designer should determine the most appropriate way to provide safe, convenient, and comfortable accommodation for all users within the context of the project. This process is aided by input from the public and the City of Norwalk during project planning. Descriptive cases for a range of accommodations are provided to assist the designer's understanding of user accommodation approaches that may be applicable in a variety of contexts.

Multimodal Accommodation Performance Goal: The designer should provide safe, convenient, and comfortable travel for all roadway users.

The first three cases describe roadway sections bounded by curb and sidewalk. These cases are most likely to be found in the more densely developed area types introduced in Chapter 1-2 (Urban, Suburban Village and Town Center, Suburban High Density, and Rural Village). The remaining two cases are for areas without curb and sidewalk and are most likely to be found in the less developed area types (Rural Natural, Rural Developed, and Suburban Low Density).

These descriptive cases are not intended to be "typical sections" applied to roadways without regard for travel speeds, vehicle mix, adjacent land use, traffic volumes, and other factors since application of "typical sections" can lead to inadequate user accommodation (underdesign) or superfluous width (overdesign). Typical sections also leave little room for judgment reflecting the purpose and context of individual projects and can oversimplify the range of values that may be selected for each element of the cross-section.

In the following descriptions, the multimodal accommodation cases are conceptual and reflect a range of potential dimensions for each element. Once the designer determines the multimodal accommodation desired for the project, the designer should select specific dimensions for each cross-section element within the ranges provided later in this chapter. When assembled, the specific elements influence the necessary right-of-way to achieve the accommodation desired for the project. This desired cross-section can then be compared to environmental constraints and available right-of-way. If necessary, additional right-of-way requirements can be identified and/or further refinements to the cross-section can be made.

3.2.1 Case 1: Separate Accommodation for All Users

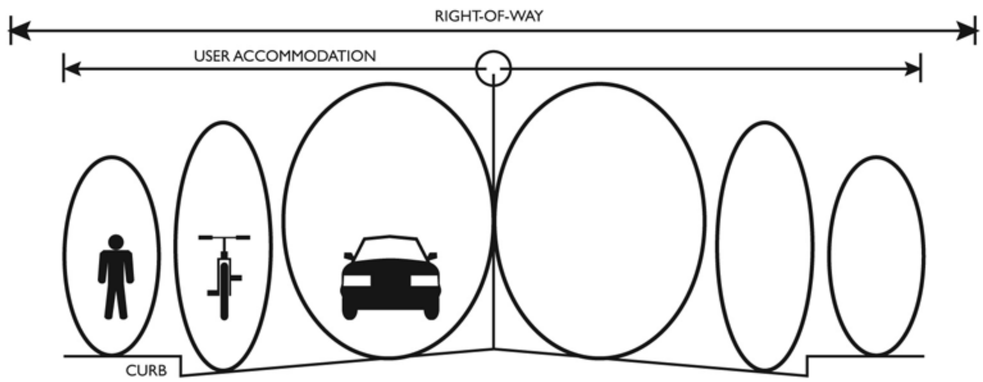
Case 1 provides the maximum separate accommodation for all modes of travel, as illustrated in Exhibit 3-1. This is often the preferred option in terms of providing safe, convenient, and comfortable travel for all users. It is usually found in areas of moderate to high density (urban areas, suburban villages and town centers, suburban high density areas, and rural villages) with curbed roadways.

Case 1 provides for the maximum separation of users, which can provide the highest level of safety and comfort for all users in areas with high levels of activity or where large speed differentials between the motorized and non-motorized modes are present. Case 1 usually requires the most width. In locations where the speed differential between different roadway users is small, or overall activity is low, Case 1 may not be necessary to safely accommodate all users. However, in some instances, this case might be achieved by reallocating space within an existing roadway, thus eliminating potential impacts to the roadside environment.

This case might be considered in a wide variety of conditions including: areas with moderate to high pedestrian and bicycle volumes; areas with moderate to high motor vehicle speeds and traffic volumes; and areas without substantial environmental or right-of-way constraints.

In Case 1, pedestrians are provided with a sidewalk separated from the roadway by a raised curb and preferably a landscaped buffer. The clear width of the sidewalk should be sufficient to allow pedestrians or wheelchair users to pass without interfering with each others' movement (at least 5 feet excluding the curb and clear from items along the sidewalk such as fire hydrants, signs, trees and utility poles). Sidewalks should be provided on both sides of the street unless there is a condition that suggests that a sidewalk is not needed on one side of the street. This might happen, for example, if there is physical impediment that would preclude development on one side of the street, such as a railroad track or stream.

Exhibit 3-1 Case 1: Separate Accommodation For All Users



Provision of a striped bicycle lane or shoulder suitable for bicycle use (4 feet minimum, 5 feet preferred) encourages cyclists to use the roadway. The bicycle lane/shoulder also provides for additional separation between motor vehicle traffic and pedestrians. If on-street parking is present, the bicycle lane should be at least 5 feet wide so that the cyclist is provided with an additional buffer along the parked cars.

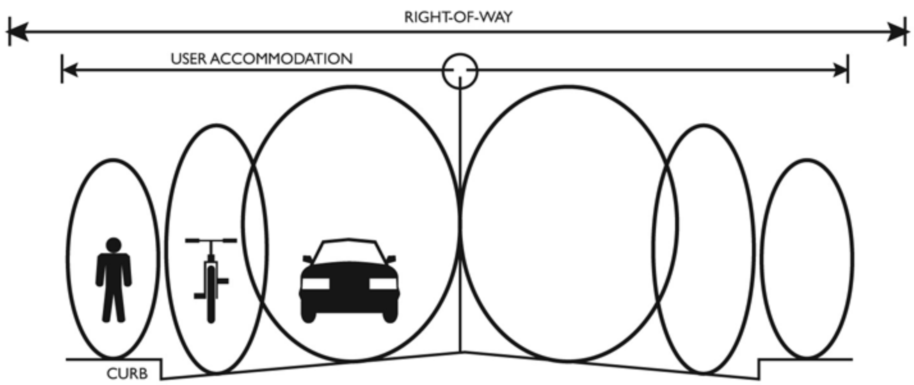
Motor vehicles are accommodated within travel lanes wide enough to eliminate encroachment by wider vehicles on either the adjacent bicycle lane or on the opposing motor vehicle travel lane. In addition to providing space for bicycles, shoulders also accommodate emergency stopping, maneuvering, and other functions. Where on-street parking is provided, shoulders or bicycle lanes should be maintained between on-street parking and the travel lane.

3.2.2 Case 2: Partial Sharing for Bicycles and Motor Vehicles

There are instances in which the width necessary to provide accommodation for Case 1 is not available. There are also instances where some sharing and overlap between bicyclists and motor vehicle traffic is acceptable to achieve other environmental or design objectives. Case 2 describes an approach to multimodal accommodation in these situations and is illustrated in Exhibit 3-2.
Case 2 is common in areas of moderate to high density (urban areas, suburban villages and town centers, suburban high density areas, and rural villages), where curbed roadway sections and separate sidewalks are provided.

Pedestrians are provided with a sidewalk separated from the roadway by a raised curb and preferably a landscaped buffer, increasing the safety and comfort of the pedestrian. The clear width of the sidewalk should be sufficient to allow pedestrians or wheelchair users to pass without interfering with each other’s movement (at least 5 feet excluding the curb and clear of other roadside obstructions).

Exhibit 3-2 Case 2: Partial Sharing for Bicycles and Motor Vehicles



In Case 2, there is some overlap between the space provided for bicycle use and that provided for motor vehicle travel. Signs or pavement markings indicating that the roadway is shared between cyclists and motor vehicles are appropriate for Case 2 roadways.

This type of accommodation is often used in areas with low motor vehicle speeds, low to moderate motor vehicle traffic volumes, and areas of environmental or right-of-way constraint where a smaller cross-section is necessary.

The designer should carefully consider the allocation of width to travel lanes and bicycle lanes/shoulders to provide the best balance of accommodation between bicycles and motor vehicles. In many instances, on-street parking will also be provided and additional width may be needed to reduce conflicts between bicycles and the adjacent parking. There are different possible configurations of lanes and shoulders possible in Case 2, but all feature some overlap in the space needed by bicyclists and motor vehicles:

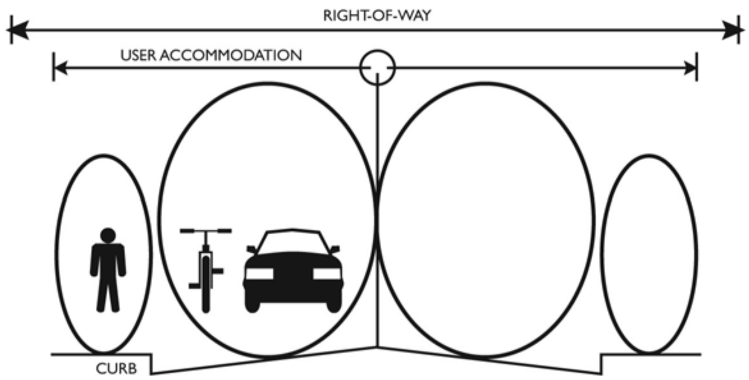
- Typical travel lanes combined with narrow shoulders (i.e. 11- to 12-foot lanes with 2- to 3-foot shoulders) provide maneuvering width for truck and bus traffic within the travel lane; however, bicyclists may be forced to ride along and over the pavement markings.
- Narrow travel lanes combined with wide shoulders (i.e. 9 to 11-foot lanes with 4 to 8 foot shoulders) provide greater separation between motor vehicle and bicycle traffic, but may result in motor vehicle traffic operating closer to the center line or occasionally encroaching into the opposing travel lane.

Wide curb lanes have also been used in Case 2; however, studies have shown that motorists and bicycles are less likely to conflict with each other and motorists are less likely to swerve into oncoming traffic as they pass a bicyclist when shoulder striping is provided.

3.2.3 Case 3: Shared Bicycle/Motor Vehicle Accommodation

In Case 3, the accommodation of bicycles and motor vehicles is shared and separate pedestrian accommodation is maintained as illustrated in Exhibit 3-3. Case 3 is most likely to be found in the most densely developed areas (urban areas, suburban villages and town centers and some rural villages) where right-of-way is most constrained. It is also applicable to most residential streets where speeds and traffic volumes are low.

Exhibit 3-3 Case 3: Shared Bicycle/Motor Vehicle Accommodation



Pedestrians are provided with a sidewalk separated from the roadway by a raised curb and preferably a landscaped buffer, increasing the safety and comfort of walking along this roadway. The clear width of the sidewalk should be sufficient to allow pedestrians or wheelchair users to pass without interfering with each other's movement (at least 5 feet excluding the curb and sidewalk clear of other roadside obstructions).

