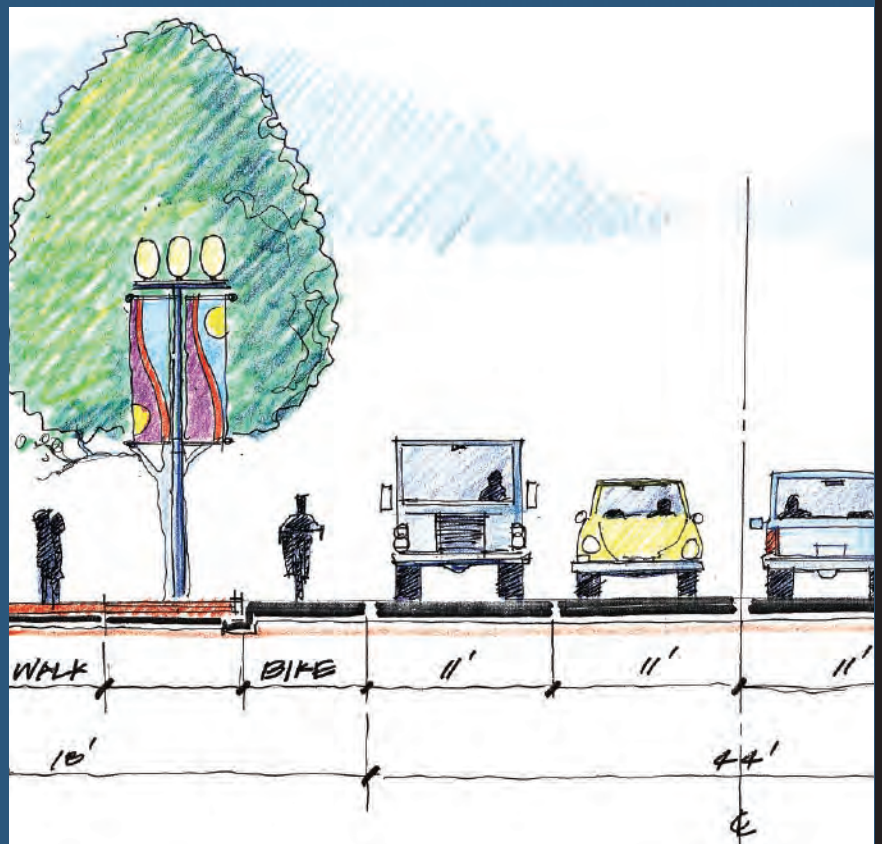


Chapter 5

Cross-Section and Roadside Elements



Cross-Section and Roadside Elements

5.1 Introduction

The basic design controls described in Chapter 3 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.

5.1.1 Multimodal Accommodation and Context Sensitivity

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

- (1) 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.
- (2) 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 communities, highway officials, and designers, this Guidebook provides options and recommendations for safe accommodation of

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.

pedestrians, bicycles, vehicular traffic, and public transit operations.

General approaches to cross-section formulation are discussed in Section 5.2.

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 as required under Chapter 87 of state law.

Detailed description of the following cross-section elements associated with different roadway users are described in Section 5.3:

■ **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 3.

5.1.2 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.

5.1.2.1 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 5.4 and include:

- Rail transit facilities,
- Bus stops, and
- Dedicated lanes.

5.1.2.2 Other Cross-section Design Features

Section 5.5 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.

5.1.2.3 Roadside Elements

Section 5.6 provides recommendations for treatment of the roadside elements including:

- Clear zones,
- Slopes and cuts,
- Ditch sections, and
- Barrier systems.

5.1.2.4 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 5.7.

5.1.2.5 Right-of-Way

Section 5.8 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).

5.2 Multimodal Accommodation

*Multimodal
Accommodation
Performance Goal:*

*The designer should
provide safe, convenient,
and comfortable travel for
all roadway users.*

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 MassHighway 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.

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 3 (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. When an improvement is being pursued as a Footprint Roads project, the designer should provide the best accommodation for pedestrians and bicyclists to the extent possible, consistent with Chapter 87 of the Acts of 1996.

5.2.1 Case 1: Separate Accommodation for All Users

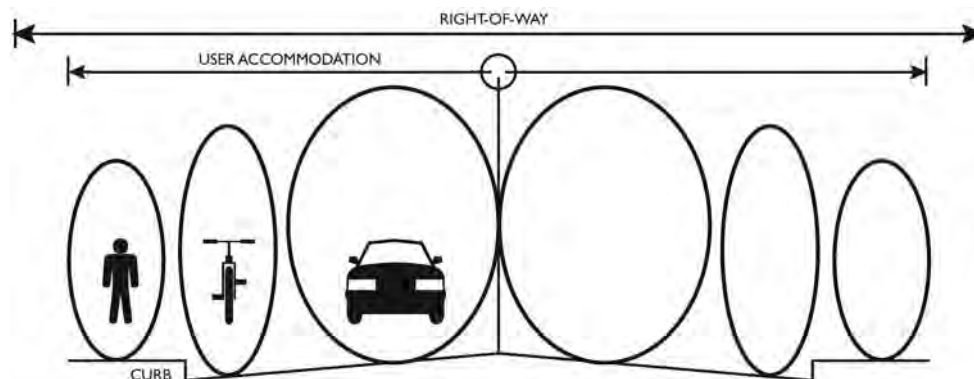
Case 1 provides the maximum separate accommodation for all modes of travel, as illustrated in Exhibit 5-1. This is often the preferred option in terms of providing safe, convenient, and comfortable travel for all users. It is usually found in areas of moderate to high density (urban areas, suburban villages 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.

Exhibit 5-1

Case 1: Separate Accommodation For All Users



Source: MassHighway

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.

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.

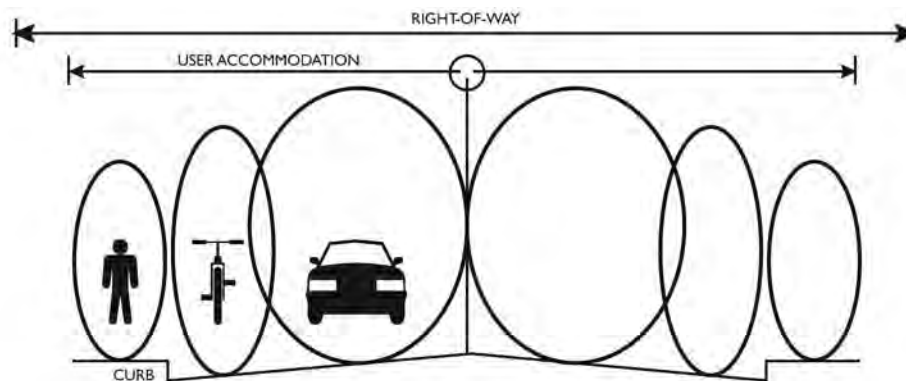
5.2.2 Case 2: Partial Sharing for Bicycles and Motor Vehicles

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 5-2.

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 5-2 Case 2: Partial Sharing for Bicycles and Motor Vehicles



Source: MassHighway

In Case 2, there is some overlap between the space provided for bicycle use and that provided for motor vehicle travel. Depending on the lane and shoulder widths provided, Case 2 accommodation may require a Design Exception. 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.

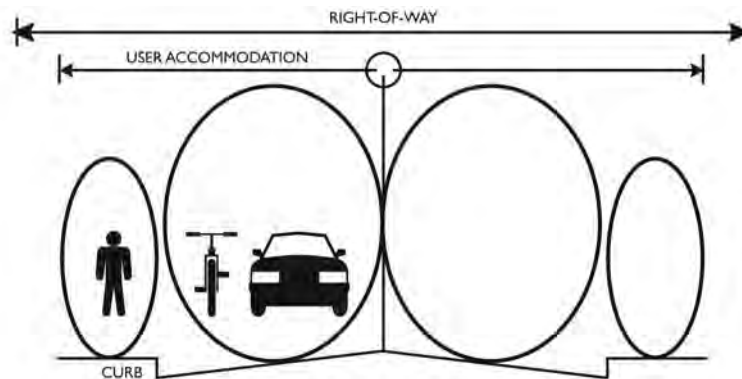
Wide curb lanes have also been used in Case 2; however, studies have shown that motorists and bicycles are less likely to conflict with each other and motorists are less likely to swerve into oncoming traffic as they pass a bicyclist when shoulder striping is provided.

5.2.3 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 5-3. 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 5-3

Case 3: Shared Bicycle/Motor Vehicle Accommodation



Source: MassHighway

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. For arterial and collector roadways, application of Case 3 will require a Design Exception. 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.

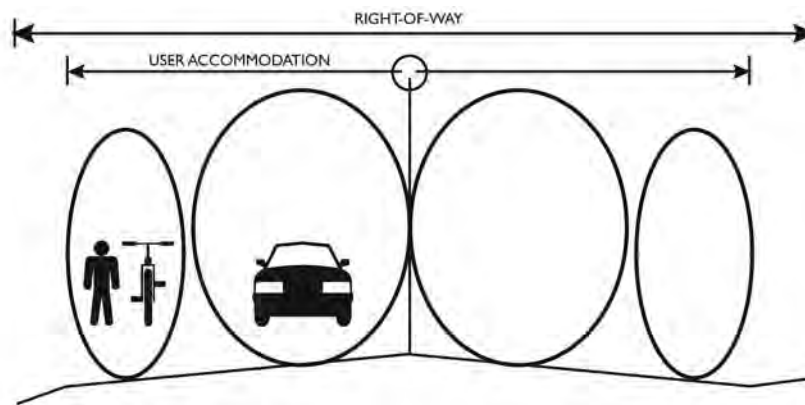
Signs and pavement markings indicating that the roadway is shared between cyclists and motor vehicles should be provided for Case 3 roadways. On-street parking is often found on these roadways and separate shoulders or bicycle lanes are not available.

5.2.4 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 5-4.

Exhibit 5-4

Case 4: Shared Bicycle/Pedestrian Accommodation



Source: MassHighway

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.

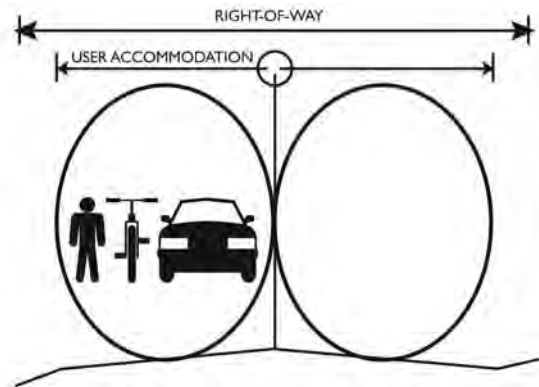
5.2.5 Case 5: Shared Accommodation for All Users

Vehicles, bicycles, and pedestrians are sometimes accommodated in one shared travel lane, as illustrated in Exhibit 5-5. This condition occurs when there is low user demand and speeds are very low, or when severe constraints limit the feasibility of providing shoulders. With the exception of local roads, Case 5 accommodation will require a Design Exception.

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. The designer should note that these paths may be subject to strict interpretation of

the walkway design criteria specified in 521 CMR (*Rules and Regulations of the Massachusetts Architectural Access Board*).

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



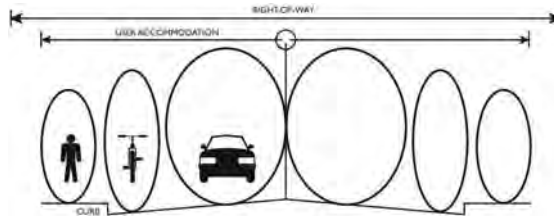
Source: MassHighway

5.2.6 Summary of Accommodation Option

Exhibit 5-6 provides a summary of the multimodal accommodation options available to the designer.

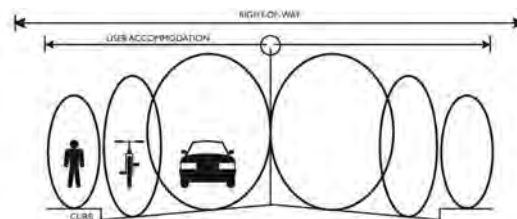
Exhibit 5-6 Summary of Multi-modal Accommodation Options

Case 1: Separate Accommodation for All Users



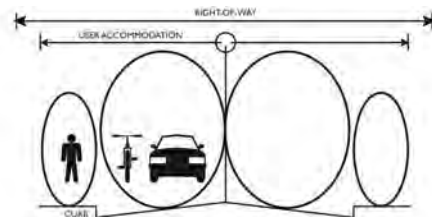
- Often the preferred option to provide safe, convenient, and comfortable travel for all users.
- Appropriate for areas with moderate to high levels of pedestrian and bicycle activity.
- Appropriate for roadways with moderate to high motor vehicle speeds.
- Appropriate in areas without substantial environmental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

Case 2: Partial Sharing for Bicycles and Motor Vehicles



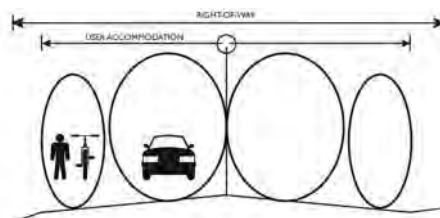
- Used in areas where the width necessary to provide Case 1 accommodation is not available.
- Under Case 2, pedestrians are provided with a sidewalk or separate path while space for bicyclists and drivers overlap somewhat.
- Appropriate in areas with low motor vehicle speeds and low to moderate motor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

Case 3: Shared Bicycle/Motor Vehicle Accommodation



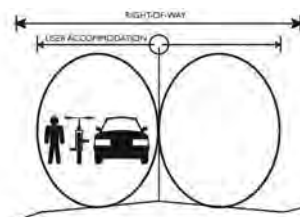
- Under Case 3, pedestrians remain separate but bicycle and motor vehicle space is shared.
- Used in densely developed areas where right-of-way is constrained.
- Also applicable to most residential/local streets where speeds and traffic volumes are low.

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.

Source: MassHighway

5.3 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.

5.3.1 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, as further discussed in Chapter 11.

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 16.

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.

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. 521 CMR (*Rules and Regulations of the Massachusetts Architectural Access Board*) apply to "prepared pedestrian ways." Whenever a pedestrian path is created, it must meet the minimum standards for sidewalks ("prepared walks in the public way") or walkways (an exterior path with a prepared surface intended for pedestrian use). These requirements are further discussed in Chapter 6.

5.3.1.1 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.

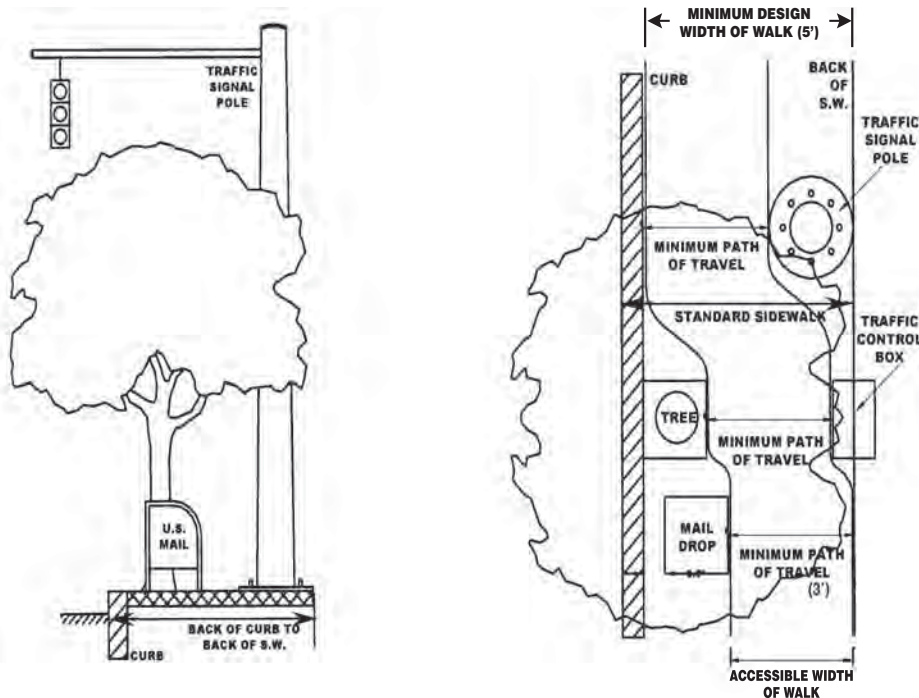
Dimensions and Clear Width

The spatial requirements of pedestrians are described in Chapter 3. The minimum width for a sidewalk is 5 feet excluding the width of the curb, although a 3 foot clear width (plus the width of the curb) is sufficient to bypass occasional obstructions, as illustrated in Exhibit 5-7. 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.

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.

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.

Exhibit 5-7 Clear Accessible Path

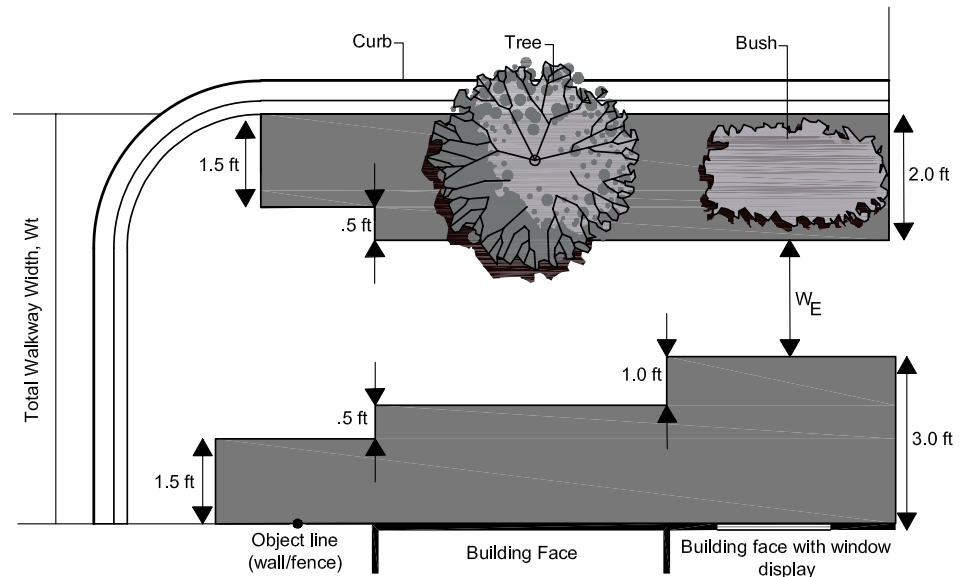


Source: Adapted from the Guide for the Planning, Design, and Operation of Pedestrian Facilities, AASHTO, 2004. Chapter 3 Pedestrian Facility Design

Sidewalks commonly accommodate **street furniture** which includes items such as, trees, utilities, 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 5-8.

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.

Exhibit 5-8 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 521 CMR (*Rules and Regulations of the Massachusetts Architectural Access Board*).

Sidewalks are also crossed by driveways and intersected by streets. These crossings are described in more detail in Chapter 6. *MassHighway's Standard Construction and Traffic Details* provide illustrations for driveway crossings. 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.

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).

5.3.1.2 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 5.3.3.1, 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. When shoulder use is the pedestrian accommodation, it should meet the requirements of “walkways” under 521 CMR, the Massachusetts Architectural Access Board rules and regulations, to the extent feasible.

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

5.3.1.3 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. When shared lanes are the pedestrian accommodation, they should meet the requirements of “walkways” under 521 CMR, the Massachusetts Architectural Access Board rules and regulations, to the extent feasible.

5.3.1.4 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.

Off-road paths must comply with 521 CMR. Depending on their location to the roadway, these off-road paths may need to meet 521 CMR’s “walkway” regulations as opposed to its “sidewalk” regulations. The slope of sidewalks can follow that of the natural terrain, but the slope of walkways is limited to 5 percent. A walkway that has slopes between 5 percent and 8.3 percent is permitted, but it must meet 521 CMR’s ramp requirements for handrails and rest areas. A walkway that is not along a vehicular way can not have a slope exceeding 5 percent in the build environment. A ramp can not have a slope exceeding 8.3 percent. This is discussed in detail in Chapter 6. The U.S. Access Board guidelines presented in its proposed *Guidelines for Outdoor Developed Areas* provide additional information on the design of paths. The design standards for off-road paths and trails are presented in Chapter 11.

5.3.2 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 and community plans.

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 3. 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 (see Chapter 11 for more details) 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* provides a useful tool for reviewing the suitability of various approaches to bicycle

accommodation. The types of accommodation typically used are described in the following sections.

5.3.2.1 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 6.

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.

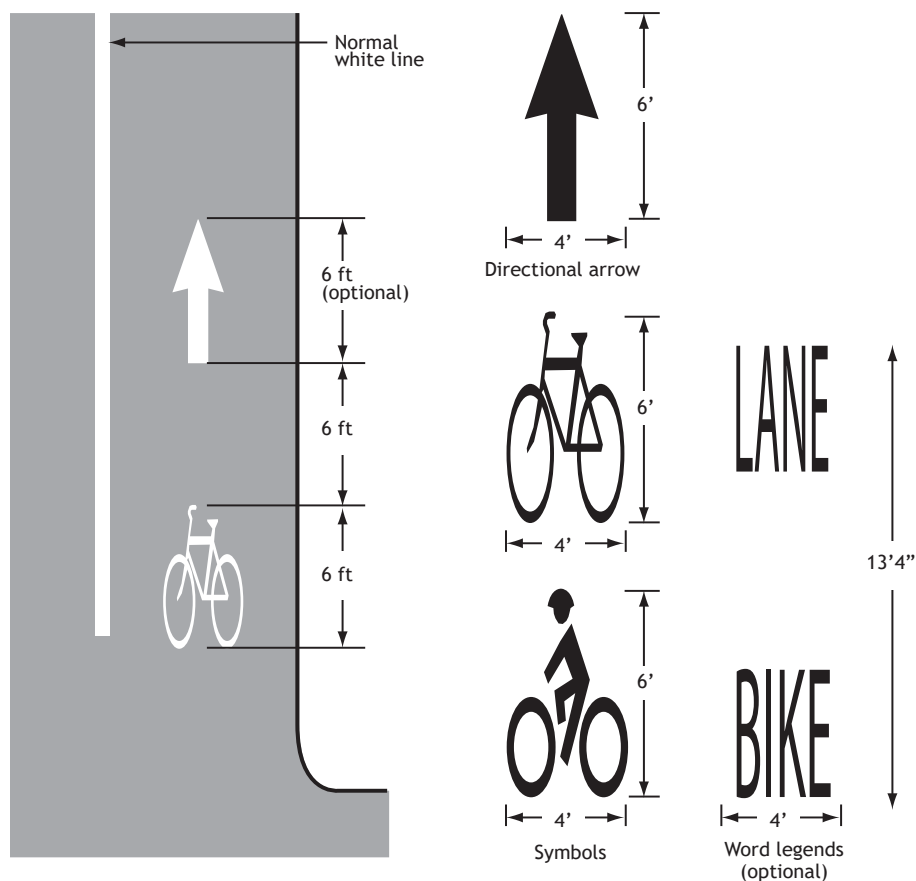
Bicycle lanes should be designated by a 6-inch solid white line on the right edge of the motor vehicle travel lane. This marking should change to a broken white line before any intersections on the right side, providing sufficient distance for motorists to merge to the right side of the roadway before 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 5-9, and signage can also be installed to reinforce the intended use of the bicycle lane.

5.3.2.2 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 5-9 Bicycle Lane Pavement Markings



Source: Guide for the Development of Bicycle Facilities, AASHTO, 1999. Chapter 2 Design
Manual on Uniform Traffic Control Devices, FHWA, 2003. Chapter 3 Pavement Markings

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.

5.3.2.3 Shared Lanes

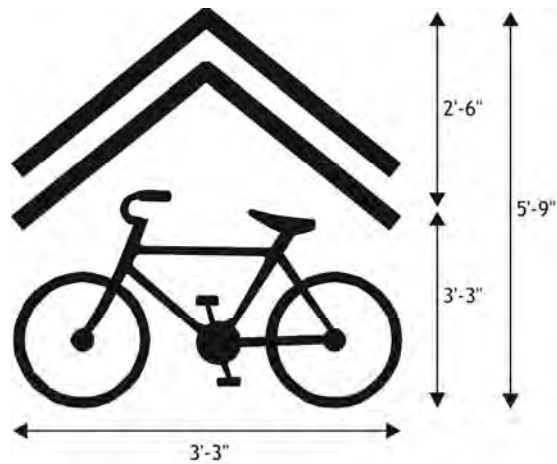
Shared lanes refer to use of the normal travel lanes by both motor vehicles and bicyclists. By law, bicyclists may use the travel lane. Most roadways in Massachusetts have neither shoulders nor bicycle lanes. Thus lanes shared by motorists and bicyclists are the most common situation. Lanes at least 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 bicycle sharing pavement markings such as those illustrated in Exhibit 5-10 (a demonstration marking currently in use in other states) and "Share the Road" 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 5-10 Shared Street Pavement Markings



Source: San Francisco Bicycle Guide

5.3.2.4 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. Design guidance for shared use paths is provided in Chapter 11.

5.3.3 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 recent guidelines from AASHTO including the recently published *Guide for Achieving Flexibility in Highway Design*. Flexibility is permitted to encourage independent designs tailored to particular situations. For example, MassHighway's Footprint Roads Program is one way designers can seek exemptions from established design criteria under very 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 3. 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.

5.3.3.1 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 5-11. Shoulders do not include on-street parking since the shoulders can not serve the purposes listed in Exhibit 5-11 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. These considerations should be thoroughly documented in the *Project Planning Report*.

Exhibit 5-11 Minimum Shoulder Width (in feet) to Provide Various Functions

Shoulder Function	Roadway Type	
	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 5-12 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.

In areas where horseback riders and agricultural equipment are common, wider shoulders can provide accommodation for these users. In these cases some of the shoulder width can be unpaved.

Exhibit 5-12 Widths of Usable Shoulders (In Feet)

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

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

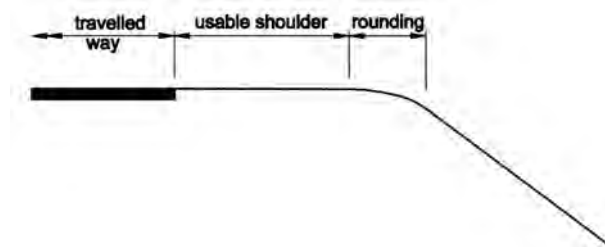
1 Left shoulders are required on Freeways and other divided roadways. See the AASHTO Green Book for left-shoulder guidance.

2 Shoulder widths less than the values shown above may be used if a design exception is obtained. See Chapter 2 for a description of the design exception procedure. 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 a design exception 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. Footprint road projects, as described in Chapter 2, could also consider narrower shoulders.

Exhibit 5-13 Usable Shoulders



Source: Adapted from A Policy on Geometric Design of Highways and Streets, AASHTO 2004, Chapter 4 Cross-Section Elements.

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 5-13. 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.
- Along high speed, high volume roadways, such as freeways, safety considerations may warrant shoulder rumble strips at appropriate locations. (Where bicyclists are permitted, shoulder rumble strips should not be used unless 5 feet of clear shoulder width exists between the rumble strips and the outer edge of the shoulder).

5.3.3.2 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 (see Chapter 16 for details).