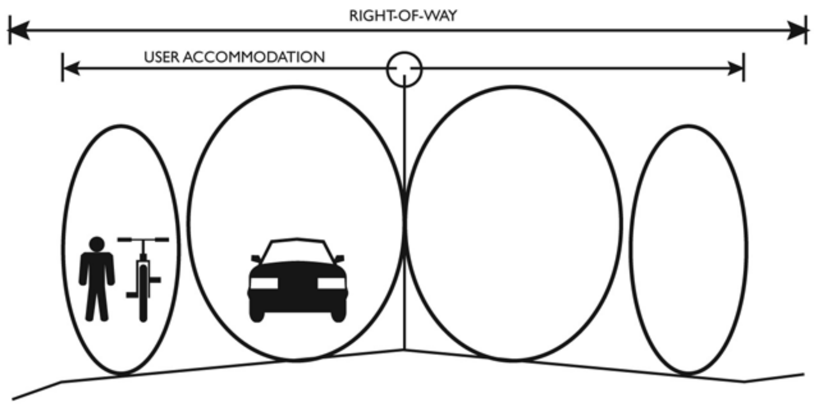
In Case 3, one lane is provided for joint use by motor vehicles and bicycles. This type of accommodation is used in the following conditions: areas with low to moderate motor vehicle traffic volumes; low motor vehicle speeds; and areas of severe right of way constraint where only a minimum pavement section is feasible.

Signs and pavement markings indicating that the roadway is shared between cyclists and motor vehicles should be provided for Case 3 roadways. On-street parking is often found on these roadways and separate shoulders or bicycle lanes are not available.

3.2.4 Case 4: Shared Bicycle/Pedestrian Accommodation

In sparsely developed areas (such as rural natural, rural developed, and suburban low density areas), curbed roadway sections bounded by sidewalk are less common. This case is illustrated in Exhibit 3-4.

Exhibit 3-4 Case 4: Shared Bicycle/Pedestrian Accommodation



In these areas, pedestrians and cyclists are often accommodated on the roadway shoulder. This type of accommodation may be appropriate for areas with infrequent pedestrian activity. In areas with higher pedestrian volumes (either current or anticipated), the pedestrian accommodation described in Cases 1, 2, and 3 is desirable. Pavement striping and a paved shoulder (at least 4-feet wide) for shared pedestrian and bicycle use helps delineate the travel way for motor vehicles, thus increasing safety for all users. Wider shoulders should be provided as motor vehicle speeds and traffic volumes increase.

In Case 4, motor vehicles are accommodated within travel lanes wide enough to eliminate encroachment on the shoulder or the opposing motor vehicle lane. For Case 4, the designer should carefully consider the allocation of right-of-way between travel lanes and shoulders. For example:

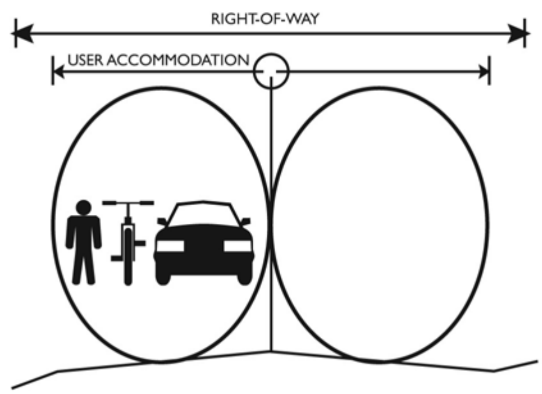
- Typical travel lanes combined with wide shoulders (i.e. 11 or 12-foot lanes with 6-foot or wider shoulders) provide for increased separation between pedestrians, bicyclists motor vehicles. Wider shoulders also provide clearance for emergency stopping and maneuvering.
- Typical travel lanes combined with narrow shoulders (i.e. 11 or 12-foot lanes with 4-foot shoulders) provide maneuvering width for truck and bus traffic within the travel lane, reducing encroachment into opposing lanes and the shoulder. However, conflicts between bicycles and pedestrians are more likely.
- Narrow travel lanes combined with wide shoulders (i.e.,10 to 11-foot lanes with 6 to 8 foot shoulders) provide greater separation between bicyclists and pedestrians, but may result in motor vehicle traffic operating closer to the center line or encroaching on the shoulder.

3.2.5 Case 5: Shared Accommodation for All Users

Vehicles, bicycles, and pedestrians are sometimes accommodated in one shared travel lane, as illustrated in Exhibit 3-5. This condition occurs when there is low user demand and speeds are very low, or when severe constraints limit the feasibility of providing shoulders.

This case provides the smallest pavement width while accommodating all users effectively only in low volume, low speed conditions. Fences, rock walls, tree lines, and other roadside constraints, can further restrict emergency movement by all users. Additional unpaved shoulders or clear zones should be carefully considered to provide additional flexibility and safety. Additionally off-road paths should be considered to improve the accommodation of pedestrians. These paths do not need to follow the road alignment precisely and can sometimes avoid obstacles that preclude sidewalks and shoulders.

Exhibit 3-5 Case 5: Shared Accommodation for All Users

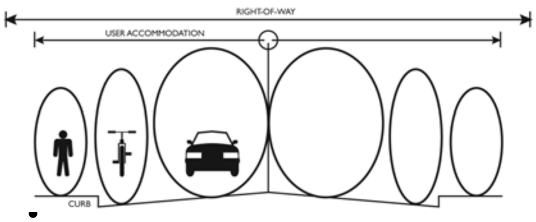


3.2.6 Summary of Accommodation Option

Exhibit 3-6 provides a summary of the multimodal accommodation options available to the designer.

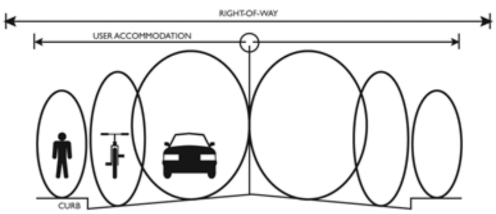
Exhibit 3-6 Summary of Multi-modal Accommodation Options

Case 1: Separate Accommodation for All Users



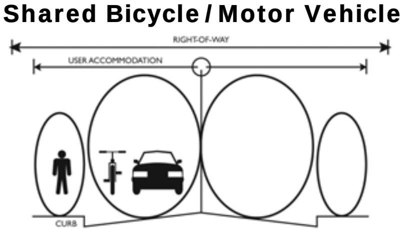
- Often the preferred option to provide safe, convenient, and comfortable travel for all users.
- Appropriate for areas with moderate to high levels of pedestrian and bicycle activity.
- Appropriate for roadways with moderate to high motor vehicle speeds.
- Appropriate in areas without substantial environmental or right-of-way constraints.

Case 2: Partial Sharing for Bicycles and Motor Vehicles



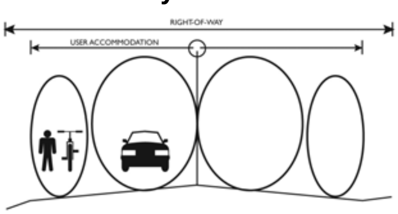
- Used in areas where the width necessary to provide Case 1 accommodation is not available.
- Under Case 2, pedestrians are provided with a sidewalk or separate path while space for bicyclists and drivers overlap somewhat.
- Appropriate in areas with low motor vehicle speeds and low to moderate motor vehicle volumes.

Case 3: Shared Bicycle / Motor Vehicle Accommodation



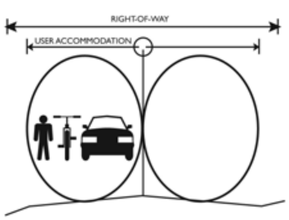
- Under Case 3, pedestrians remain separate but bicycle and motor vehicle space is shared.
- Used in densely developed areas where right-of-way is constrained.
- Also applicable to most residential/local streets where speeds and traffic volumes are low.

Case 4: Shared Bicycle / Pedestrian Accommodation



- Under Case 4, pedestrians and bicyclists share the shoulder.
- Common in rural or sparsely developed areas.
- Appropriate for areas with infrequent pedestrian and bicycle use.

Case 5: Shared Accommodation for All Users



- Under Case 5, all users share the roadway.
- Appropriate where user demands and motor vehicle speeds are very low or when severe constraints limit the feasibility of providing separate accommodation.

3.3 Design Elements

Once the approach to multimodal accommodation is determined, the designer should determine the dimensions of each element to be included in the cross-section. These elements are assembled to develop a desired cross-section. The following sections describe the dimensions of specific cross-section elements that serve different roadway users.

3.3.1 Pedestrians

Pedestrian accommodation should be consistent with the project context, including current or anticipated development density, roadway characteristics, right-of-way dimensions and availability, and community plans. Options for pedestrian accommodation include sidewalks, shoulder use, and shared lanes, as described below, and off-road or shared use paths.

All roadways along which pedestrians are not prohibited should include an area where occasional pedestrians can safely walk, whether on unpaved walkways, on shoulders in rural or less developed areas, or on sidewalks in more urban areas.

In addition to the type of accommodation, the designer should include other design features that improve the pedestrian environment. For example, the designer can consider selecting a lower motor vehicle design speed that will increase the comfort and safety of the facility for pedestrians. Similarly, the designer should consider geometric features that improve the pedestrian environment, such as crossing islands, curb extensions, and other traffic calming features discussed in more detail in Chapter 1-6.

The walking path should have a smooth, stable and slip resistant surface that does not induce vibration in wheelchairs and is free of tripping hazards. These requirements are further discussed in Chapter 1-4.

3.3.1.1 Sidewalks and Buffers

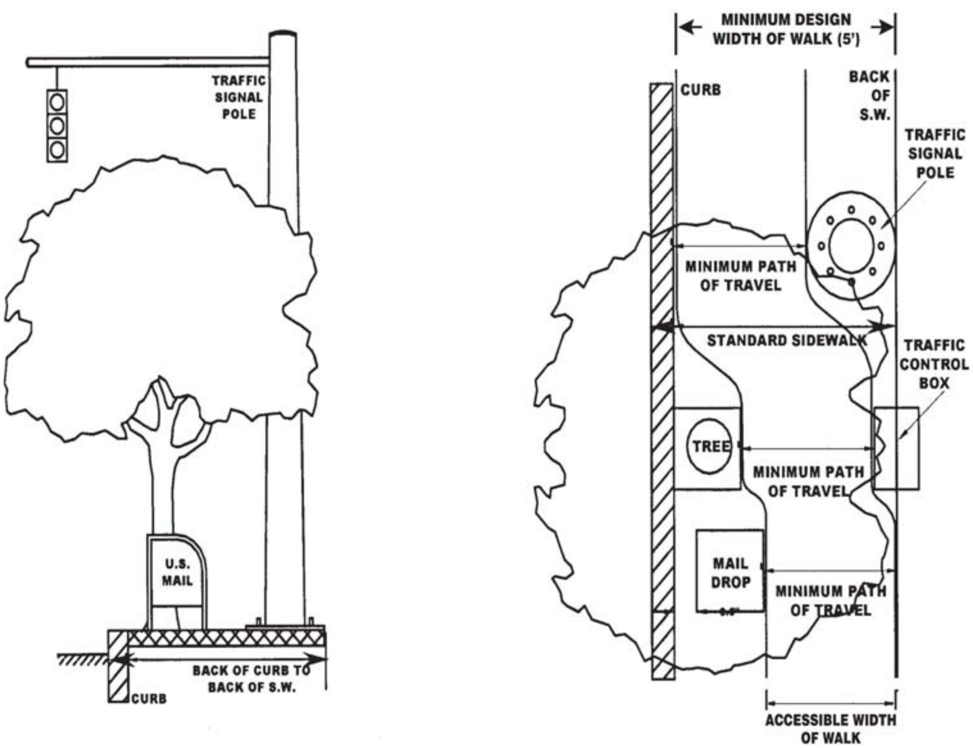
Sidewalks are paved areas provided along the edges of roadways suitable for pedestrian use. Sidewalks are the most common accommodation provided for pedestrians. Sidewalks are desirable in all areas where pedestrian activity is present, expected, or desired. Sidewalks should be provided in residential areas, near schools, libraries, parks, and commercial areas. Sidewalks should also be provided between transit stops and nearby destinations. Sidewalks should be provided to link residential areas with nearby employment, shopping, and service centers.

In urban areas or village/town centers, raised curb and curb cut ramps are usually provided with sidewalks. A landscaped buffer between vehicular traffic and the sidewalk can provide greater separation from motor vehicles, increasing the comfort and safety of pedestrians. In rural or suburban settings for minor arterials or collector roads with 5 feet or more of buffer space, curbing may not be needed. On-street parking, shoulders, and bicycle lanes can also act as sidewalk buffers.

Dimensions and Clear Width

The spatial requirements of pedestrians are described in Chapter 1-2. The minimum width for a sidewalk is 5 feet excluding the width of the curb, although a 4 foot clear width (plus the width of the curb) is sufficient to bypass occasional obstructions, as illustrated in Exhibit 3-7. When developing plans, the sidewalk is sometimes measured including the width of the curb. If this method of measurement is used, the minimum width of sidewalk is 5 ½ feet.

Exhibit 3-7 Clear Accessible Path



Source: Adapted from the Guide for the Planning, Design, and Operation of Pedestrian Facilities, AASHTO, 2004. Chapter 3 Pedestrian Facility Design

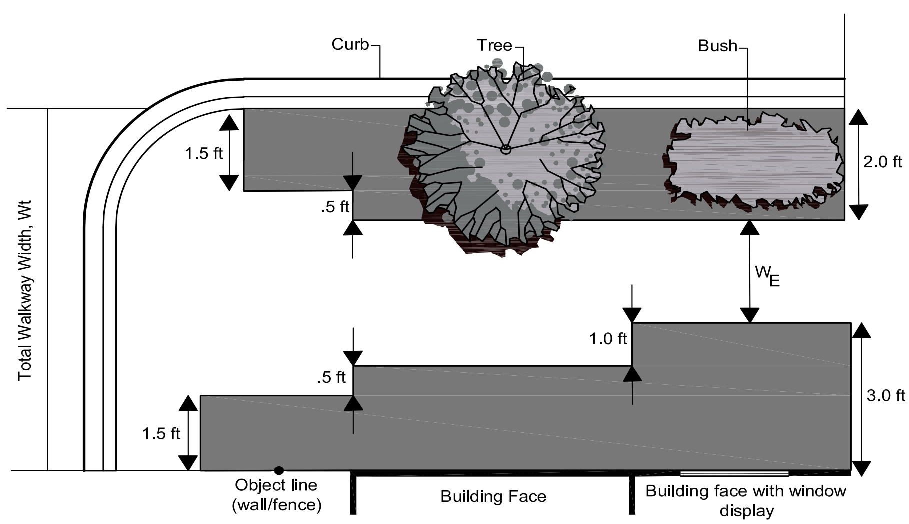
Wider sidewalks are desirable where there are high pedestrian volumes and where there is no buffer between high speed or high volume roadways. Sidewalk widths of 6 to 12 feet are preferred for most town center and urban locations. Very wide sidewalks (12 to 20+ feet) are also encountered in these settings. Common widths of landscape buffer are between 2 and 6 feet, although larger buffers are possible.

Landscape buffers accommodate a variety of functions, including: safety separation, snow storage, street furniture, landscaping, utilities and traffic control devices. As such, it is preferable that such buffers be at least 5 feet wide..

If the sidewalk is not buffered from motor vehicle traffic, then the desirable total width for a curb-attached sidewalk is 6 feet in residential areas and 8 feet in commercial areas.

Sidewalks commonly accommodate ***street furniture*** which includes items such as, trees, utilities, traffic signals, traffic signs, streetlights, parking meters, bicycle parking, benches, and refuse barrels. Additionally, sidewalks often abut fences, building edges, or vegetation along their outside edge. These elements influence the required width necessary to accommodate pedestrians, as pedestrians tend to "shy" from these obstructions. The designer should consider the desired location for these sidewalk features and, where they exist, the designer should provide appropriate offsets (or shy distances) to the pedestrian path. Typical ***shy distances*** are illustrated in Exhibit 3-8.

Exhibit 3-8 Typical Shy Distances Between Sidewalk Elements and Effective Pedestrian Path



Source: Adapted from the Guide for the Planning, Design, and Operation of Pedestrian Facilities, AASHTO, 2004. Chapter 3 Pedestrian Facility Design

All new and reconstructed sidewalks must be accessible to and usable by persons with disabilities. A minimum clear path (W_E) of 3 feet must be continuously provided along a sidewalk. Sidewalk dimensions and clear widths must conform to the accessibility requirements established under Connecticut General Laws. To allow free passing of pedestrians, including those with disabilities, a walkway that is at least five-feet wide (excluding the curb width) and clear of obstructions is required at every 200-feet intervals.

Sidewalks are also crossed by driveways and intersected by streets. These crossings are described in more detail in Chapter 1-4. As a general approach, the sidewalk should be continuous across driveways and include appropriate transitions for the grade changes associated with these interfaces. For most driveways, it is desirable for the sidewalk elevation to control the driveway design, rather than for the driveway to cut through the sidewalk. However, high volume driveways or driveways exiting high speed roads may be more appropriately designed as intersections, with level connections between the roadway and the driveway. In these cases, pedestrian ramps and crosswalks should be included to provide a continuous path of travel. All facilities should comply with ADA requirements including the sidewalks, pedestrian ramps and crosswalks.

Placement

In developed areas, continuous sidewalks should be provided on both sides of a roadway, minimizing the number of pedestrian crossings required. If a sidewalk is provided on only one side of a roadway, the context of the roadway should be the basis for this decision. For example, in undeveloped or low-density areas, or where development is heavily concentrated on one side of the roadway, or there are a significant number of public shade trees, sidewalks on only one side of the road may be sufficient. In these cases, the sidewalk should be provided on the side that minimizes the number of pedestrian crossings. Crosswalks should be provided at reasonable intervals (typically every 200 to 300 feet with maximum separation in developed areas of approximately 500 feet).

3.3.1.2 Shoulder Use

In areas where pedestrian volumes are low, or where both traffic volumes and speed are low, a paved usable shoulder, as described in Section 3.3.3.1, can provide pedestrian accommodation. This occurs primarily in rural natural areas, rural developed, and some suburban low density areas.

On most roadways through sparsely developed areas, a minimum 4-foot shoulder is usually adequate for pedestrian use. A wider shoulder is desirable when there is significant truck traffic or high traffic speeds. The width of shoulders is usually determined through an assessment of pedestrian, bicycle, and motor vehicle needs.

The decision to use shoulders rather than sidewalks or parallel paths should consider existing and future pedestrian volumes. Even with low pedestrian volumes, it is desirable to provide sidewalks or paths to serve schools, libraries, shops and transit stops.

3.3.1.3 Shared Lanes

Walking within travel lanes may be appropriate for some roadways with very low traffic volumes and vehicle speeds. However, sidewalks or usable shoulders are the preferred accommodation.

Before deciding to provide shared lanes as the only pedestrian accommodation, the designer should be certain that the traffic volumes and vehicle speeds will be low enough, now and in the future, so that all pedestrians can comfortably use the street.

3.3.1.4 Off Road and Shared Use Paths

A ***shared use path*** is a dedicated facility for pedestrians, bicyclists, roller bladers, etc. Although sidewalks are generally preferred, off-road paths are sometimes suitable in rural and suburban low-density areas. The path should provide the same connectivity as the roadway but can be set back from the roadway and its route can deviate around sensitive environmental areas.

This is discussed in detail in Chapter 1-4. The U.S. Access Board guidelines presented in its proposed *Guidelines for Outdoor Developed Areas* provide additional information on the design of paths as does AASHTO's *2012 Guide for the Development of Bicycle Facilities.*

3.3.2 Bicycles

Bicycle accommodation should also be consistent with the project's context, roadway characteristics, right-of-way, community plans, and the level of service provided for the bicyclist. The designer should ensure that bicycle accommodation is based on anticipated development, community plans, and the expected level of skill of the intended bicyclist.

Bicycles may be present on all highways where they are permitted (bicycles are typically excluded from freeways). In addition to determining the type of accommodation for bicyclists, the designer should include other design features that improve the safety and comfort of the roadway for bicyclists. For example, if motor vehicle speeds are too high, the designer should consider selecting a lower motor vehicle design speed to increase the comfort and safety of the facility for bicycles. Additionally, the designer could consider narrowing motor vehicle lanes to provide wider shoulders. In constrained corridors, even a few feet of striped shoulder can make traveling along a roadway more accommodating for bicycles.

Specific design features that can make roadways more compatible to bicycle travel include uniform widths (where possible), bicycle-safe drainage grates, smooth pavements, adequate sight distances, and traffic signals that detect and respond to bicycles. These design features should be included on all roadways.

Wide cracks, joints, or drop-offs at the edge of the traveled way parallel to the direction of travel can trap a bicycle wheel and cause loss of control, as can holes and bumps in the pavement surface. These conditions should be avoided on all roadways.

Drainage inlet grates and utility covers are potential obstructions to bicyclists. Therefore, bicycle-safe grates must be used, and grates and covers should be located to minimize severe and/or frequent avoidance maneuvering by cyclists. Inlet grates or utility covers in the path of bicycle travel, must be installed flush with the pavement surface. Grates should be hydraulically-efficient versions that do not pose a hazard to cyclists.

The spatial requirements of bicycles are described in Chapter 1-2. For design purposes a width of 4 or 5 feet is commonly used to accommodate bicycle travel. This portion of the roadway should have adequate drainage to prevent ponding, washouts, debris accumulation and other potentially hazardous situations for bicyclists.

Approaches to bicycle accommodation include bicycle lanes, the use of shoulders, and shared roadways. Off-road shared-use or bicycle paths are also an option for bicycle accommodation in some limited cases. Also, in some cases, novice bicyclists and children also use sidewalks for cycling.

The FHWA's *Bicycle Compatibility Index* and AASHTO's *2012 Guide for the Development of Bicycle Facilities* serves as useful tools for reviewing the suitability of various approaches to bicycle accommodation. The types of accommodation typically used are described in the following sections.