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. Due to its impacts on traffic flow and the safety implications of parking maneuvers at high speeds, on-street parking should not be provided with high design speeds (over 45 miles per hour).

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.



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

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.

At the time of this Guide's printing, the Federal Access Board's ADA Accessibility Guidelines for public rights of way had not yet been finalized. Notwithstanding this lack of regulation, the Commonwealth and municipalities are required to provide accessible parking if public parking is provided. Accessible parking spaces should be provided in numbers agreed to by localities, 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.

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. Additional considerations for angle parking are presented in Chapter 16.

5.3.3.3 Travel Lanes

Travel lanes are the component of the roadway cross section that serves 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 Chapters 2 and 3). 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 5-14 summarizes travel lane widths for various area and roadway types.

Exhibit 5-14
Range of Travel Lane Widths (In Feet)

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

¹ Lane widths less than the values shown above may be used if a design exception is obtained. See Chapter 2 for a description of the design exception procedure. 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 2004, Chapter 4 Cross-Section Elements.

In addition to through lanes, **auxiliary lanes** such as additional turning lanes, high-occupancy vehicle (HOV) 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 6. 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.

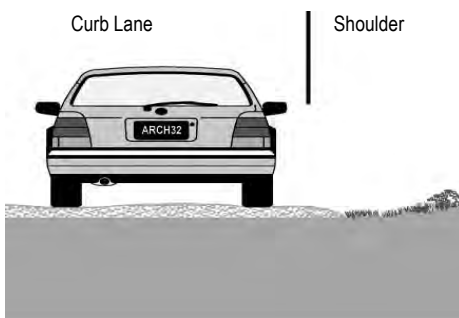
Lanes Narrower than 11-Feet

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.

5.3.3.4 Curb Lane Plus Shoulder Width



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 5-11 and 5-14. This example results in a width of 28 feet for a two-lane collector. Using the minimum values in Exhibits 5-11 and 5-

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 5.2.

5.3.4 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 3 including a discussion of the specific elements and dimensions commonly used in different area types.

5.3.4.1 Freeways

Freeways are the only class of road on which pedestrian and bicycle travel is prohibited, except in unusual or emergency circumstances. Shared use paths are possible within freeway right-of-way to accommodate pedestrian and bicycle travel. The design guidelines for these paths are presented in Chapter 11.

Freeways should have a minimum of two through lanes for each direction of travel. The lanes should be 12 feet wide. Right and left shoulders should also be provided on freeways. Along the right side of freeways, 10-foot shoulders should be provided. The right shoulder should be increased to 12 feet when truck and bus volumes are greater than 250 per hour.

Along the left side of four-lane freeways, 4-foot shoulders should be provided and 8-foot shoulders are desirable. On six (or more) lane freeways, 10-foot left shoulders should be provided. If truck and bus volumes are greater than 250 per hour, then the left shoulder should be increased to 12 feet. An additional 2-foot offset is required from the edge of usable shoulder to any vertical barrier. Additionally, for freeways, rumble strips are recommended along the outside edge of the traveled way to alert errant drivers that they have left the traveled way.

Freeway design standards for Interstate Highways are established by the Federal Highway Administration (FHWA) since they are components of the National Highway System (NHS). Freeways are unlikely to pass through rural villages and suburban town centers since the design characteristics of freeways are incompatible with these area-types.

Some two-lane major arterials are also designed as high-speed roadways with access limited to grade-separated interchanges. Freeway standards may also be appropriate for these roadways.

5.3.4.2 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 5.2.



Minor arterial in a town center

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.

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. When design speeds are high (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.

5.3.4.3 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 5.2, 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.

5.3.4.4 Local Roads

Local roads are generally constructed to comply with municipal requirements. However, 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. Local requirements should be used to determine the cross-section required for these roadways. 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.



Local roads should meet municipal standards

5.4 Public Transit Operations

Public transit often operates on roadways. In some cases, rail transit operates within the roadway right-of-way. In other 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 6.

5.4.1 Rail Transit Facilities

In some areas, rail transit operates within the roadway right-of-way. The designer needs to coordinate with the transit agency to ensure that the physical and operational needs of the rail transit facilities are accommodated within the design. In many cases, the cross-section needs to establish an adequate width to support the track layout, stations and waiting areas. It also needs to accommodate the use of lifts or ramps that might be located within the rail vehicle or on the loading platform. The spatial requirements for these elements varies depending upon the type of rail transit operation and rail vehicle characteristics present or planned for the roadway.

5.4.2 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 communities. 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 6. 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.

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

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.

5.4.2.1 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. Where 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.



60-foot transit bus

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.

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.

5.4.2.2 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 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 waiting area

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.

5.4.3 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.

On freeways and other high-speed, limited access arterials, transit operations, such as express bus routes, can be accommodated in high

occupancy vehicle lanes. These lanes are usually located adjacent to a center median.

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.

5.5 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.

5.5.1 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 16. 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 6. Several different types of medians are possible as described in the following sections.

5.5.1.1 **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 6 feet which allows for a 4-foot raised area with a 1-foot offset between the outside edge of the raised area and the travel lane. 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.



Typical raised median on an urban arterial

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.

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.

5.5.1.2 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.

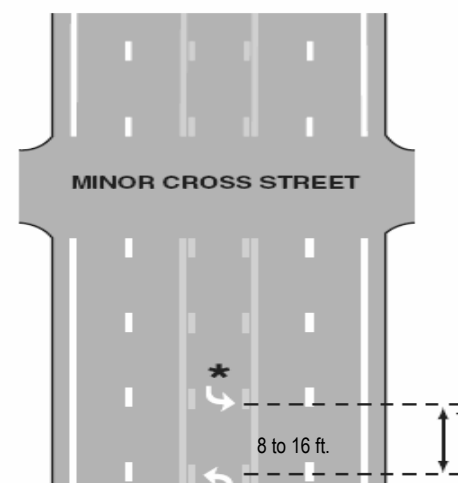
A flush median is generally paved and may or may not have a barrier depending on traffic conditions. It is normally crowned to provide positive drainage and discourage parking. The median is often designated using scored concrete or pavement markings. All flush medians should be marked according to the 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.

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 ¼ 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.



Center two-way left turn lane striping

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 15.

5.5.1.3 Depressed Medians

Depressed medians contain a downward sloping central area below the roadway surface, which is usually grassed. Depressed medians are found on freeways and high speed, multilane arterials in rural and suburban settings. Depressed medians are used to separate traffic flows and to provide for roadway drainage. Depressed medians also facilitate the separate alignments for the two directions of the roadway.

A depressed median is usually unpaved and wide enough to provide for a drainage ditch below the roadway gravel subbase. Generally, depressed medians provide better drainage and snow storage than flush or raised medians.

A depressed median is normally a minimum of 60 feet wide, which accommodates most clear zone requirements (see Section 5.6) and allows for two 4-foot left shoulders, 1v:6h or flatter slopes, a 3-foot wide ditch bottom and a 3-foot ditch depth. Greater median widths, within the constraints of right of way, environmental impacts, and construction costs, are desirable. When selecting a width for a depressed median, these additional factors should be considered:

- The appropriate roadside recovery area for the roadway should be considered as outlined in Section 5.6, and
- Provisions for future additions of traffic lanes should be considered.

5.5.1.4 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.

5.5.1.5 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 5-15 and discussed in the following sections.

Exhibit 5-15 Typical Median Functions by Roadway Type

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

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

Freeways

All freeways include medians, although the width varies depending upon the surrounding context and the presence of barriers within the median. The median width is often selected to eliminate the need for a center barrier since the warrants for a median barrier are partially dependent upon the median width (see Section 5.6). Many times, the median widths of 60 feet or more are selected. Freeway medians, either with or without a center barrier should provide sufficient width for emergency stopping, maintenance activity, and snow storage.

Designing medians to ensure proper drainage is of the utmost importance since the highest speed on freeways and multilane arterials usually occurs in the left lane along the median edge.

Arterials

Medians are also 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.

5.5.2 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. 521CMR requires that these cross slopes may never exceed 2 percent in the built condition. MassHighway requires that designers specify them at 1.5 percent to allow for construction tolerances.

5.5.3 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 5-16. The construction details for these elements are illustrated in the *MassHighway Standard Construction and Traffic Details*.

Exhibit 5-16 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, 2004.
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.

5.6 Roadside Elements

Roadside features significantly affect safety, construction and maintenance costs, right of way requirements, drainage, environmental impacts, and aesthetics. The following sections outline the clear zone concept, the treatment of ditch sections and transverse slopes, roadside and median barriers, and impact attenuators. The designer should consult the 2002 AASHTO *Roadside Design Guide* 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.

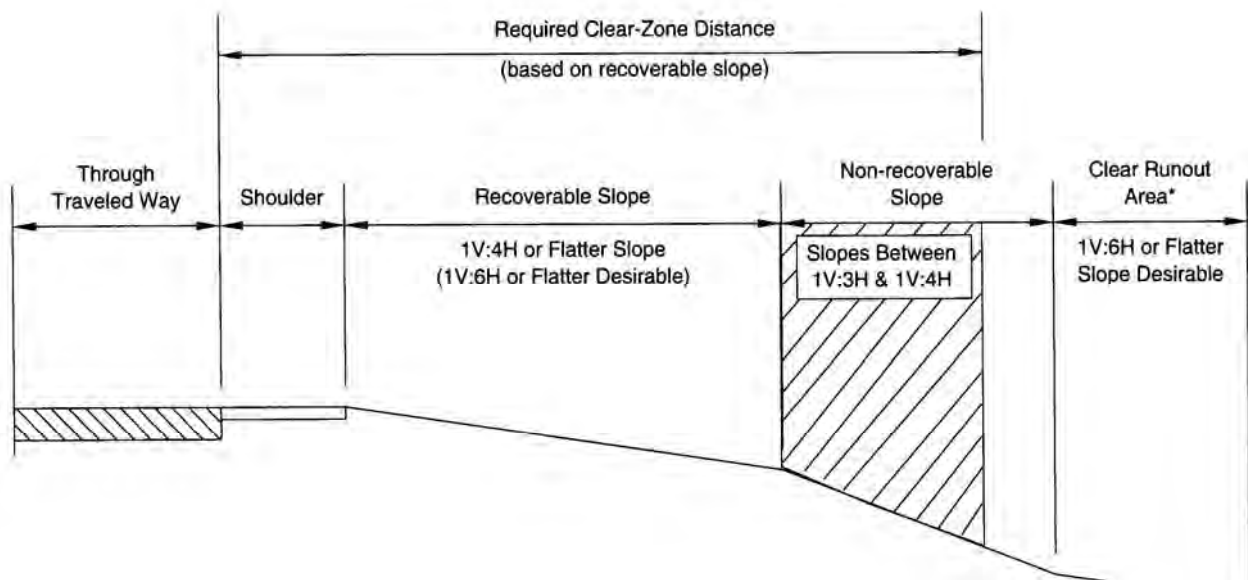
5.6.1 Clear Zones

Clear zones, also referred to as recovery areas, are traversable, unobstructed roadside areas beyond the edge of the traveled way, available for safe use by errant vehicles. This area may consist of a shoulder, a recoverable slope, a non-recoverable slope, and/or a clear run-out area. It should be free and clear of hazards or fixed objects. The width is dependent upon the traffic volumes and speeds, and on roadside geometry. If clear zones cannot be provided, the designer should provide roadside barriers to shield hazards. Clear zones are not normally used in the low speed environment found in densely developed urban and suburban areas.

The designer should consult the 2002 AASHTO *Roadside Design Guide* for further information on clear zones. Obstacles located within the clear zone should be removed, relocated, redesigned or shielded by traffic barriers or crash cushions. If signs, lighting and/or traffic signals are required within the recovery area, breakaway posts should be used or safety treatments must be provided.

The presence of longitudinal slopes, horizontal curves along the roadway, drainage channels, and transverse slopes may influence the recommended clear zone distances. Engineering judgment must be used to determine how much clear zone to provide. These considerations are discussed below and illustrated in Exhibit 5-17.

Exhibit 5-17
Illustration of Clear Zones, Slopes, and Runout Areas



* The Clear Runout Area is additional clear-zone space that is needed because a portion of the Required Clear Zone (shaded areas) falls on the non-recoverable slope. The width of the Clear Runout Area is equal to that portion of the Clear Zone Distance that is located on the non-recoverable slope.

Source: Roadside Design Guide, AASHTO, 2002. Chapter 3 Roadside Topography and Drainage Features

5.6.1.1 Longitudinal Slopes

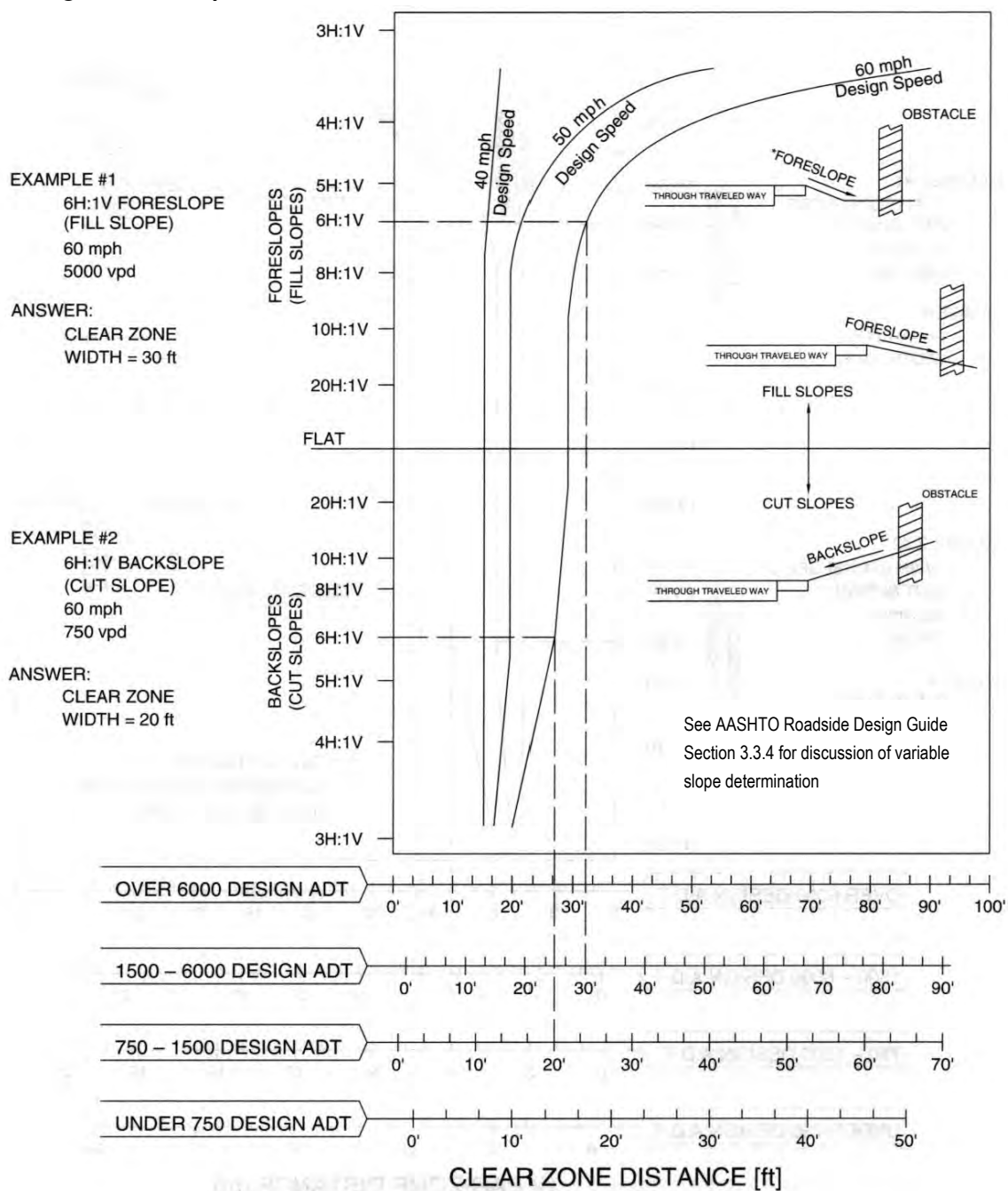
Longitudinal slopes can be either foreslopes or backslopes and run parallel to the roadway. The designer will need to account for these slopes when determining the recommended clear zone. A **foreslope** occurs when the roadway is located on a fill and the clear zone slopes down from the roadway. **Backslopes** occur when the roadway is located on a cut and the clear zone slopes up from the roadway.

In the case of a backslope within the clear zone, the required distance may be less than the clear zone indicated for a flat roadside. In the case of a foreslope, the required distance may be greater than the clear zone indicated for a flat roadside. Foreslopes can be either recoverable, traversable non-recoverable, or non-traversable, defined as follows:

- **Recoverable Slopes** - A roadway foreslope of 1v:4h or flatter on which a motorist may retain or regain control of a vehicle.
- **Traversable Non-Recoverable Slope** - A roadway foreslope steeper than 1v:4h but flatter than 1v:3h. With slopes of this type in the clear zone, additional run-out area is required at the toe of slope to provide adequate recovery area
- **Non-Traversable Slope** - A roadway foreslope 3h:1v or steeper. On these slopes the errant vehicle is likely to overturn. These slopes are by definition non-traversable and non-recoverable. Barrier protection should be considered when these slopes are located within the clear zone.

The clear zone distance accounting for longitudinal slopes will depend on the degree of the slope, design speed, and roadway design ADT. Exhibit 5-18 illustrates the influence of slopes on the recommended clear zone distances. Exhibit 5-19 provides the recommended clear zones for various slope conditions. When the clear zone contains a traversable non-recoverable foreslope, additional clear zone distance is needed to account for this slope.

Exhibit 5-18 Longitudinal Slope Influences on Clear Zone Distances



Source: Roadside Design Guide, AASHTO, 2002. Chapter 3 Roadside Topography and Drainage Features

Exhibit 5-19

Recommended Clear Zone Distances

Design Speed	Design ADT	Foreslopes			Backslopes		
		6h:1v or flatter	5h:1v to 4h:1v	3h:1v	3h:1v	5h:1v to 4h:1v	6h:1v or flatter
40 mph or less	Under 750	7-10	7-10	**	7-10	7-10	7-10
	750-1500	10-12	12-14	**	10-12	10-12	10-12
	1500-6000	12-14	14-16	**	12-14	12-14	12-14
	Over 6000	14-16	16-18	**	14-16	14-16	14-16
45-50 mph	Under 750	10-12	12-14	**	8-10	8-10	10-12
	750-1500	14-16	16-20	**	10-12	12-14	14-16
	1500-6000	16-18	20-26	**	12-14	14-16	16-18
	Over 6000	20-22	24-28	**	14-16	18-20	20-22
55 mph	Under 750	12-14	14-18	**	8-10	10-12	10-12
	750-1500	16-18	20-24	**	10-12	14-16	16-18
	1500-6000	20-22	24-30	**	14-16	16-18	20-22
	Over 6000	22-24	26-32*	**	16-18	20-22	22-24
60 mph	Under 750	16-18	20-24	**	10-12	12-14	14-16
	750-1500	20-24	26-32*	**	12-14	16-18	20-22
	1500-6000	26-30	32-40*	**	14-18	18-22	24-26
	Over 6000	30-32*	36-44*	**	20-22	24-26	26-28
65-70 mph	Under 750	18-20	20-26	**	10-12	14-16	14-16
	750-1500	24-26	28-36*	**	12-16	18-20	20-22
	1500-6000	28-32*	34-42*	**	16-20	22-24	26-28
	Over 6000	30-34*	38-46*	**	22-24	26-30	28-30

* Where a site-specific investigation indicates a high probability of continuing crashes, or such occurrences are indicated by crash history, the designer may provide clear-zone distances greater than the clear-zone shown in Exhibit 5-18. Clear zones may be limited to 30 feet for practicality and to provide a consistent roadway template if previous experience with similar projects or designs indicates satisfactory performance.

** Since recovery is less likely on the unshielded, traversable 3h:1v slopes, fixed objects should not be present in the vicinity of the toe of these slopes. Recovery of high-speed vehicles that encroach beyond the edge of the shoulder may be expected to occur beyond the toe of slope. Determination of the width of the recovery area at the toe of slope should take into consideration right-of-way availability, environmental concerns, economic factors, safety needs, and crash histories. Also, the distance between the edge of the through traveled lane and the beginning of the 3h:1v slope should influence the recovery area provided at the toe of slope. While the application may be limited by several factors, the foreslope parameters which may enter into determining a maximum desirable recovery area are illustrated in Exhibit 5-17.

Source: Roadside Design Guide, AASHTO, 2002. Chapter 3 Roadside Topography and Drainage Features

5.6.1.2 Horizontal Curves

The presence of a horizontal curve along the roadway may influence the designers recommended clear zone along the outside of the curve. Exhibit 5-20 may be used to adjust the outside clear zone distance based on the degree of the horizontal curve and the design speed of the roadway. These modifications are normally considered only when crash history indicates a need, or a specific site investigation shows a definitive crash potential that could be lessened by increasing the clear zone width, and when such increases are cost-effective. The designer may use superelevation on the horizontal curve which may offset the need to increase the clear zone distance. However, snow and ice conditions may limit the ability to use increased superelevation.

Exhibit 5-20 K_{CZ} (Curve Correction Factor)

Radius (ft.)	Design Speed (mph)						
	40	45	50	55	60	65	70
2860	1.1	1.1	1.1	1.2	1.2	1.2	1.3
2290	1.1	1.1	1.2	1.2	1.2	1.3	1.3
1910	1.1	1.2	1.2	1.2	1.3	1.3	1.4
1610	1.1	1.2	1.2	1.3	1.3	1.4	1.5
1430	1.2	1.2	1.3	1.3	1.4	1.4	—
1270	1.2	1.2	1.3	1.3	1.4	1.5	—
1150	1.2	1.2	1.3	1.4	1.5	—	—
950	1.2	1.3	1.4	1.5	1.5	—	—
820	1.3	1.3	1.4	1.5	—	—	—
720	1.3	1.4	1.5	—	—	—	—
640	1.3	1.4	1.5	—	—	—	—
570	1.4	1.5	—	—	—	—	—
380	1.5	—	—	—	—	—	—

$$CZ_c = (L_c) (K_{CZ})$$

Where: CZ_c = clear zone on outside of curvature, meters (feet)

L_c = clear zone distance, feet, refer to Exhibit 5-18/Exhibit 5-19 (or Figure 3.1/Table 3.1 in 2002 Roadside Design Guide)

K_{CZ} = curve correction factor

Note: The clear-zone correction factor is applied to the outside of curves only. Curves flatter than 2,860 feet do not require an adjusted clear zone.

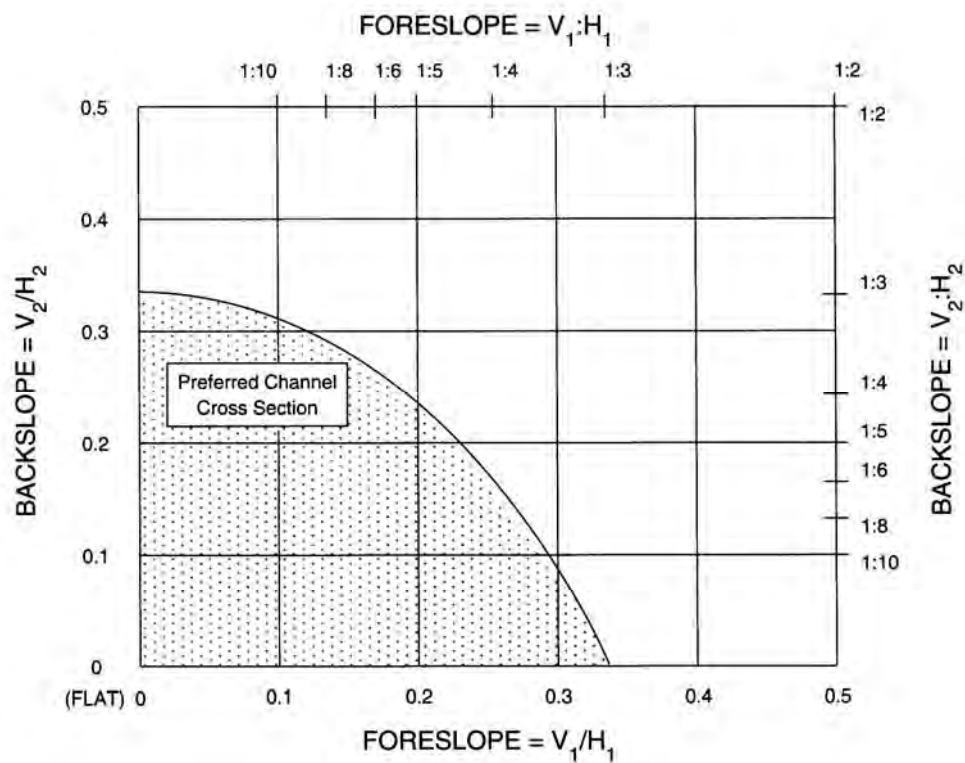
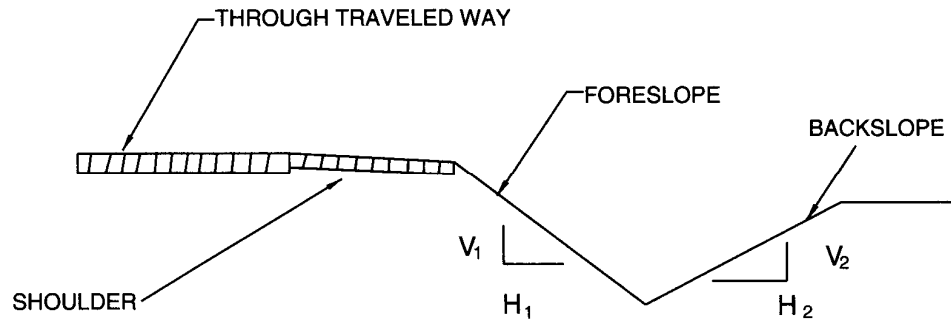
Source: Roadside Design Guide, AASHTO, 2002. Chapter 3 Roadside Topography and Drainage Features

5.6.1.3 Drainage Channels

Drainage channels must be designed, built, and maintained with consideration given to their effect on the roadside environment.

Drainage channels must also be in compliance with the MassHighway Stormwater Handbook. Drainage channel may be located within the roadway's clear zone provided it meets specific geometric requirements to safely accommodate an errant vehicle. The geometric requirements for these channels are discussed in Chapter 8 of this Guidebook, and Chapter 3 of the AASHTO *Roadside Design Guide*, and illustrated in Exhibits 5-21 and 5-22.