3.3.2.1 Bicycle Lanes

Bicycle lanes are portions of the traveled way designed for bicycle use. Bicycle lanes should be incorporated into a roadway when it is desirable to delineate available road space for preferential use by bicyclists and motorists, and to provide for more predictable movements by each. Bicycle lane markings can increase a bicyclist's confidence in motorists not straying into their path of travel. Likewise, passing motorists are less likely to swerve to the left out of their lane to avoid bicyclists on their right. Bicycle lanes are generally considered the preferred treatment for bicycle accommodation. In some cases, they are neither necessary nor desirable due to low-traffic conditions.

Bicycle lanes are most commonly implemented in urban and suburban settings. Frequently, bicycle lanes are found in combination with on-street parking, raised curbs, and sidewalks. In these areas, the bicycle lane also serves the roadway shoulder functions associated with motor vehicles, described in more detail later in this chapter. Contraflow bicycle lanes may be appropriate on one-way streets to increase cyclists connectivity. The treatment of bicycle lanes at intersections and their relationship to turning lanes is provided in Chapter 1-4. Bicycle lanes proposed on all roadways under State jurisdiction will require approval from the Office of State Traffic Administration (OSTA).

Dimensions and Clear Width

The minimum width for bicycle lanes is 4 feet when the bicycle lane is adjacent to the edge of pavement; however, 5-foot bicycle lanes are preferred for most conditions, especially when the lane is adjacent to curbside parking, vertical curb, or guardrail. On roadways with higher speeds (50 miles per hour or more) or higher volumes of trucks and buses (30 or more per hour) the minimum bicycle lane width is 5 feet and 6-foot bicycle lanes are desirable. Bicycle lanes wider than 6 feet are generally not used since they may encourage inappropriate use by motor vehicles.

Placement

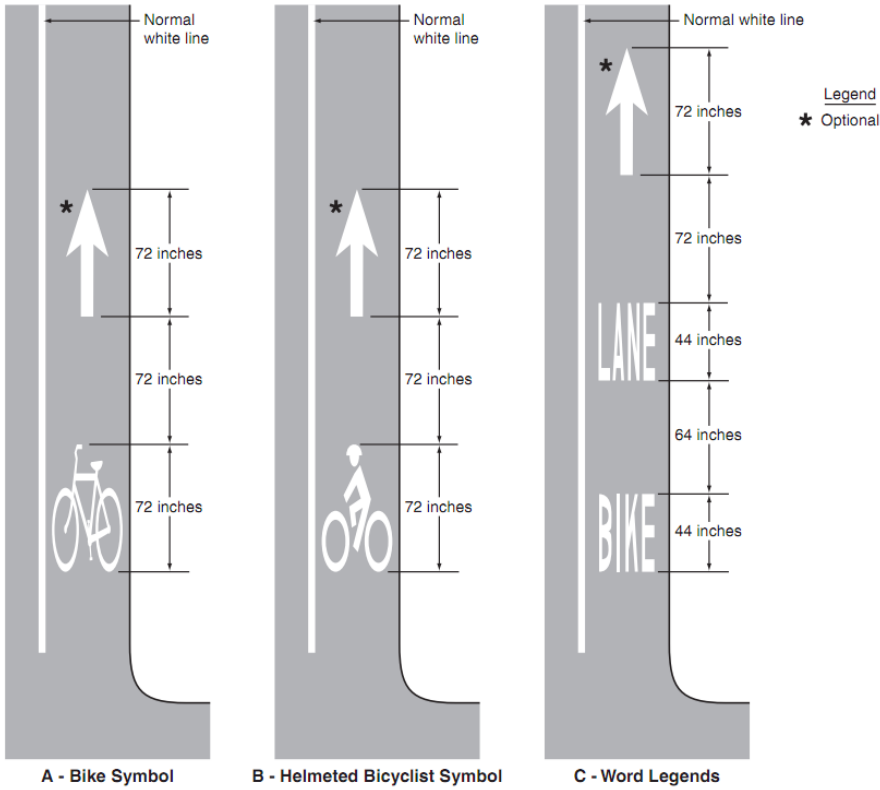
Bicycle lanes are one-way facilities that carry bike traffic in the same direction as the adjacent motor vehicle traffic. Bicycle-specific wrong-way signage may be used to discourage wrong-way travel. On one-way streets, bicycle lanes should be provided along the right side of the road unless unusual conditions suggest otherwise. Bicycle lanes should be designated by a 6-inch solid white line on the right edge of the motor vehicle travel lane. Bicycle lanes within roadways should not be placed between a parking lane and the curb. This situation creates poor visibility at intersections and driveways and it is difficult to prevent drivers from parking in the bicycle lane.

Bicycle lanes shall be designated by a solid white line on the right edge of the motor vehicle travel lane (4-inch minimum , 6-inch preferred) and bicycle symbol or word markings. This marking should change to a broken white line before any intersections on the right side, providing sufficient distance for motorists to merge to the right side of the roadway before making a right-turn. A 4-inch solid white line or parking space markings on the right edge of the bicycle lane are recommended for added delineation of the bicycle lane when adjacent to parking areas. These markings will encourage parking closer to the curb, providing greater separation between bicycles, parked cars, and moving motor vehicles. These markings can also discourage use of the parking lane and bicycle lane for motor vehicle travel when parking activity is light. Additional bicycle lane pavement markings, as illustrated in Exhibit 3-9, and signage can also be installed to reinforce the intended use of the bicycle lane.

3.3.2.2 Shoulder Use

Much like bicycle lanes, paved shoulders provide space for bicycling outside of the travel lanes. One difference between shoulders and bicycle lanes is that shoulders are usually used for bicycle accommodation in rural and suburban low density areas, where on-street parking, curbs, and sidewalks are rarely encountered. In these locations, shoulders may provide shared accommodation for pedestrians and bicyclists. Another difference between shoulders and bicycle lanes is that the width of shoulders is usually determined through an assessment of combined pedestrian, bicycle, and motor vehicle needs, discussed later in this chapter, in the context of project goals and available space. Additionally, shoulders do not typically include bicycle lane pavement markings.

Exhibit 3-9 Bicycle Lane Pavement Markings



Source: Manual on Uniform Traffic Control Devices, FHWA, 2009. Chapter 9 Traffic Control for Bicycle Facilities

To provide bicycle accommodation, shoulders should be at least 4 feet wide. The measurement of the usable shoulder should not include the shy distance from a curb or guardrail where a 5-foot minimum width is recommended. Minimum 5-foot shoulders are also recommended in areas with vehicular speeds over 50 miles per hour, or where truck and bus volumes exceed 30 vehicles per hour, or in areas with on street parking.

Rumble strips, raised pavement markers, or embedded reflectors should not be used where shoulders are to be used by bicyclists, unless there is a minimum clear path of 1-foot from the rumble strip to the traveled way and 4 feet from the rumble strip to the outside edge of paved shoulder. In places adjacent to curb, edging, guardrail or other vertical obstacles, 5 feet between the rumble strip and the outside edge of pavement is desirable. With rumble strips, the total width of the shoulder should be between 7 and 8 feet.

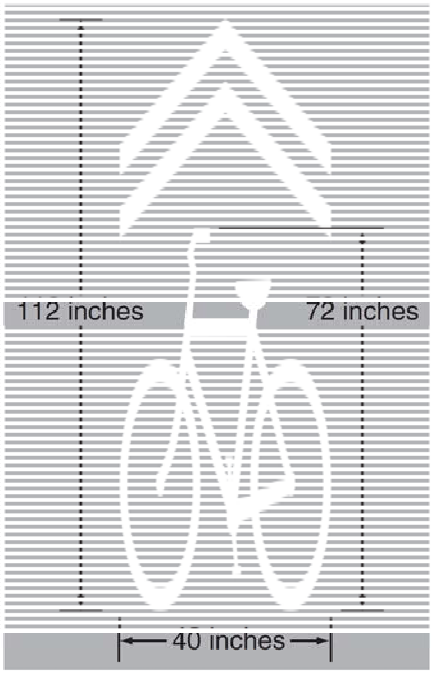
3.3.2.3 Shared Lanes

Shared lanes refer to use of the normal travel lanes by both motor vehicles and bicyclists. By law, bicyclists may use the travel lane. Most roadways in Norwalk have neither shoulders nor bicycle lanes. Thus lanes shared by motorists and bicyclists are the most common situation. Lanes at least 14 feet wide are generally wide enough to permit motorists to pass bicyclists without changing lanes. On low-volume roadways, motorists will generally be able to pass bicyclists without waiting. If traffic volumes are above a critical threshold, it is desirable to provide enough width for lane sharing.

In cases of low speed, low to moderate traffic volumes, and low occurrence of trucks and buses, the shared lanes may be adequate to support bicycling. Before deciding to provide shared lanes as bicycle accommodation, the designer should be certain that the traffic volumes and motor vehicle speeds will be low enough so that all types of bicyclists can comfortably use the roadway.

In locations where shared lanes are used, the designer should consider using shared lane pavement markings such as those illustrated in Exhibit 3-10. “Bicycles May Use Full Lane” signs as defined in the Manual on Uniform Traffic Control Devices (MUTCD) may also be included in the design. It is important to bear in mind that signs are only a supplement to adequate bicycle accommodation and should never be considered a substitute for them.

Exhibit 3-10 Shared Lane Pavement Markings



Source: Manual on Uniform Traffic Control Devices, FHWA, 2009. Chapter 9 Traffic Control for Bicycle Facilities

3.3.2.4 Shared Use Paths

Shared use paths are facilities on exclusive right-of-way with minimal cross flow by motor vehicles. Shared use paths should be thought of as a complementary system of off-road transportation routes for bicyclists and others that serves as a necessary extension to the roadway network. The presence of a shared use path near a roadway does not eliminate the need to accommodate bicyclists within a roadway.

Provision of shared-use paths is particularly suited to high-speed, high-volume roadways where the characteristics of traffic flow, roadway geometrics and traffic control are incompatible with bicycle use, except for advanced cyclists. Similarly, shared-use paths can provide a bicycling route parallel to freeways, where bicycling is prohibited. Shared-use paths are also an option in areas of limited right of way or where environmental or cultural resources limit the width of a roadway and a nearby pathway is available. Finally, shared use paths can provide recreational amenities in waterfront areas or near other attractions.

3.3.3 Motor Vehicles

The major components of the roadway cross-section serving motor vehicle travel are usable shoulders or on-street parking, and travel lanes. In addition to the width of these individual elements, the right lane plus shoulder dimension is important for determining the minimum width for a two-lane two-way roadway, as described later in this chapter.

The width recommendations presented in this section are based on established practices and supplemented by guidelines from AASHTO including the *Guide for Achieving Flexibility in Highway Design*. Flexibility is permitted to encourage independent designs tailored to particular situations. For example, designers can seek exemptions from established design criteria under specific conditions to provide for the preservation of rural, suburban, and village roads.

The width associated with the cross-section elements described in this section is based on the spatial dimensions of design vehicles discussed in Chapter 1-2. The largest vehicle likely to use the facility on a regular basis is usually selected as the design vehicle and impacts the selection of shoulder and lane width. Usable shoulders, on-street parking, travel lanes, and the right-lane plus shoulder dimension are described in the following sections.