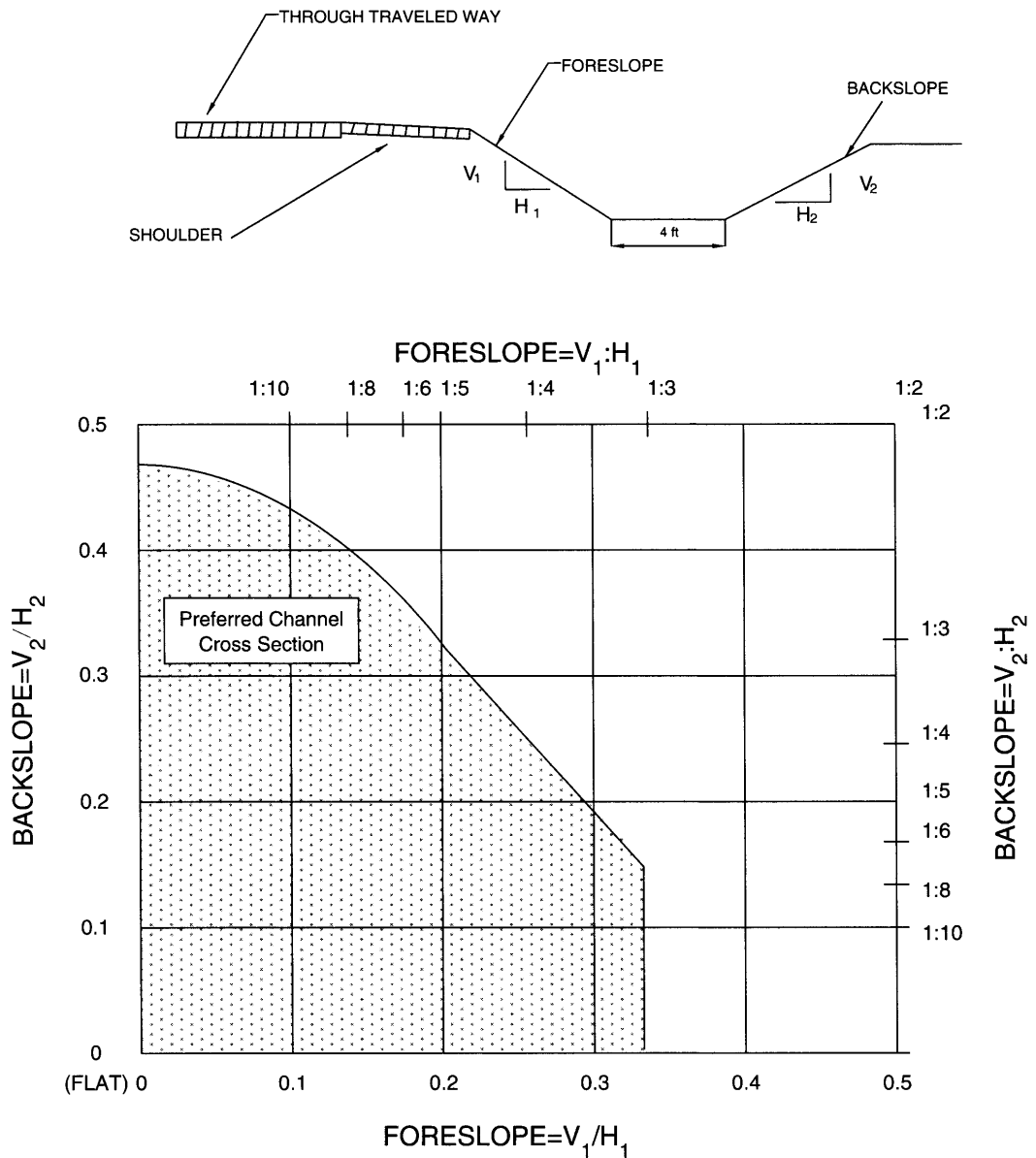
Exhibit 5-21
Preferred Ditch Cross-section



* This chart is applicable to all Vee ditches, rounded channels with a bottom width less than 8 ft. and trapezoidal channels with bottom widths less than 4 ft.

Source: Roadside Design Guide, AASHTO, 2002. Chapter 3 Roadside Topography and Drainage Features

Exhibit 5-22 Preferred Trapezoidal Channel Cross-section



This chart is applicable to rounded channels with bottom widths of 8 feet or more and to trapezoidal channels with bottom widths of 4 feet or more.

Source: Roadside Design Guide, AASHTO, 2002. Chapter 3 Roadside Topography and Drainage Features

5.6.1.4 Transverse Slopes

Common obstacles on roadsides are transverse slopes created by median crossovers, berms, driveways, or intersecting side roads. A **transverse slope** is a slope, offset into the clear zone, created by median crossovers, berms, driveways, or intersecting side roads. These are generally more critical to errant motorists than longitudinal slopes because they are stuck head-on by errant vehicles. Transverse slopes of 1v:10h or flatter are desirable. Transverse slopes of 1v:6h or flatter are suggested for high-speed roadways, particularly for that portion of the slope that is located immediately adjacent to traffic. This slope can then be transitioned to a steeper slope as the distance from the through traveled way increases. Transverse slopes steeper than 1v:6h may be considered for densely developed areas or lower speed facilities.

5.6.2 Roadside Barriers

Roadside recovery areas as discussed in Section 5.6.1 should be provided when practical. Where this is not feasible or practical, roadside barriers must be considered when there is a history of run-off-road collisions or when there is a significant potential for such collisions. A **roadside barrier** is a longitudinal barrier used to shield motorists from natural or manmade obstacles located along the roadway. Barriers may occasionally be used to protect pedestrians and bicyclists from vehicular traffic. A single-faced longitudinal barrier installed either in the median or on the outside of the roadway is referred to as a roadside barrier. A double-faced longitudinal barrier which is designed to redirect vehicles striking either side of the barrier is referred to as a median barrier, as described in Section 5.6.3.

The primary purpose of barriers is to prevent a vehicle from leaving the roadway and striking a fixed object or terrain feature that is considered more dangerous than the barrier itself. This is accomplished by containing and redirecting the impacting vehicle.

Several design selection criteria are consulted when determining the type of roadside barrier.

Roadside barriers are usually categorized as flexible, semi-rigid, or rigid, depending on their deflection characteristics on impact. Flexible systems are generally more forgiving than the other categories since much of the impact energy is dissipated by the deflection of the barrier. Rigid systems are generally more durable and relatively low in cost when considering their maintenance-free characteristics. Semi-rigid systems provide a combination of these characteristics.

Once it has been decided that a roadside barrier is warranted, the designer must choose the appropriate type of barrier. This choice is based on a number of factors including performance criteria, cost (construction and maintenance), and aesthetics. The *Roadside Design Guide* should be consulted for more information on barrier selection. The following factors should be considered when selecting a barrier system.

- **Performance Capability:** The barriers must be structurally able to contain and redirect the design vehicle.
- **Deflection:** Barriers may require a buffer to account for their flexing during impact. The expected deflection of the barrier must not exceed the available room for this deflection.
- **Site Conditions:** The slope approaching the barrier and the distance from the traveled way may preclude or suggest the use of some barrier types.
- **Compatibility:** The barrier must be compatible with the planned end anchor and capable of transition to other barrier systems such as bridge railings
- **Cost:** Standard barrier systems are relatively consistent in cost, but high-performance railings and aesthetically designed barriers can cost significantly more.
- **Maintenance:** Several factors relating to maintenance are important considerations in barrier selection. These include:
 - **Routine:** Few systems require a significant amount of routine maintenance.
 - **Collision:** Generally, flexible and semi-rigid systems require significantly more maintenance after a collision than rigid systems.
 - **Materials Storage:** Consistency in barrier systems used reduces the needed inventory of spare parts.
 - **Simplicity:** Simple designs cost less and are more likely to be properly installed and maintained.
 - **Aesthetics:** Barrier aesthetics are an important consideration to ensure visual consistency with the surrounding context. These considerations are discussed further in Chapter 13.

- ❑ **Field Experience:** Performance and maintenance monitoring data of existing systems should be considered to identify problems that could be reduced or eliminated through selection of a different barrier system.

The following sections describe the types of barriers typically used.

5.6.2.1 Flexible Systems

Flexible systems are designed to provide substantial “give”, or even break away upon impact. They slow an errant vehicle, but sometimes will not completely prevent a vehicle from leaving the roadway area. For this reason, flexible systems require large “clear zones” beyond the edge of the traveled portion of a roadway.

Cable Systems

In the past, a common type of flexible system used routinely in Massachusetts was the three-strand cable system. Three and four-strand cable systems have also been used by other states. Cable systems use posts that are driven into the ground at fixed vertical intervals along the roadside and have other cables attached to them. This system is designed to wrap around the colliding vehicle and redirect it with minimal impact to the vehicle and its occupants. The vehicle's force stretches the cables and the posts bend or break. As this occurs the vehicles' kinetic energy is dissipated. There are numerous variations on this basic system that have differing hardware, terminal treatments, post intervals, and cable heights. Because this system requires elasticity to deflect the vehicle, adequate clear space from potential hazards beyond the guardrail is essential.

Cable systems are inexpensive and simple to install and they are relatively inexpensive to repair. Because they have little surface area, cable systems do not create much wind resistance or accumulate drifting snow. This facilitates winter maintenance. Roadway snow removal is also simplified because snow can be pushed through the cables. Finally, the cable systems are quite unobtrusive, aiding visibility and forming a visually attractive alternative to many heavier guardrail systems.

However, the cable systems also have several drawbacks. They can sustain considerable damage in vehicular crashes or by snowplows. Also, to be fully effective, the cables must be maintained at the proper tension levels and at the right heights. In a majority of instances,

cable tension relaxes over time, creating slackness. Maintenance is required to keep the cables properly tensioned.

Approximately 95 percent of rollover crashes are caused by what is known as "tripping force." Tripping force occurs when an errant vehicle slides with lateral motion, often with its wheels dug into soft soils or granular materials. If the vehicle reaches critical sliding velocity and hits a low obstacle, such as a slack cable, it is likely to roll over. This is especially true for sport utility vehicles that have a high center of gravity. Alternatively, low weight vehicles can hit a slack cable system and "trampoline" back into traffic causing multi-vehicle crashes.

For these reasons, MassHighway does not routinely use cable systems. However, cable systems are sometimes appropriate in areas that have low to moderate traffic speeds and volumes, and abundant clear space beyond the edge of the roadway, provided that the use of such a system is based on sound engineering judgment. The AASHTO Roadside Design Guide should be consulted for more information on cable systems.

5.6.2.2 Semi-Rigid Systems

The following semi-rigid systems are often used on MassHighway projects:

- **Blocked-Out W-Beam** - This system uses a heavy post with a block out and corrugated steel face (W-beam). Typical post spacing is 6 feet 3 inches on center. Posts may be either steel or wood. The details for this system are shown in the *MassHighway Construction Standards*.
- **Blocked-Out Thrie Beam** - This system is similar to the blocked-out W-beam guardrail, except a deeper corrugated metal face is used. The deeper beam will minimize the possibility of underride or vaulting by impacting vehicles. The details for this system are shown in the *MassHighway Construction Standards*.
- **Steel Backed Timber Rail** - This system consists of heavy wood rail backed with a steel plate and installed on heavy wood posts. Its rustic appearance is sometimes more compatible with the surrounding area. The cost premium may be an important consideration. It may be used only on low volume facilities with design speeds under 55 miles per hour as confirmed by recent crash tests reported in 2002 *AASHTO Roadside Design Guide*.



Because only the full height straight sections have been crash tested, this system must transition to other approved systems at termini and on sharp curves.

5.6.2.3 Rigid Systems

The concrete safety shape barrier is often used in MassHighway projects. The most commonly used concrete safety shape barrier is the F-shape barrier. The F-shape barrier is preferred over other designs because of its better performance with small vehicle impact with respect to vertical roll and redirection. The details for this system are shown in the *MassHighway Construction Standards*.

5.6.2.4 Roadside Barrier Requirements

Once a potential roadside hazard (fixed objects or non-traversable slopes) has been identified, determining barrier warrants involves these steps:

- 1) Is the hazard within the recovery zone?
- 2) Can the hazard be removed, relocated, or made breakaway?
- 3) Can the slope be flattened to provide recovery area?
- 4) Is the barrier less of an obstacle than the hazard it will shield?
- 5) Is a barrier installation practical, based on engineering judgment?

Barrier installation guidelines are presented below:

- **Fixed Object and Non-Traversable Hazards** - The barrier warrants for hazards within the roadside recovery zone are to be found in the most recent AASHTO *Roadside Design Guide*, also shown in Exhibit 5-23.
- **Embankments** - Generally, barrier is required to protect slopes steeper than 1:4. Barrier may also be warranted based on the speed, traffic volumes, crash history, and cost-effectiveness. See Exhibit 5-24 to 5-26 for embankment warrant criteria.
- **Bridge Rails or Parapets** (overpass) - These will require an approach section which will securely attach to the rail or parapet. Roadside barrier should also be installed on the trailing end of the bridge, if its end is within the recovery area for opposing traffic. The *MassHighway Construction Standards* provide the details for the transition and attachment to the bridge.
- **Ditches** - See the AASHTO *Roadside Design Guide*.

- **Traffic Signal Support** - Isolated traffic signals within the recovery area on high speed rural facilities may require shielding.

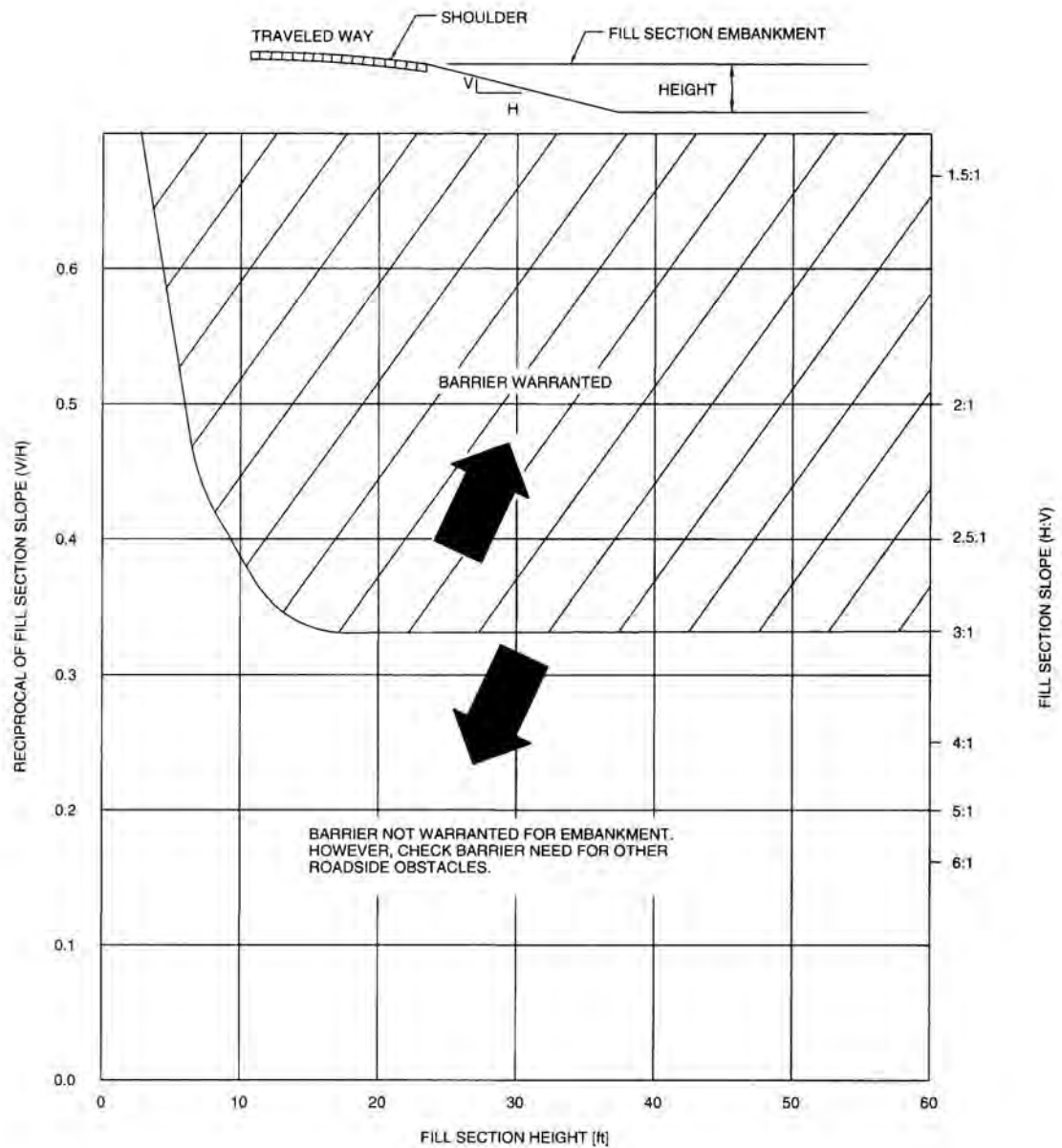
Exhibit 5-23
Barrier Warrants for Non-Traversable Terrain and
Roadside Obstacles ^{1,2}

Obstacle	Warrants
Bridge piers, abutments, and railing ends	Shielding generally required
Boulders	Judgment decision based on nature of fixed object and likelihood of impact
Culverts, pipes, headwalls	Judgment decision based on size, shape, and location of obstacle
Cut & fill slopes (smooth)	Shielding not generally required
Cut & fill slopes (rough)	Judgment decision based on likelihood of impact
Ditches (parallel)	Refer to Exhibit 5-21 and 5-22
Ditches (transverse)	Shielding generally required if likelihood of head-on impact is high
Embankment	Judgment decision based on fill height and slope (see Exhibit 5-24)
Retaining walls	Judgment decision based on relative smoothness of wall and anticipated maximum angle of impact
Sign/luminaire supports ³	Shielding generally required for non-breakaway supports
Traffic signal supports ⁴	Isolated traffic signals within clear zone on high-speed rural facilities may warrant shielding
Trees	Judgment decision based on site-specific circumstances
Utility poles	Utility poles Shielding may be warranted on a case-by-case basis
Permanent bodies of water	Judgment decision based on location and depth of water and likelihood of encroachment

Source: Roadside Design Guide, AASHTO, 2002. Chapter 5 Roadside Barriers

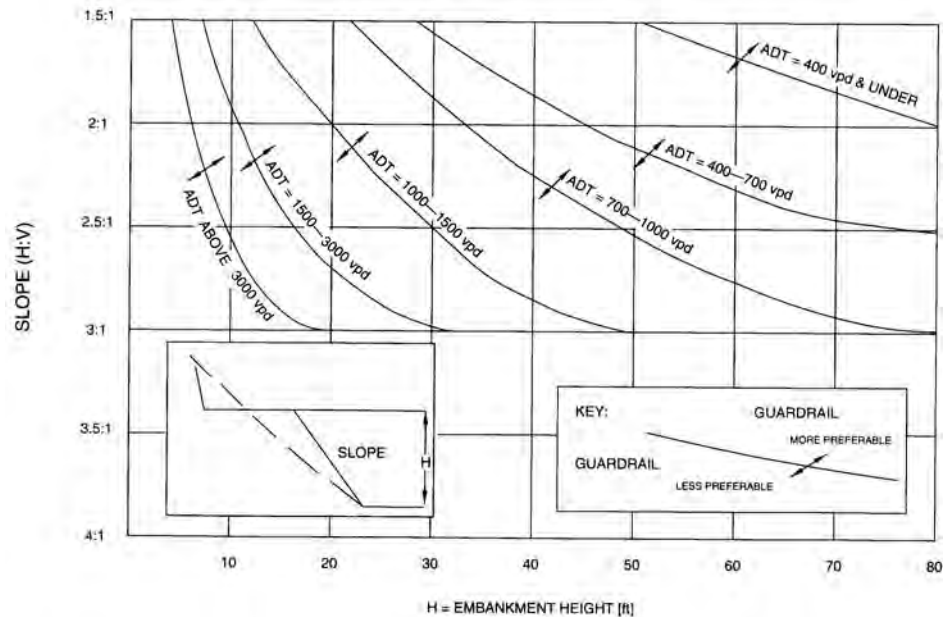
1. Shielding non-traversable terrain or a roadside obstacle is usually warranted only when it is within the clear zone and cannot practically or economically be removed, relocated, or made breakaway, and it is determined that the barrier provides a safety improvement over the unshielded condition.
2. Marginal situations, with respect to placement or omission of a barrier, will usually be decided by crash experience, either at the site or at a comparable site.
3. Where feasible, all sign and luminaire supports should be a breakaway design regardless of their distance from the roadway if there is reasonable likelihood of their being hit by an errant motorist. The placement and locations for breakaway supports should also consider the safety of pedestrians from potential debris resulting from impacted systems.
4. In practice, relatively few traffic signal supports, including flashing light signals and gates used at railroad crossings, are shielded. If shielding is deemed necessary, however, crash cushions are sometimes used in lieu of a longitudinal barrier installation.

Exhibit 5-24 Comparative Risk Warrants For Embankments



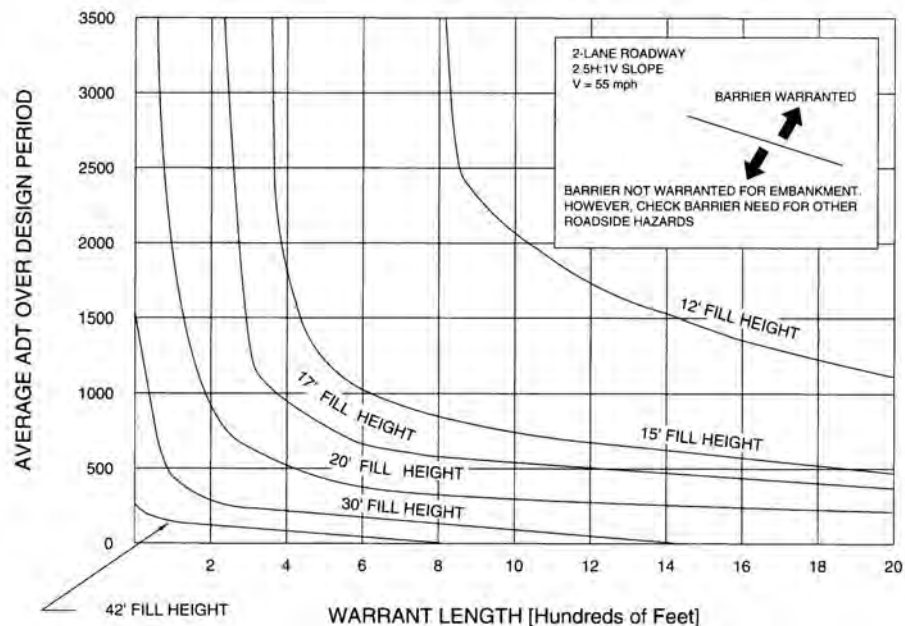
Source: Roadside Design Guide, AASHTO, 2002. Chapter 5 Roadside Barriers

Exhibit 5-25
Example design chart for Embankment Warrants Based on Fill height, slope, and traffic volume



Source: Roadside Design Guide, AASHTO, 2002. Chapter 5 Roadside Barriers

Exhibit 5-26
Example design chart for cost-effectiveness embankment warrants based on traffic speeds and volumes, slope geometry, and length of slope



Source: Roadside Design Guide, AASHTO, 2002. Chapter 5 Roadside Barriers

Once it has been determined that a roadside barrier is warranted, the designer must select a barrier type. The most desirable barrier type is usually one that offers the required degree of shielding at the lowest cost for the specific application. Exhibit 5.27 from the 2002 AASHTO Roadside Design Guide summarizes some key factors for selecting the barrier type.

Exhibit 5-27 Selection Criteria for Roadside Barriers

Criteria	Comments
1. Performance Capability	Barrier must be structurally able to contain and redirect design vehicle.
2. Deflection	Expected deflection of barrier should not exceed available deflection distance.
3. Site Conditions	Slope approaching the barrier and distance from traveled way may preclude use of some barrier types.
4. Compatibility	Barrier must be compatible with planned end anchor and capable of transitioning to other barrier systems (such as bridge railing).
5. Cost	Standard barrier systems are relatively consistent in cost, but high-performance railings can cost significantly more.
6. Maintenance	
A. Routine	Few systems require a significant amount of routine maintenance.
B. Collision	Generally, flexible or semi-rigid systems require significantly more maintenance after a collision than rigid or high-performance railings.
C. Material Storage	The fewer different systems used, the fewer inventory items/storage space required.
D. Simplicity	Simpler designs, besides costing less, are more likely to be reconstructed properly by field personnel.
7. Aesthetics	Occasionally, barrier aesthetics are an important consideration in selection.
8. Field Experience	The performance and maintenance requirements of existing systems should be monitored to identify problems that could be lessened or eliminated by using a different barrier type.

Source: Roadside Design Guide, AASHTO, 2002. Chapter 5 Roadside Barriers

5.6.2.5 Roadside Barrier Design

The following are important considerations in barrier design.

Lateral Offset

The distance from the edge of the traveled way, beyond which a roadside object will not be perceived as an obstacle and result in a motorist's reducing speed or changing vehicle position on the roadway is called the shy line offset. This distance varies for different design speeds as indicated in Exhibit 5-28. If possible, a roadside barrier should be placed beyond the shy line offset, particularly for relatively short, isolated installations. For long continuous lengths of railings, this offset distance is not so critical.

Exhibit 5-28

Suggested Shy Line Offset (L_s) Values

<u>Design Speed</u> [mph]	<u>Shy Line Offset, L_s</u> [ft]
80	12.1
75	10.5
70	9.2
60	7.9
55	7.2
50	6.6
45	5.6
40	4.6
30	3.6

Source: Roadside Design Guide, AASHTO, 2002. Chapter 5 Roadside Barriers

Deflection Distance

The distance between the barrier and the obstacle must not be less than the dynamic deflection of the barrier system. This distance is based on crash tests with a full-size car at 30 miles per hour and a 25-degree angle of impact. The distance is measured from the face of the barrier to the front of the obstacle.

Exhibit 5-29 provides the offset distance for the barrier systems used in Massachusetts based on the crash tests at 30 miles per hour. Concrete barrier is assumed to have no deflection.

Exhibit 5-29 Barrier Offset Distance

Post Spacing	Beam Description	Minimum Offset* (Ft)
Single	Single W - Beam	4.1
Single	Single Thrie - Beam	3.6
Double	Single W - Beam	3.1
Double	Double W - Beam	2.8
Double	Single Thrie - Beam	3.0
Double	Double Thrie - Beam	2.6
Quadruple	Double W - Beam	2.3
Quadruple	Single Thrie - Beam	2.5
Quadruple	Double Thrie - Beam	2.3

*Minimum Offset - Measured from the face of the rail to the front of the obstacle.