3.3.3.1 Shoulders

The use of shoulders for pedestrian and bicycle accommodation is discussed in the previous sections. ***Shoulders*** are paved and graded areas along the travel lanes to serve a number of purposes as shown in Exhibit 3-11. They should be delineated by a 4-inch wide solid white stripe to separate the travel lane and the edge of pavement. Shoulders do not include on-street parking since the shoulders cannot serve the purposes listed in Exhibit 3-11 if they are occupied by parked cars. On-street parking and its relationship to pedestrian and bicycle accommodation are discussed later in this chapter.

During the planning process, the designer should select an appropriate shoulder width given the roadway's context, purpose and need, bicycle and pedestrian accommodation, speed, and transportation demand characteristics.

Exhibit 3-11 Minimum Shoulder Width (in feet) to Provide Various Functions

	Roadway Type	
Shoulder Function	Arterials	Collectors
Drainage of Traveled Way	1.0	1.0
Lateral Support of Pavement	1.5	1.0
Encroachment of Wide Vehicles	2.0	2.0
Off-tracking of Wide Vehicles	2.0	2.0
Errant Vehicles	3.0	2.0
Bicycle and Pedestrian Use	4.0	4.0
Emergency Stopping	6.0	6.0
Emergency Travel	6.0	6.0
Mail Delivery and Garbage Pickup	6.0	6.0
Law Enforcement Operations	8.0	6.0
Large Vehicle Emergency Stopping	10.0	10.0
Occasional Travel/Detours	10.0	9.0
Highway Maintenance	8.0	8.0

Source: *Flexibility in Highway Design*, AASHTO 2004. Chapter 6 Cross Section Elements

Exhibit 3-12 provides ranges of shoulder width for different area and roadway types. As shown above, shoulders provide many important safety and operational advantages and the designer should strive to provide 6- to 8-foot shoulders for most arterials. As described in the previous sections, if shoulders are provided for pedestrian or bicycle accommodation their minimum width should be 4 feet.

Exhibit 3-12 Widths of Usable Shoulders (In Feet)

	Roadway Type		
Area Type	Arterials[1]	Collectors[1]	Local Roads
Rural Natural	4 to 12	4 to 10	2 to 8
Rural Developed	4 to 12	4 to 10	2 to 8
Rural Village	4 to 12	4 to 10	2 to 8
Suburban Low Density	4 to 12	4 to 10	2 to 8
Suburban High Density	4 to 12	4 to 10	2 to 8
Suburban Village/Town Center	4 to 12	4 to 10	2 to 8
Urban	4 to 12	4 to 10	2 to 8

Source: *Flexibility in Highway Design*, AASHTO 2004. Chapter 6 Cross Section Elements

1 Shoulder widths less than the values shown above may be used if approval from the City of Norwalk is obtained. Situations where narrower shoulders may be considered are described below.

Note: An additional 2-foot offset from the edge of the shoulder is required to vertical elements over 6-inches in height (such as guardrail).

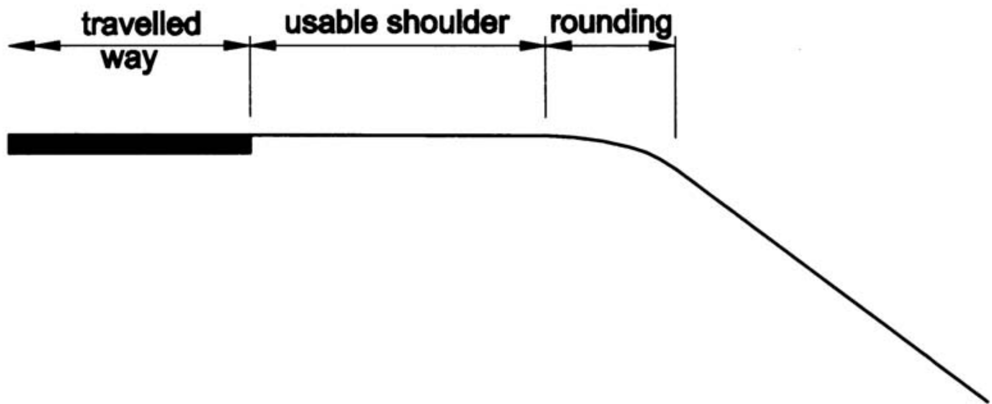
Minimum 4-foot shoulders are recommended for all arterials and collectors because of the value they provide for bicycle and pedestrian (particularly in rural areas) accommodation, and motor vehicle safety. If approval from the City of Norwalk is obtained, shoulders narrower than 4 feet may be used in constrained areas where separate pedestrian accommodation is provided and shared bicycle/motor vehicle accommodation is suitable. Examples of these conditions are where design speeds are less than 45 miles per hour and traffic volumes are relatively low (less than 4,000 vehicles per day), or where the design speed is 30 miles per hour or less.

The **usable shoulder** is composed of both a graded shoulder, and, in some cases, rounding of grade transitions at the edge of the roadway, as shown in Exhibit 3-13. Usable shoulders have the following characteristics:

- The area must have a side slope of 1 foot vertical to 6 feet horizontal (1v:6h) or flatter, including rounded areas for grade transitions.
- The area is usually flush with the adjacent roadway and must be free of vertical obstructions higher than 0.5 feet (guardrail, walls, trees, utility poles).
- Shoulders are usually paved. If unpaved, shoulders should be flush with the roadway surface and sufficiently stable to support vehicular use in all kinds of weather without rutting. Additionally, sufficient paved width to accommodate bicycles should be provided.

- An additional 2 feet of clearance should be added to the usable shoulder dimension to allow for an offset to vertical roadway elements over 0.5 feet in height, such as guardrail, bridge rail, concrete barrier, walls, trees, utility poles, etc.
- Usable shoulders must be cleared of snow and ice during the winter months in order to function properly. Therefore, it is often practical for usable shoulders to be paved.
- The edge of the usable shoulder should not be located at the edge of right-of-way. An offset is required for road maintenance, snow removal, and placement of signs.
- In certain instances, usually to control drainage, the use of a mountable berm or edging is permissible within a shoulder area, as discussed later in this chapter.
- At intersections, usable shoulders may be eliminated in order to better provide for turning movements or shorten pedestrian crossing distances. However provisions for bicyclists must be considered when the shoulder is eliminated at intersections.

Exhibit 3-13 Usable Shoulders



Source: Adapted from A Policy on Geometric Design of Highways and Streets, AASHTO 2011, Chapter 4 Cross-Section Elements.

3.3.3.2 On-street Parking

On-street parking is provided in place of usable shoulders in many different settings to support adjacent land uses. If shoulders are used to accommodate bicycles outside of the on-street parking zone, the designer should maintain the continuity of bicycle routes through the parking zone through the use of bicycle lanes or, at a minimum shared lane markings. Curb extensions are an effective design treatment at intersections and pedestrian crossings that help prohibit illegal parking, reduce the crossing distance for pedestrians, and improve visibility. Curb extensions can be carefully designed so that bicycle travel is not compromised and should only be used in conjunction with active curb-side uses (such as parking or transit stops). Curb extensions should extend no further than 6 feet from the curb.

Sidewalks are almost always provided adjacent to on-street parking. Parking provides a buffer between motor vehicle traffic and pedestrians on the sidewalk. On-street parking can also influence the traffic flow along roadways, sometimes resulting in reduced speeds, reduced capacity, and increased conflicts for both bicycle and motor vehicle traffic. Although not common on Norwalk roadways not under state jurisdiction, on-street parking should not be provided with high design speeds (over 45 miles per hour) due to its impacts on traffic flow and the safety implications of parking maneuvers at high speeds.

Parking often replaces usable shoulders in village, town center, and urban settings.

Parallel on-street parking requires a minimum of 7 feet of paved cross-section in addition to the required travel lane width and should not be permitted where this width is not available. For areas with high turnover, areas with truck loading, and areas with bus stops, 8 feet of width is recommended. Parking lane widths of 10 feet are desirable in areas with substantial amounts of truck parking or bus stops. Wider parking lanes, up to 12 feet, are established to preserve roadway capacity for possible conversion to travel lanes, or for use as travel lanes during peak periods. However, parking regulations and enforcement are required to preserve the desired operational characteristics of the roadway in these instances.

Requirements for the striping and signage of parallel on-street parking is provided in the *Manual on Uniform Traffic Control Devices* (MUTCD). Parking can be marked and regulated by time-of-day or other restrictions in high demand/high turnover areas. In other locations, parking may be permitted, but is not formally marked or regulated.

Accessible parking spaces should be provided in numbers agreed to by the City of Norwalk or the State, and should be located at the end of a block so that they are near a curb cut ramp. Each accessible parking space should be designated with an International Symbol of Access and be consistent with the requirements set forth in the ConnDOT Highway Design Manual at least on roadways under State jurisdiction, but preferably on all roads. Parking should also meet current Americans with Disabilities Act (ADA) design guidelines.

On-street angle parking is currently permitted in some rural villages, suburban town centers, and urban areas. Where angle parking is created or retained, the designer should consider back-in angle parking as an alternative to traditional head-in angle parking. Accessible parking should be provided with an adjacent 5-foot to 8-foot access aisle. Eight foot acceptable aisles can accommodate vans with lifts.

All parking located on State roadways, including No Parking, durational parking, handicap parking, and loading zones require approval from the Office of State Traffic Administration (OSTA). The CT General Statutes prohibits on-street parking within 10 feet of a fire hydrant and within 25 feet of an intersection, marked crosswalk or stop sign.

3.3.3.3 Travel Lanes

Travel lanes are the component of the roadway cross section that serve motor vehicle travel, or in some cases, joint use. In most cases, the travel lanes are the widest component of the roadway cross-section. The number of lanes in each direction should be determined based on the design year transportation demand estimates and the selected design level of service determined in the project planning process (see Chapter 1-2). In some instances it may be possible to reduce the number of travel lanes to provide sidewalks, landscape buffers, bicycle lanes, and crossing islands.

The width of travel lanes is selected through consideration of the roadway context, approach to multimodal accommodation, the physical dimensions of vehicles, speeds, and other traffic flow characteristics. The normal range of design lane width is between

10 and 12 feet. Travel lanes between 11 and 12 feet in width are usually selected for design cross-sections and are particularly desirable for roadways with higher design speeds (45 miles per hour or more), higher traffic volumes (2,000 or more vehicles per day), or higher truck and bus activity (greater than 30 per hour). Exhibit 3-14 summarizes travel lane widths for various area and roadway types. On State roadways, lane widths should be consistent with the Department's Highway Design Manual.