Source: MassHighway

Length of Need

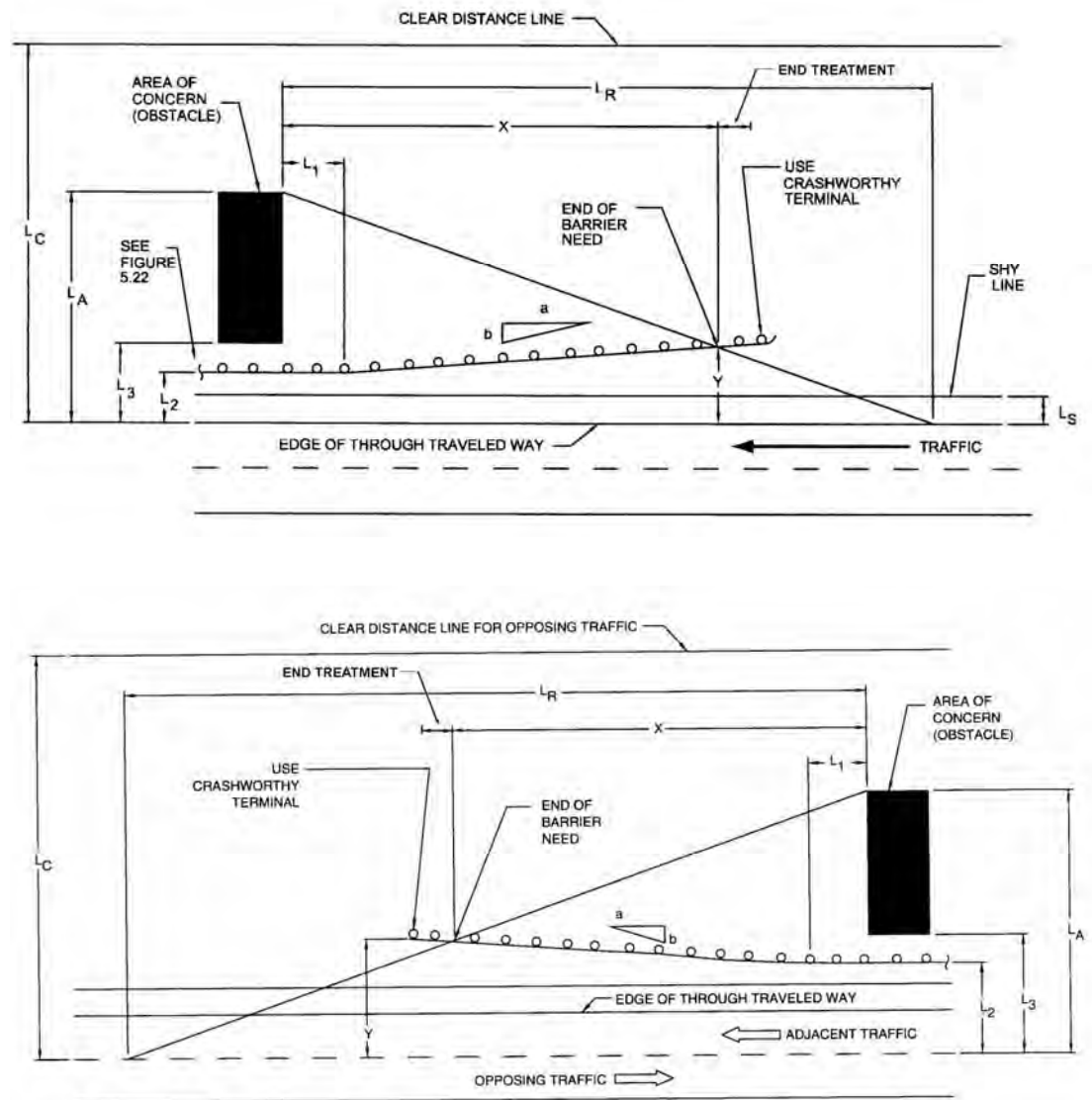
The barrier must be long enough to sufficiently shield the hazard from errant vehicles. The length of the barrier depends on factors depicted on Exhibit 5-30 which include:

- **(b/a)** - the barrier flare rate (when the barrier is not parallel to the traveled way), see Exhibit 5-31 for suggested flare rates;
- **L_R** - the vehicle runout length (the distance needed for an errant vehicle to come to a stop) which is a function of the traffic volume and design speed, measured from the upstream extent of the obstructions along the roadway to the point at which a vehicle is assumed to leave the roadway, see Exhibit 5-32 for suggested runout lengths;
- **L_A** - the lateral setback from the edge of the traveled way to the back of the obstacle.
- **L₁** - the tangent length of the barrier upstream from the obstacle; and
- **L₂** - the lateral distance from the edge of the traveled way to the barrier.

The AASHTO recommended formula used for determining the length of need (X) is:

$$X = \frac{L_A + \left(\frac{b}{a}\right)(L_1) - L_2}{\left(\frac{b}{a}\right) + \left(\frac{L_A}{L_R}\right)}$$

Exhibit 5-30 Approach Barrier Layout Variables



Source: Roadside Design Guide, AASHTO, 2002. Chapter 5 Roadside Barriers

Exhibit 5-31 Suggested Flare Rates for Barrier Design

Design Speed (mph)	Flare Rate for Barrier Inside Shy Line	Flare Rate for Barrier Beyond Shy Line	
		*	**
70	30:1	20:1	15:1
60	26:1	18:1	14:1
55	24:1	16:1	12:1
50	21:1	14:1	11:1
45	18:1	12:1	10:1
40	16:1	10:1	8:1
30	13:1	8:1	7:1

* Suggested maximum flare rate for rigid barrier system.

** Suggested maximum flare rate for semi-rigid barrier system.

Source: Roadside Design Guide, AASHTO, 2002. Chapter 5 Roadside Barriers

Exhibit 5-32 Suggested Runout Lengths for Barrier Design (L_R)

Design Speed (mph)	Traffic Volume (ADT)			
	Over 6000 vpd	2000 – 6000 vpd	800 – 2000 vpd	Under 800 vpd
	Runout Length (ft) L_R	Runout Length (ft) L_R	Runout Length (ft) L_R	Runout Length (ft) L_R
70	475	445	395	360
60	425	400	345	330
55	360	345	315	280
50	330	300	260	245
45	260	245	215	200
40	230	200	180	165
30	165	165	150	130

Source: Roadside Design Guide, AASHTO, 2002. Chapter 5 Roadside Barriers

End Treatments

The barrier end terminals are used to reduce severity of impacts by gradually slowing and bringing the vehicle to a stop or by redirecting it around the object of concern. Generally, the vehicle must remain upright during and after the collision and not be redirected into adjacent traffic lanes. A terminal can be designed to have full redirection capabilities along its entire length (known as a **non-gating terminal**), or it can be designed to allow controlled penetration along a portion of its length (known as a **gating terminal**).

To be crashworthy, the end treatment should not spear a vehicle, cause a vehicle to vault or roll a vehicle for head-on or angled impacts.

Improper roadside barrier end treatment is extremely hazardous to vehicles if hit. Preferably, the roadside barrier should be flared away from the travel lane and, if feasible, should be terminated outside the recovery area. A crashworthy end treatment is considered essential if the barrier terminates within the clear zone or is in an area where it is likely to be hit head-on by an errant motorist. To be crashworthy, the end treatment should not spear a vehicle, cause a vehicle to vault or roll a vehicle for head-on or angled impacts. For impacts within the length of need, the end treatment must have the same redirection characteristics of a standard roadside barrier until the full length of need is reached. Additionally, the trailing end of the barrier must be protected with a crashworthy end treatment if it is within the clear zone of opposing traffic.

The *MassHighway Construction Standards* illustrate the standard end treatment for roadside barriers. Intersecting streets and driveways may cause special problems for providing the proper roadside barrier end treatment. These must be considered on a case-by-case basis. The following end treatments are most commonly used by MassHighway.

■ **Anchored in Back Slope**

A back slope can be used to eliminate the hazard posed by the ends of traffic barriers. Where conditions permit this is the MassHighway preferred barrier end treatment. Anchorage in back slope should be used wherever a back slope is conveniently near the end of the length of need of the barrier. Full height barrier must be flared a minimum rate of 5:1 to a point in the back slope beyond the recovery area. A 1v:12h or flatter ground slope must be provided in front of the barrier. Consult the *MassHighway Construction Standards* for details on guardrail installation.

■ **Special End Treatments**

Where it is not appropriate for either anchoring in back slope, special end treatments may be used. These must meet *NHCRP 350* testing requirements and be approved by FHWA for general use for the intended application (see Section 9.5 of *NCHRP 350*).

For more details about roadside barrier end treatments, consult the 2002 AASHTO *Roadside Design Guide*.

Minimum Functional Length and Guardrail Gaps

Short runs of guardrail have little value. Likewise, short gaps between runs of guardrail are undesirable. The following general criteria are suggested:

- A minimum length guardrail of 165 feet of full height guardrail plus the end treatment is suggested.
- Gaps of less than 335 feet between guardrail termini should be avoided to the extent possible. The two barrier runs should be connected into a single run. However, this may not be possible at intersecting streets and driveways.

These general criteria for lengths and gaps between successive guardrail termini are not always applicable and are only provided as an initial reference for the designer. In many cases, especially in rural areas along narrow roadways, the designer may have to develop a workable alternative to these suggested criteria.

Placement on Slopes and Behind Curbs

If guardrail is improperly located on slopes or behind curbs, an errant vehicle could impact the barrier too high or too low, with undesirable results. Therefore, these criteria apply:

- Guardrail height is measured from the ground or pavement surface at the guardrail face. For W-beam and for Thrie beam guardrail, this dimension is 1'9"±1". See the *MassHighway Construction Standards* for details.
- Berm and curb must be located to minimize vaulting potential. See the *MassHighway Construction Standards* for details.
- Where guardrail is required to be offset from the edge of pavement, it should not be placed on a slope steeper than 1v:12h.
- Where sidewalks are provided, guardrail should be located along the back edge of the sidewalk.

Transitioning

Transition sections are necessary to provide continuity of protection when two different roadside barriers join, when a roadside barrier joins another system such as a bridge railing, or when a barrier is attached to a rigid object. The transition design should produce a gradual transition in the stiffness and overall protection system so that vehicle

pocketing, snagging, or penetration can be reduced or avoided at any position along the transition area. For transition details, consult the *MassHighway Construction Standards* and the *AASHTO Roadside Design Guide*.



Typical Roadside Barrier

Once a type of barrier is selected for a particular longitudinal application, the selected type should be used throughout the run. Transitions from concrete barrier to guardrail or guardrail to concrete barrier should be avoided where possible. Where stiffer sections are required for runs of guardrail, extra posts and rails should be considered. If a transition from steel guardrail to concrete barrier is required, a gradual strengthening and secure attachment to the concrete is required similar to the guardrail to bridge rail transition shown in the construction standards.

If a guardrail run crosses over a retaining wall or culvert, it should be secured to the top of the wall rather than transition to a concrete section. If the section can be installed with only a single post missing, this post can be omitted with nested steel rail. If a concrete run crosses drainage structures, the concrete barrier should be specially designed to accommodate the drainage structure which may be formed in steel in the same shape as the adjacent concrete barrier.

5.6.3 Median Barriers

Median Barriers are double faced longitudinal systems. Median barriers are normally used in narrow medians for separating opposing traffic or for separating traffic flowing in the same direction, i.e. collector-distributor roadways and High-Occupancy Vehicle lanes.

5.6.3.1 Types

MassHighway uses the following types of median barrier systems:

- **Blocked-Out W-Beam**

This W-Beam system may be used as median barrier on roadways with design speeds of 40 mph or less. The *MassHighway Construction Standards* present the design details.

- **Blocked-Out Thrie-Beam**

Thrie beam must be used for median barrier system on highway facilities with design speeds over 40 mph.

- **Concrete Median Barrier Double-Faced**

This barrier is reinforced concrete in which the sloped shape of the

face is designed to minimize occupant injury, redirection into traffic, and the possibility of rollover. Two types, the F-shape and Jersey shape are used for barrier systems. The F-shape is preferred because it better redirects passenger vehicles.

In areas with heavy truck volume, poor roadway geometry, and a history of truck crashes, tall concrete barriers with heights of 3.5 feet or higher may be used. See the *MassHighway Construction Standards* for details. See Chapter 14 of this guidebook for a discussion on how concrete median barriers impact wildlife.

■ **Cable Systems**

As described earlier, cable systems can be used in medians, however, MassHighway typically uses the barrier systems described above due to the maintenance and safety considerations associated with cable systems. The *AASHTO Roadside Design Guide* provides for information on the design of cable barrier systems.

Once it has been decided that a median barrier is warranted, the designer must choose the appropriate type of barrier. This choice is based on a number of factors including performance criteria, cost (construction and maintenance), aesthetics, traffic impacts and personnel hazards of performing maintenance, and aesthetics. The most desirable system is usually one that offers the required degree of shielding at the lowest cost and provides the desired aesthetic for the area. Factors that should be considered when selecting a barrier system are presented in Section 5.6.2. Aesthetic considerations are discussed further in Chapter 13. Additionally, the *AASHTO Roadside Design Guide* should be consulted for more information.

In general, the designer will choose between Thrie Beam Double-Faced Guard Rail and a concrete safety shape. The choice between guardrail or concrete should be based on factors such as the width of median, barrier deflection, cost (construction and maintenance), traffic impacts and personnel hazards of performing maintenance, and aesthetics. Guardrail which deflects upon impact is generally preferred due to the lower impact forces on the vehicle and its occupants. W-beam and cable systems deflect even further than the Thrie beam system. However, the design speed of the roadway usually suggests the use of the Thrie beam system (the majority of roadways in developed areas have a design speed over 40 mph).

On high speed, high volume roadways with significant truck volumes and narrow medians of less than 14 feet, concrete barrier should be strongly considered due to the possibility that if guardrail is used it may deflect into the opposing lanes. Consideration should also be given to the increased likelihood that the barrier may be damaged which could result in higher maintenance costs for guardrail than for concrete. The designer should consider, however, that concrete barrier may not be aesthetically appropriate in undeveloped areas and that the open appearance of guardrail may appear less imposing and may be more acceptable to the public.

Homogeneous barrier type is recommended.