Exhibit 3-14 Range of Travel Lane Widths (In Feet)

	Roadway Type		
Area Type	Arterials[1]	Collectors[2]	Local Roads
Rural Natural	11 to 12	10 to 12	9 to 12
Rural Developed	11 to 12	10 to 12	9 to 12
Rural Village	11 to 12	10 to 12	9 to 12
Suburban Low Density	11 to 12	10 to 12	9 to 12
Suburban High Density	11 to 12	10 to 12	9 to 12
Suburban Village/Town Center	11 to 12	10 to 12	9 to 12
Urban	11 to 12	10 to 12	9 to 12

1 Lane widths less than the values shown above may be used if approval from the City of Norwalk is obtained. Situations where narrower lanes may be considered are described below.
2 Minimum 11-foot lanes are required for design speeds of 45 miles per hour or greater.
N/A Not Applicable
Source: Adapted from A Policy on Geometric Design of Highways and Streets, AASHTO 2011, Chapter 4 Cross-Section Elements.

In addition to through lanes, ***auxiliary lanes*** such as additional turning lanes, climbing lanes, or other lanes may be provided on steep grades, at intersections, or in other special circumstances. Turning lanes at intersections are discussed in detail in Chapter 1-4. Other auxiliary lanes are discussed later in this chapter. For multilane roadways, the additional lanes (if provided) may be different widths than the curb lanes.

Lanes Wider than 12 Feet

Lanes wider than 12 feet are sometimes used where shoulders are not provided, such as in rural villages, suburban high-density areas, suburban villages and town centers, or urban areas. Another application of wide lanes is in areas with high driveway density. This application provides more maneuvering room for drivers entering or exiting driveways, or in areas of limited sight distance. In these cases wide lanes are typically 12 to 14 feet wide. However, if more than 12 feet is available, it is often preferable to stripe a shoulder.

If necessary, the designer should include additional width on curves to minimize encroachment into opposing traffic, adjacent travel lanes, bicycle lanes, or sidewalks since vehicles off-track, which means that their travel path exceeds the width of the vehicle.

If high volumes of bus and truck traffic are anticipated on a roadway, such as in an industrial park, or on a dedicated busway, the designer may consider whether lanes wider than 12 feet are appropriate.

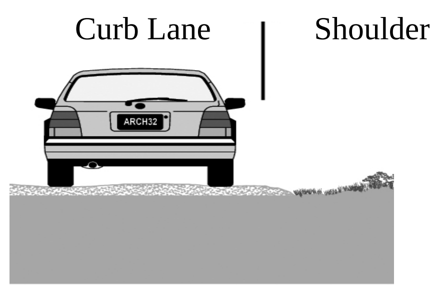
Lanes Narrower than 11-Feet

Narrower lanes reduce the amount of right-of-way dedicated to motor vehicle travel, leaving room for wider sidewalks, bicycle lanes, shoulders and on-street parking. Narrower lanes also reduce the crossing distance for pedestrians and can encourage lower operating speeds. In some settings, narrower lanes help to reduce the impact to roadside environmental or cultural resources. For lower speed, lower volume roads that primarily provide access to adjoining property, (such as minor collectors and local roads) narrower lanes may be appropriate to minimize right-of-way requirements and potential impacts to the built and natural environment.

In areas of limited right-of-way, 10-foot lanes can be provided so that the width of the shoulder can be increased to provide greater separation between pedestrians and bicycles and motor vehicles. The following section discusses the relationship between lane width and shoulder width.

Travel lanes narrower than 10 feet are only appropriate for local roadways and some minor collectors with very low traffic volumes and speeds. Lanes narrower than 9 feet are generally not recommended. However, on some low-volume local roads in residential areas, shared streets that do not allow two cars to pass simultaneously may be provided.

3.3.3.4 Curb Lane Plus Shoulder Width



Curb lane plus shoulder

Independent of the allocation between shoulders and travel lanes, the total width of the curb lane plus shoulder available for bicycle and motor vehicle travel is an important design element. For two-lane roadways, the curb lane plus shoulder width is key for determining the minimum cross-section. For example, a 14-foot curb lane plus shoulder dimension will allow a motor vehicle to pass a bicyclist without needing to change lanes (on a multilane section) or swerve into the oncoming lane (on a two lane section) and is the minimum value for collectors determined using Exhibit 3-11 and 3-14. This example results in a width of 28 feet for a two-lane collector. Using the minimum values in Exhibits 3-11 and 3-14, the minimum width for a two-lane arterial is 30 feet. Although these minimum examples are provided, the allocation of the pavement width between the curb lane and shoulder should be determined on a project-specific basis, as described in Section 3.2.

3.3.4 Complete Cross-Section Guidance

The previous sections provide guidance and dimensions for accommodation of individual roadway users within the cross-section. The following sections provide more specific guidance for the assembly of cross-sections based on the area and roadway types introduced in Chapter 1-2 including a discussion of the specific elements and dimensions commonly used in different area types. A discussion of freeways has been intentionally omitted from this Plan. Although there are freeways in Norwalk, they are under the jurisdiction of the State of Connecticut and are subject to design standards for Interstate Highways established by the Federal Highway Administration (FHWA) since they are components of the National Highway System (NHS).

3.3.4.1 Arterials and Major Collectors

Arterials and major collectors vary widely in character depending upon the areas through which they pass. Arterials and major collectors almost always accommodate pedestrian and bicycle travel. In most instances, arterials and major collectors are designed to accommodate pedestrians and bicycles using the first four cases described in Section 3.2.

Sidewalks are usually provided in developed areas (suburban high density areas, suburban villages and town centers and urban areas). Sidewalks may also be desirable in areas with lower development density such as suburban low density areas, rural developed areas and rural villages. In rural natural areas and other sparsely developed areas, pedestrian travel is often accommodated in the shoulder or by side paths.

Minor arterial in a town center

Usable shoulders are usually provided on arterials and major collectors outside of densely developed areas. In most cases, these shoulders are at least 4 feet wide to accommodate bicycle travel. Shoulders between 6 and 8 feet wide are desirable for emergency stopping and other functions, especially in high volume and high truck and bus areas. Although not common in Norwalk, in the case of high design speeds (greater than 45 miles per hour) 10-foot shoulders should be considered. In the case of wide shoulders, it is possible to provide a combination of paved and unpaved surfaces if the circumstances dictate such a treatment.

In rural villages, suburban town centers, and urban areas, usable shoulders are often replaced with on-street parking. In these areas it is desirable to provide bicycle lanes to maintain separate accommodation for bicycles. If there is insufficient right-of-way to support bicycle lanes and parking, then the designer should determine which element to provide within the available right-of-way or should consider traffic calming and shared lane pavement markings to improve the performance of shared bicycle/motor vehicle accommodation.

Travel lanes of 11 and 12 feet are usually provided on arterials and major collectors. In high volume, high truck and bus percentage, and high design speed areas, 12 foot lanes are particularly desirable. 10-foot lanes are sometimes used if speeds and truck and bus volumes are low (less than 250 per day or 30 in one hour), in multilane sections, or to provide wider shoulders in areas of limited right-of-way. Major collectors are sometimes constructed with 10 foot lanes in rural villages, suburban villages and town centers, and urban areas where right of way is particularly limited and competing demands are especially high. Lanes narrower than 10 feet are generally not used on arterials or major collectors.

In most cases, the designer should provide a combined shoulder plus curb lane dimension of at least 14 feet so that motor vehicles can pass bicycles without changing lanes or swerving. On State roadways, however, the maximum shoulder width shall be 8-feet.

3.3.4.2 Minor Collectors

The design of minor collectors is similar to that described above, especially for areas with higher traffic volumes and speeds. However, minor collectors are often designed for low speed, low volume operations. In these cases, minor collectors are sometimes designed to provide shared accommodation for all users, as described in Section 3.2, Case 5, with a curb-lane plus shoulder width of at least 12 feet. The designer may need to consider traffic calming measures to ensure that motor vehicle speeds are appropriate for shared use of the roadway.

3.3.4.3 Local Roads

The guidance provided for arterials and major collectors is suitable for local roads with high volumes and high speeds. Much like minor collectors, local roads are sometimes designed to provide shared accommodation for all users. On some low-volume local roads in residential areas, shared streets that do not allow motor vehicles to pass simultaneously are acceptable. The designer may need to consider traffic calming measures to ensure that motor vehicle speeds are appropriate for shared use of the roadway.

3.4 Public Transit Operations

Public transit often operates on roadways. In some cases, buses operate within mixed traffic and stop along the curbside. Also, a roadway design can incorporate lanes dedicated to, or with priority for, transit operations. The following sections discuss these public transit considerations associated with roadway cross-section. A more detailed discussion of design for transit stops at intersections is provided in Chapter 1-4.

3.4.1 Bus Stops

Project designers must consult with regional transit authorities to determine proper locations for bus stops..

The spacing of bus stops is a critical determinant of transit vehicle and system performance. The consideration of where to locate bus stops is a balance between providing short walking distances to bus stops and the increased travel time when the bus stops frequently. Thus, the decision of bus stop location should be made by the transit agencies and the City. On State roadways, bus stop determinations require approval from the Office of State Traffic Administration (OSTA) and should be made in conjunction with its staff. Bus stop locations also need to carefully consider the availability of sidewalks, crosswalks, and waiting areas. The role of the designer is to evaluate proposed locations to ensure that they are appropriate with regards to safety and operations.

This chapter focuses on mid-block bus stops since bus stops located at intersections are discussed in Chapter 1-4. Mid-block stops are generally located adjacent to major generators of transit ridership and offer the following advantages:

- Mid-block stops minimize the sight distance impacts of buses on pedestrians crossings (i.e. limited ability to see around the bus).
- Mid-block stops may result in less congested passenger waiting areas.

There are difficulties associated with mid-block stops; for example, mid-block stops create crossing difficulties for pedestrians unless a mid-block crosswalk is also provided. Bus stops and pedestrian routes should be considered together to make sure that the stops are safe and convenient for users (people tend to walk up to ¼ mile to access bus routes). Mid-block stops also require the removal of on-street parking for a substantial distance to accommodate the pull-in, stop, and pull-out maneuvers.

3.4.1.1 Bus Stop Dimensions

The two primary categories of bus stops are (1) curb-side bus stops and (2) bus bays. The most common are curb-side bus stops where the bus simply stops at the curb in the travel lane, shoulder or parking lane. A variation of this is a stop at a curb extension. Bus bays allow the through traffic to flow freely past the stopped bus. Most bus bays occur at mid-block locations, although it is sometimes desirable to create bus bays for far-side stops, with or without a queue jumper lane.

Curbside Bus Stop Zones

The minimum length of bus stops is 80 feet for mid-block bus stops and 60 feet for bus stops at intersections. These dimensions are for a typical 40-foot transit bus. If articulated buses are used, an additional 20 feet is required. Shorter distances may be acceptable to accommodate transit vans or mid-size buses.

An additional 50 feet of length is needed for every additional bus that is typically at the stop at the same time. Unless the stop is used for the layover of buses, a single stop position will be adequate if peak hour bus flow is less than 30 per hour.

Often the curbside stop makes use of a parking lane. Parking lanes are typically 7 to 8 feet wide. Buses require a minimum width of 10 feet. Therefore, if there is significant bus activity along a corridor and it is desirable to allow through traffic to pass unimpeded, a wider parking lane should be provided. In areas without on-street parking, a wide shoulder should be provided if bus stops are frequent and dwell times are long. Some variation to these guidelines may be necessary in constrained areas with sensitive roadside resources.

Bus Bays

The designer must determine when bus bays are more appropriate than curb-side bus stop zones. Among the factors are:

- Traffic in the curb lane exceeds 250 vehicles during the peak hour,
- Traffic speed is greater than 40 mph,
- Bus volumes are 10 or more per peak hour on the roadway,
- Passenger volumes exceed 20 to 40 boardings an hour,
- Average peak-period dwell times exceed 30 seconds per bus, and
- Buses are expected to layover at the location.

It should be noted, however, that when traffic volumes approach 1,000 vehicles per hour per lane, bus drivers tend not to use bus bays due to difficulties encountered in re-entering traffic lanes. Consideration should be given to these operational issues when contemplating the design of a bay on a high-volume road. Acceleration lanes, signal priority, or far-side placements are potential solutions.

60-foot transit

Ideally the design of bus turnouts should include tapers and lanes for deceleration and merging, but it is usually not practical to provide deceleration and merging lanes. Some key design elements are:

- A taper of 5 feet in length for every 1 foot of depth (5:1) is the minimum for deceleration. When the bus stop is on the far side of the intersection, the intersection may be used as the entry area to the stop.
- A taper of 3 feet of length for every 1 foot of depth (3:1) is the minimum for reentry. Where the stop is on the near side of the intersection, the width of the cross street is usually sufficient to provide the needed merging space.
- Bus bay widths should be 12 feet, although 10 feet is sufficient when traffic speeds are 30 mph or less.

3.4.1.2 Bus Stop Waiting Areas

The design for the curb-side elements of the bus stop (shelters, boarding platforms, walkways) must conform to ADA requirements. The ADA regulations, as well as the TCRP report *Guidelines for the Location and Design of Bus Stops*, provide detailed information. Among the key design elements are:

- An accessible pedestrian route to the bus stop.
- To accommodate use of a wheelchair lift, there must be a level (2 percent) landing area at least 60 inches wide. The depth of the landing area must be 8 feet. The bus stop pad must be free of obstructions.

Bus waiting area

- Bus shelters are typically 5 to 6 feet wide and 10 feet long. Interior clearance of 4 feet is required. Ideally, the shelters area should be sized for the anticipated volume of waiting passengers during peak boarding periods. They must be at-grade or ramped to accommodate a person using a wheelchair. Bus shelters should not be placed where they will restrict vehicular sight distance.

In addition to ADA requirements, the designer should consider urban design issues associated with the location of bus stops including:

- The character and adequacy of access routes for pedestrians, cyclists, and other potential transit users,
- Connectivity to nearby demand centers,
- Streetscape treatments to improve the visual character of the bus stop, and
- Architectural elements of shelter design or selection.

3.4.2 Dedicated Lanes

In some locations, lanes are provided for the exclusive or preferential use by transit vehicles. On most arterials and collectors, the curb lane is most commonly designated as a dedicated or priority transit lane. This choice allows the transit vehicle to stop at curbside bus stops. Often, these lanes are shared with bicycles, right-turning vehicles, taxicabs, bicyclists, or high occupancy vehicles.

Another alternative is to provide dedicated transit lanes within a center median. In this case, passengers must cross the other roadway lanes to reach the transit facility. This alternative operates in a manner similar to rail transit, described earlier in this section.

For all dedicated or priority lanes, the designer should strive to provide adequate lane and shoulder width so that transit vehicles operate with minimal interference from general traffic.

3.5 Other Cross-section Elements

The following sections describe three important elements of cross section design, medians and auxiliary lanes, cross-slopes required for positive drainage, and curbing.

3.5.1 Medians and Auxiliary Lanes

A ***median*** is the portion of a roadway separating opposing directions of the traveled way. Medians can influence the quality of service and safety provided for all roadway users. For example, medians can break up the width of a roadway and provide refuge for pedestrians crossing the street and vehicles (including bicycles) making turning or crossing movements.

Continuous medians can increase the speeds along a roadway, improving its efficiency for motor vehicles; however, this increased speed can have a negative impact on neighborhoods and on the safety of pedestrians and bicyclists. Potential traffic calming applications of medians are discussed further in Chapter 1-6. Medians can also be used to manage property access, channelize traffic movements, and accommodate aesthetic treatments.

Median width is expressed as the dimension between the edges of traveled way and includes left shoulders if they are provided. A uniform median width is desirable. However, variable width medians may be advantageous where right of way is restricted, at-grade intersections are widely spaced, or an independent alignment is desirable to minimize cut and fill, to minimize environmental impacts, or for aesthetic purposes.

The type of median selected and its dimensions will depend upon many factors, including:

- Area type,
- Roadway type,
- Availability of right of way,
- Transportation demands,
- Pedestrian and bicycle crossings,
- Presence and type of transit operations,
- Design speed,
- Clear zone and recovery area guidelines,
- Landscaping and aesthetic considerations,
- Drainage needs,
- Snow and ice impacts,
- Maintenance considerations, and
- Superelevation impacts.

Medians are most frequently used on multilane roads. Medians may also be included on two-lane roadways; however additional travelway width is often required for emergency vehicle access.

In some cases, medians include auxiliary (turning) lanes that provide access to driveways or increase capacity and safety at intersections. These auxiliary lanes are discussed in more detail in Chapter 1-4. Several different types of medians are possible as described in the following sections.

3.5.1.1 Raised Medians

Raised medians are central areas at an elevation higher than the surface of the road. A raised curb usually provides this elevation difference. Raised medians are usually found on arterials, collectors and local roads in more densely developed areas with design speeds of 45 miles per hour or less.

Raised medians are often the preferred median type in areas with high pedestrian crossings, where access control is desired, or where decorative landscaping is desired. Raised medians offer some advantages over other median treatments including:

- Mid-block left turns are eliminated,
- Space is available for aesthetic treatments,
- A protected location is available for traffic signs, signals, pedestrian, bicycle, and turning traffic refuge;,
- Left-turns can be more effectively channelized,
- A location is provided for snow storage,
- The median edges are discernible, and
- Drainage may be improved.

Some disadvantages of raised medians when compared to other median treatments include:

- They are more expensive to construct,
- They may require greater widths than other median to serve the same function (e.g., left-turn lanes at intersections),
- Curbs may cause a driver to lose control if struck, and
- Prohibiting mid-block left turns may overload street intersections and may increase the number of U-turns

The minimum total width of the raised median should be 4 feet including curbs, and on State roadways it should be consistent with the Department's Highway Design Manual. In areas with low pedestrian and bicycle activity, raised areas may use sloped edging. This configuration provides the minimal width median and minimum offsets between the travel lane and vertical curb.

In most cases, it is desirable to provide an 8- to 10-foot median with a 6-foot raised refuge area and 1- to 2-foot offsets between the vertical curb and the travel lane. Where refuge is required for pedestrians and bicycles vertical curb should be used. Additionally, crossings should be carefully located to serve desired crossing locations and accessibility must be provided for wheelchair users.

Typical raised median on an urban arterial

Wider medians, between 10 and 18 feet, more effectively support landscaping, provide higher quality refuge, provide increased lateral clearance to signage, streetlights, and landscape features, and support left-turn lanes. When left turns are provided at intersections, an 18-foot width is desirable to support a 12-foot turn lane and maintain a 6-foot median, although narrower configurations are possible. The designer must consider sight distance limitations and potential obstacles when selecting median plantings.

3.5.1.2 Flush Medians

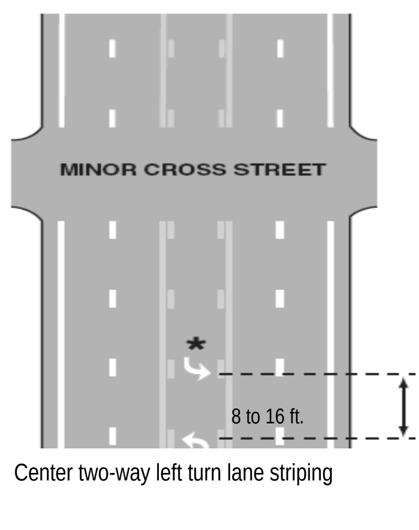
Flush medians contain a central area at approximately the same elevation as the roadway surface. Flush medians are usually found on arterials, collectors and local roads in areas with limited right-of-way. Flush medians may be found on freeways if combined with a median barrier.

A flush median is generally paved and may or may not have a barrier depending on traffic conditions. It is normally crowned to provide positive drainage and discourage parking. The median is often designated using scored concrete or pavement markings. All flush medians should be marked according to the criteria in the *Manual on Uniform Traffic Control Devices* (MUTCD).

When included on arterials, collectors and local roads to provide left-turn lanes, the median is usually between 12 feet and 16 feet wide. The 16-foot median provides for a 4-foot separation from the opposing traffic. In areas with low truck and bus volumes, a left-turn lane as narrow as 10 feet can be provided, reducing the desirable median width to 14 feet. Where left shoulders are provided, the dimension required for usable shoulder should be added to the above median widths.

Two-Way Continuous Left-Turn (TWLT) Lanes

The ***two-way left-turn lane*** is a special application of flush medians which allows turning movements along its entire length. TWLTs may be appropriate in areas with frequent driveway spacing in highly developed, or commercialized areas. Two-way left-turn lanes are appropriate on roadways with no more than two through lanes in each direction and where operating speeds are in the range of 30 miles per hour.



Center two-way left turn lane striping

TWLT lanes may be used where daily traffic through volumes are between 10,000 and 20,000 vehicle per day for 4-lane roadways and between 5,000 and 12,000 vehicles per day for

2-lane roadways. Left-turn movements should consist of at least 70 turns per quarter mile during the peak hours and/or 20 percent of the total volume. Careful evaluation of individual sites is required for implementation of TWLT lanes.

The signage and striping patterns for TWLT lanes should be designed in accordance with the MUTCD. Lane widths between 12 and 16 feet are suitable for TWLT lanes. On roadways with high volumes, or moderate to high speeds (30 to 45 miles per hour) a 14-foot TWLT lane should be provided. TWLT lanes are not appropriate on roadways with design speeds greater than 45 miles per hour.

In most cases, it is preferable to provide a raised median with periodic turn lanes serving major driveways and intersecting streets instead of a TWLT lane. This preferred treatment provides improved delineation of turning movements and improved pedestrian refuge. However, if driveway spacing is frequent and turning volumes are heavy, then the two-way left-turn lane may be suitable. Access management techniques such as driveway consolidation to facilitate the preferred treatment are discussed in Chapter 1-7.

3.5.1.3 Context Influence on Median Design

Design of medians varies considerably based on the area through which the roadway passes. In rural natural, rural developed, and suburban low density areas, wider medians are often selected. In suburban high density, and urban areas, narrow medians are more frequently encountered. The addition of medians in rural villages, suburban villages and town centers, and some urban areas may conflict with the character of these areas and should be considered carefully from an urban design perspective.

Similarly, the additional right-of-way required for medians may result in increased costs, environmental impacts, and community impacts. The benefits and impacts of providing a median and its width should also be carefully considered. In many cases medians can occupy right-of-way that could be used for other purposes such as bicycle lanes, on-street parking, and wider sidewalks. In cases where medians are proposed for aesthetic purposes, the designer should consider whether it is more advantageous to locate the landscaped space along the sides of the roadway.

In all areas, if a median is desired, a narrow median or barrier, such as double-faced guardrail or concrete “jersey” barriers, may be appropriate to limit the needed right of way and impacts to the natural or built environment. However, for freeways and major arterials, wider medians may provide greater safety and operational benefits and may allow separate alignments for each direction of travel, reducing the impact of the roadway on the surrounding context. While double-faced guardrail or concrete “jersey” barriers may conflict with the character of a particular area, there are times when a constrained width that requires separation calls for these types of barriers to minimize land use impacts.

3.5.1.4 Roadway Type Influence on Median Design

The functions that a median provides vary depending on the type of roadway on which they are found. Medians are provided on all freeways and some arterials, primarily to achieve safety and operational benefits through access management. On collectors and local roads, medians are provided primarily for access management, aesthetic reasons, to provide a location for traffic signals and signage, and to provide refuge for pedestrians or bicyclists crossing the road. Typical median functions for different roadway types are shown in Exhibit 3-15 and discussed in the following sections.

Exhibit 3-15 Typical Median Functions by Roadway Type

Median Function	Arterials	Collectors and Local Roads
Separation from opposing traffic	X	
Access management	X	X
Refuge area for pedestrians and bicyclists	X	X
Refuge for emergency stops	X	
Area for control of errant vehicles	X	
Reduction in headlight glare	X	
Area for deceleration and storage of left-turning and U-turning vehicles	X	X
Enforcement and traffic management areas	X	X
Area for storage of vehicles crossing at intersections	X	X
Space for snow storage	X	
Landscaping (Medians greater than 10 feet wide)	X	X
Increased drainage collection area	X	
Area for placement of luminary supports, traffic signs, traffic signals, guardrail, and bridge piers	X	X
Area for future additional lanes (Medians greater than 30 feet wide)	X	X

Source: *Flexibility in Highway Design*, AASHTO 2004. Chapter 6 Cross Section Elements

Arterials

Medians are desirable on arterials carrying four or more lanes. However, the designer should usually provide the most desirable accommodation for roadway users before dedicating space to a median. The median width is often selected based on the need for left-turn storage lanes. Additionally, for unsignalized or rural roadways, a median must be at least 25 feet wide to allow a crossing passenger vehicle to stop safely between the two roadways; however, at signalized intersections, wide medians can lead to inefficient traffic operations. Medians in the range of 12 to 25 feet are commonly selected for these types of roadways.

Collectors and Local Roads

Medians may also be included in the design of collectors and local streets, although these applications are less frequent given the lower speeds and volumes associated with these roadway types. In these cases, medians are often included to enhance the visual appearance of a roadway through decorative landscaping rather than to realize substantial safety or operational benefits. Medians in these circumstances are usually at least 10 feet wide to improve the health of the landscaping and to facilitate its maintenance.

3.5.2 Cross Slopes

Surface cross slopes are necessary on all components of the cross-section to facilitate drainage. This reduces the hazard of wet pavements and standing water. On hot-mix asphalt pavement travel lanes should be designed for a cross slope of 2 percent. Concrete pavements cross slopes should be designed to 1.6 percent for lanes adjacent to the crown, and 2 percent for all other lanes. For lower classes of pavement, higher cross slopes may be desirable to achieve the design drainage. Cross-slopes should also be provided on sidewalks, shoulders, parking lanes, intersections, driveway crossings, and bicycle lanes.

3.5.3 Curbs, Berms and Edging

Curbs, berms, and edging are roadside elements, usually constructed of granite or extruded bituminous concrete used to define the pavement edge and to control drainage. Typical types of curbs, berms, and edging and their heights are provided in Exhibit 3-16.

Exhibit 3-16 Typical Curb Heights

Curb Type	Vertical Height (inches)
Bridge curb	8
Barrier curb	6
Sloped edging	4
Type A berm	2

Adapted from A Policy on Geometric Design of Highways and Streets, AASHTO, 2011. Chapter 4 Cross Section Elements

Barrier curbs are vertical and are usually granite. Barrier curbs range in height from 6 to 8 inches with a batter of 15:1 or steeper. Six-inch curbs are typically used along roadways. ***Bridge curbs*** are barrier curbs, usually with 8-inch reveal used on bridges to provide additional protection for pedestrians or other bridge elements along the roadside. However, even these curbs are not adequate to prevent a vehicle from leaving the roadway. Where positive protection is required, a suitable traffic barrier should be provided.

Curbs are used extensively on urban and suburban streets and highways. Curbs are not commonly used in rural areas unless they are protecting an adjacent sidewalk. Curbs help restrict vehicles to the pavement area, and define points of access to abutting properties. Vertical curbing is appropriate on lower speed, urban streets where landscaping, signal equipment, streetlights, or other features are located within the median or along the roadside. Vertical curbing should also be used on crossing islands and other locations where protection of pedestrians is needed.

Sloped edging is usually granite and should be used for edge delineation and on traffic islands when design speeds are greater than 45 miles per hour since vertical curbs are not suitable for the high speed environment.

Type A Berm is usually extruded bituminous concrete and can be used when drainage control is needed on roadways that do not have continuous curb. It directs water to closed drainage systems, prevents sloughing of the pavement edge and provides additional lateral support. The Type A berm should be used only:

- where the longitudinal grade exceeds 5% for an extended length, or
- where control and collection of drainage is otherwise required.

Pavement milling mulch, or other suitable material, should be used in lieu of berm under guardrails and in other areas where control of erosion from roadway runoff is a concern.

If the paved shoulders on high speed facilities are not wide enough for a vehicle to move out of the traveled way, sloped edging or berms should be easily mountable to encourage motorists to park clear of the traveled way. Berms or sloped edging used in these situations is 4 inches or less in height and have rounded or plane sloping faces.

3.6 Roadside Elements

Roadside features significantly affect safety, construction and maintenance costs, right of way requirements, drainage, environmental impacts, and aesthetics. The designer should consult the 2011 AASHTO *Roadside Design Guide* (or most recent version) which provides standards and recommendations on the design of roadside elements including clear zones, roadside barriers, median barriers, impact attenuators, side slopes/cuts, and ditch sections.

3.7 Utilities and Signage

The location of utilities and the placement of signage are often significant issues in the design of roadway improvements as described below.

3.7.1 Utility Placement or Relocation

Since they provide a public service, utilities are allowed to occupy the public right-of-way. Coordination with utility companies is essential during the design and construction process to identify the appropriate location for utilities and the necessary steps for relocation of existing utilities (if required). Ideally, utility placement or relocation will occur is sequence with the construction of the roadway project so that disruption to the public minimized.

In general, overhead utility poles should be located outside the shoulders, sidewalk, and roadside recovery areas (if provided). If utility poles cannot be located outside of the sidewalk area, it is important that the minimum clear path of travel for pedestrians described previously is provided. Additionally, utility poles should be offset at least two feet from the face of curb when located within the sidewalk area or buffer strip.

It is usually advisable to assess the condition and need for replacement of below-grade utilities during the planned roadway construction. The proponent should coordinate with municipal departments and other utilities to identify any utility work to be coordinated with the roadway project.

3.7.2 Signage Placement

The types and mountings of signs varies significantly depending on the roadway type and setting. Detailed guidance for the placement of signs is contained in the MUTCD. Similar to utilities, signage cannot protrude into the shoulders or traveled way. In locations where the sidewalk is immediately adjacent to the street, it is often desirable to place signage at the back of sidewalk. If signage is placed along the curb edge, sign posts should be located no closer than ½ the width of the sign face plus one additional foot from the face of curb.

3.8 Right-of-Way

The necessary right-of-way (ROW) width is the summation of all cross-section elements: utility accommodations, clear zones, drainage ditches, sidewalks, buffer strips, curbs or berms, shoulders and bicycle lanes, motor vehicle travel lanes, and medians. Consideration should also be given to the possibility of adding travel lanes in the future. However, land use patterns, availability and cost of right-of-way may dictate the type and width of cross-section elements that are provided.

The ROW width will vary greatly and the designer must always research the current ROW width as an initial step. Typically, an undivided, two-lane rural major collector or arterial has a ROW width of 66 feet. Lower classes of roadway or low volume facilities might have narrower ROWs while major highways require more ROW. In most cases, urban streets and highways have less available ROW than rural highways.

Ideally, ROW width should be uniform along a roadway segment. In urban areas, variable widths may be necessary due to existing development. Varying side slopes and embankment heights may make it desirable to vary ROW width and ROW limits will likely have to be adjusted at intersections and freeway interchanges. Other special ROW controls should also be considered:

- At horizontal curves and intersections additional ROW acquisition may be warranted to ensure that the necessary sight distance is always available in the future.
- In areas where the desired ROW widths cannot be reasonably obtained, the designer will have to consider the advisability of using steeper slopes, revising grades, or using slope retaining treatments.
- Right of way should be acquired and reserved for future improvements such as roadway widening and interchange completion.
- On sections of highway adjacent to railroads, any encroachment on railroad ROW should be avoided, whenever possible.
- Permanent slope easements with maintenance rights should be considered to minimize public ownership of land.
- Because a road is an inherent part of a community, the engineer needs to pay special attention to right-of-way impact on cultural and commercial features.
- Additional right of way is often required for wetland mitigation.

3.9 For Further Information

- *Highway Safety Manual, 1st Edition*, AASHTO 2010.
- *A Guide to Achieving Flexibility in Highway Design*, AASHTO 2004.
- *Flexibility in Highway Design,* FHWA, 1997.
- *A Policy on Geometric Design of Highways and Streets*, AASHTO, 2011.
- *Highway Capacity Manual, Special Report No. 209*, Transportation Research Board 1995.
- *Roadside Design Guide, 4th Edition,* AASHTO, 2011.
- *A Guide for Transportation Landscape and Environmental Design*, AASHTO, 1991.
- *Guide for High Occupancy Vehicle Facilities*, AASHTO, 2004.
- *Compendium of the Safety Effectiveness of Highway Design Features*, Publication FHWA-RD-91-044 through 049 (6 volumes), 1991.
- *Americans with Disabilities Act Handbook*, December 1991.
- *AASHTO Guide for the Development of Bicycle Facilities,* 2012.
- *Urban Bikeway Design Guide*, NACTO, 2011.
- *FHWA Bicycle Compatibility Index, A Level of Service Concept, Implementation Manual,* Publication FHWA-RD-98-095, 1998.

- *AASHTO Guide for the Planning Design and Operation of Pedestrian Facilities,* July 2004.
- *Manual for Assessing Safety Hardware, 1st Edition*, AASHTO, 2009.
- *Manual on Uniform Traffic Control Devices*, Federal Highway Administration, 2009.
- *TCRP Report 19 – Guidelines for the Location and Design of Bus Stops, 1996.*