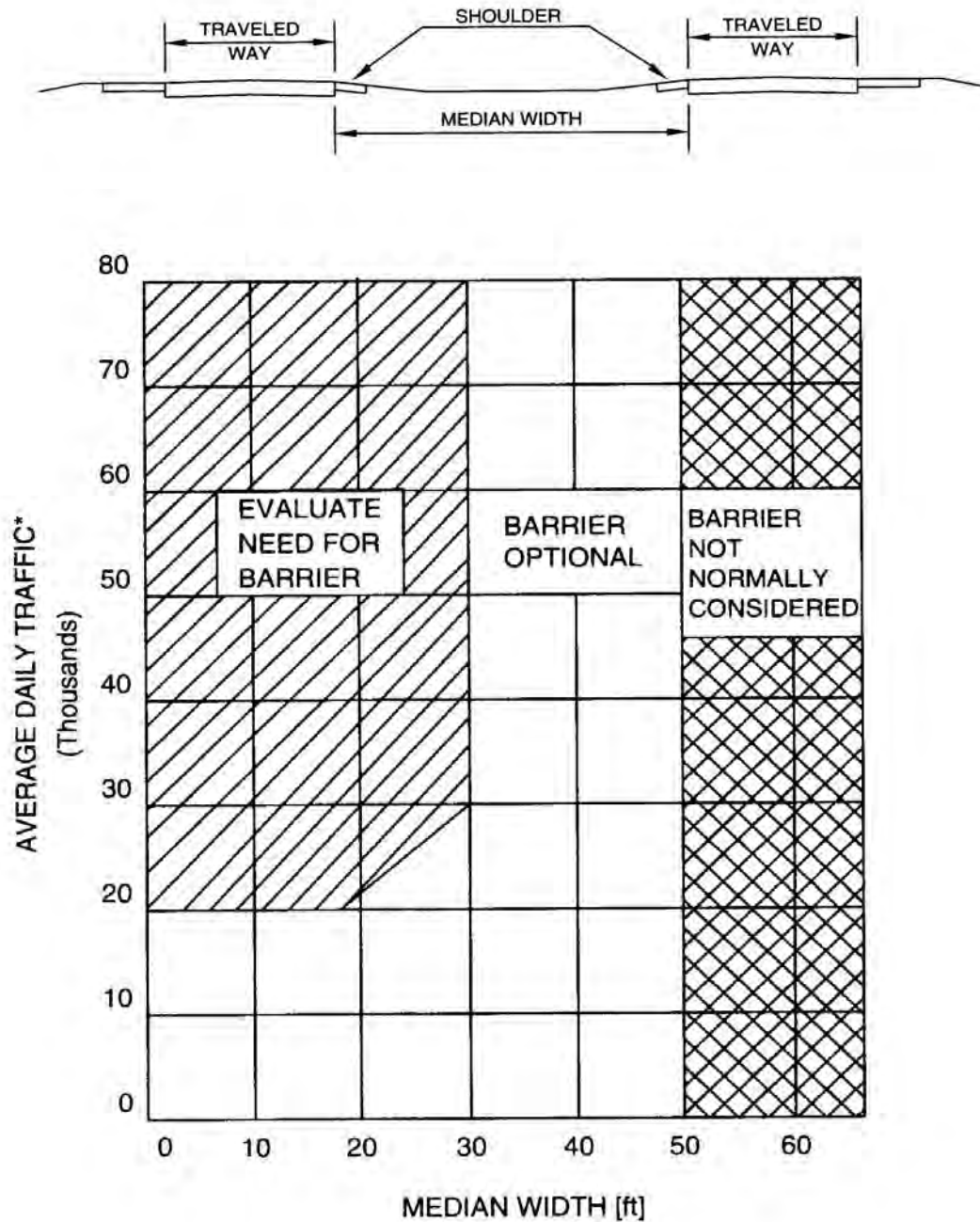
Once a type of median barrier is selected for a particular longitudinal application, it should be used throughout the run. Transitions between dissimilar barrier systems should be avoided. For instance, if a concrete median barrier run crosses drainage structures, the concrete barrier should be specially designed to accommodate the structure. This may be accomplished by forming a section of the barrier from steel in the same shape as the adjacent concrete barrier. Median barrier must be installed with no abrupt horizontal transitions. Flare rates should be designed in accordance with the AASHTO *Roadside Design Guide*.

5.6.3.2 Median Barrier Requirements

Exhibit 5-33 presents the requirements for a median barrier based on median width and traffic volumes. In the areas shown as optional, the decision to use a median barrier will be primarily based on costs and crash history. A barrier should not be used where the criteria do not require it, except where a significant number of crossover crashes have occurred. Moreover, wider medians allow more deflection and therefore less rigid and less costly barrier systems.

The exhibit was developed for freeways and expressways. On lower-speed, lower-class highways, judgment must be used and the exhibit may be used for guidance. On non-freeway highways, the designer should evaluate the crash history, traffic volumes and speeds, median width, alignment, sight distance, and construction costs to determine the need for a median barrier. On expressways and highways without access control, the median barrier must terminate at each at-grade intersection. Lower speeds will reduce the likelihood of a crossover crash.

Exhibit 5-33
Median Barrier Warrants



Source: Roadside Design Guide, AASHTO, 2002. Chapter 6 Median Barriers

5.6.3.3 Median Barrier Design

The following should be considered in the design of median barriers:

Lateral Placement

The median barrier will normally be placed in the center of the median. Where roadway conditions dictate different grades between two roadway barrels, median barrier should be placed on the high side of the median. Concrete barrier may split vertically to accommodate the two grade lines. See the *AASHTO Roadside Design Guide* and *MassHighway Construction Standards* for further guidance and details.

Cross-Slope

A maximum 1v:12h cross-slope must be used between the roadway gutter line and the median barrier. See *MassHighway Construction Standards* for details.

Flare Rate

A median barrier may have to be divided at the approach of superelevated curves or because of obstacles in the median, or flared to terminate in the wide median section. Flare rates in accordance with the *AASHTO Roadside Design Guide* should be used.

Median Barrier Openings

Emergency median crossovers are sometimes needed on access-controlled highways. Where a median barrier is warranted, the opening in the barrier should prevent crossover crashes, provide crashworthy end treatments, and provide sufficient width for emergency vehicles to use. An opening between 80 and 100 feet is a reasonable compromise. At this width, the chances of an errant vehicle passing through the opening are negligible; however, the width is sufficient to allow U-turn maneuvers by emergency or maintenance vehicles. Mechanical gate treatments for emergency openings are available.

Glare Screens

Device which may be used as part of a median barrier to eliminate headlight projection from oncoming vehicles; plantings often considered as an alternative

- Glare screens are rarely warranted in rural areas.
- Narrow medians and high traffic volumes increase the benefits of glare screens. Where the concrete median barrier is warranted

(medians 20 feet or less), a glare screen will often be cost-effective.

- On medians between 20 and 40 feet, a glare screen should be considered where the current traffic volumes exceed 20,000 ADT.
- Glare screens will not normally be used on medians greater than 40 feet wide.
- Tall concrete barrier systems may mitigate the need for glare screens.

Median Barrier End Treatments

An unprotected median barrier end presents a hazard to errant vehicles. A crashworthy end treatment for a median barrier is essential if the barrier is terminated where it is vulnerable to head-on impacts. To be crashworthy, the end treatment must not spear, snag, or roll the vehicle, and vehicle decelerations should not be excessive. The end must be properly anchored and capable of developing the full tensile strength of the barrier.

Because median barriers are normally used in narrow medians, the options for end treatments are limited. Barrier end treatments which have the potential for vaulting or rolling vehicles cannot be used. Therefore, tapered end treatments such as buried ends or ramped concrete barrier ends, are not acceptable treatments for median barrier unless the ends of the barrier can be flared a sufficient distance laterally from the traveled way so as not to be susceptible to head-on impacts.

Where feasible, the median barrier may be anchored in a back slope. This treatment should be designed in accordance with Roadside Barrier End Treatments criteria. This treatment usually requires that the barrier terminate in a wider portion of the median.

The preferred method for treating median barrier terminals in narrow medians is to use Impact Energy Attenuators. These manufactured treatments have been crash-tested to provide energy absorption and/or redirection capabilities in restricted areas.

5.6.4 Impact Energy Attenuators

The following section describes the use and application of impact energy attenuators. For more detailed information, please see the *AASHTO Roadside Design Guide*.

5.6.4.1 Attenuators/Crash Cushions

Median barrier ends located in narrow medians, roadside barrier ends, or other fixed roadside hazards which cannot be relocated must be shielded with appropriate crash cushions. Crash cushions have been crash-tested to conform to the redirection and attenuation requirements of *NCHRP 350*. All attenuators must be successfully retested for *NCHRP 350* and accepted by the FHWA for use on MassHighway projects.

MassHighway recognizes two basic types of crash cushions– a redirective crash cushion and non-directive crash cushion. A crash cushion can be designed to redirect a vehicle impacting the side of the cushion (redirective) or it can be designed to decelerate the vehicle to a stop when impacted on the side (non-directive). MassHighway specifies attenuators in a generic format in order to increase market competition, minimize the use of proprietary product, and ensure that site specific installations are used appropriately.

5.6.4.2 Requirements

Once a hazard is identified, the designer should attempt to remove, relocate, or make the hazard breakaway. If this is not feasible, then the hazard must be shielded with an attenuator. Impact attenuators are most often used to shield fixed point hazards or median barrier ends adjacent to bridge piers, sign supports, and median barrier ends. Barriers which terminate within the recovery area, if not buried in a back slope, are also hazards which must be protected with an attenuator.

The requirements for impact attenuators are under ongoing research. AASHTO prioritizes need on the basis of crash history, traffic volume, and operating speeds. For additional information the designer should consult the *Roadside Design Guide*, and the *Policy on Geometric Design of Highways and Streets*.

5.6.4.3 Design

Once the designer has determined the need for an attenuator in a particular location, the designer determines the type to be used

(gating or non-gating), and any limiting width or length for attenuator placement, or other condition to account for reverse-hit, opposite direction traffic in narrow median situations.

NCHRP Report 350 specifies testing guidelines for various roadside elements. Barriers are tested to *NCHRP 350* Condition Type II and VI. Guardrail and highway barrier is generally tested at Type II and III conditions. End treatments and attenuators are generally tested at Type II and III. Bridge rail is tested at Type IV, V, and VI conditions. Information of these testing types is included in the NCHRP Report.

The designer should refer to the current edition of the AASHTO *Roadside Design Guide* and other available literature for further information and a discussion of crash cushions and end treatments.

5.6.4.4 Side Impacts

The attenuator must be designed to sustain side impacts. Nongating attenuators normally will not require repair after side impacts. Gating attenuators, in order to provide some side impact protection, are generally designed at least 2.5 feet wider on each side than the object they protect. Greater widths should be provided where possible.

5.6.4.5 Site Conditions

Several factors at the attenuator site are important to its proper function:

- **Level Terrain** — The attenuator should be placed on a level surface. Most attenuators will not function well on cross slopes exceeding 5 percent. If the attenuator is likely to be struck by a vehicle traveling on a down grade, this additional energy must be compensated for in the design.
- **Curbs** — No curbs, berms or slope edgings are allowed at the attenuator installation. To function properly the vehicle should have a straight, smooth run at the attenuator.
- **Surface** — A paved bituminous or portland cement concrete surface must be installed under permanent attenuator installations where required. Some installations may only require a firmly packed gravel or crushed stone surface end treatment.
- **Orientation** — Gating attenuators must be oriented to maximize the chance of an impact being head-on. Where a gating system is

specified, it should be shown on the plans as set at approximately a 10 degree angle with the travel lane. The angle is measured between the longitudinal axis of the attenuator and the centerline of the highway. However, this is not necessary for those attenuators with nongating capability. Attenuators with nongating capabilities, such as "GREAT" systems, should be aligned parallel to the travel way.

5.6.5 Side Slopes and Cuts

Cut and fill slopes should be designed to ensure the stability of the roadway and be as flat as possible to enhance the safety of the roadside. Much of the necessary information will be provided in a soils report prepared by the Research and Materials Section, although not every project will require a soils report. The designer should consider the following when selecting a cut or fill slope design:

- It is desirable for fill slopes on high speed roadways to be 1v:6h or flatter. All soils (except possibly wetland or muck material) are stable at this rate. Maintenance efforts are greatly reduced, the erosion potential is reduced, and the slopes are safely traversable at 1v:6h. The designer should obtain clear zones where feasible. For fills greater than 15 feet high in wetlands and in other sensitive areas, 1v:2h slopes (with guardrail) are typical. Site conditions may require a slopes up to 1v:1h. Mechanically stabilized slope retaining treatments such as geo-textiles shall be considered for these situations.
- Erosion possibilities must be minimized. To the extent possible, the natural and existing drainage patterns should be preserved. Severely rutted side slopes can cause vehicle rollover even on relatively flat slopes. In good soil, turf can be established on slopes as steep as 1v:1h. However, flatter slopes obviously reduce the erosion potential and should be used where feasible. All slopes shall be planted with sufficient vegetation to stabilize the slope.
- Cut-to-fill transition slopes are particularly susceptible to erosion. The problem is most acute along the bottom of the fill embankment. Special protective measures should be considered here.
- Where the roadway mainline intersects a driveway, side road, or median crossing, the intersecting transverse slopes need to be carefully designed. Transverse slopes of 1v:10h or flatter are

desirable. Transverse slopes of 1v:6h or flatter are acceptable for high-speed roadways. Transverse slopes steeper than 1v:6h may be considered for urban areas or lower speed facilities.

Slopes up to vertical are possible in rock cuts using pre-splitting methods. The typical rock slope is 4v:1h, depending upon the material stability. When feasible, the bottom of the rock-cut slope should be outside of the calculated clear zone. Jagged rock outcroppings exposed to possible vehicle impacts should be avoided. A typical rock cut is shown in the *MassHighway Construction Standards*.

High earth cuts may warrant terracing. Terracing reduces erosion and enhances soil stability. As a general rule, terraces should be provided at approximately 20 foot intervals. The Geotechnical Unit shall be consulted for these designs.

For cut or fill sections, it may be necessary to reduce the clear zone for environmental, cost, right of way or aesthetic considerations. Recent requirements for clear zones frequently increase the cut and fill requirements substantially. Guardrail should be used on fill slope where recovery area is not available. A concrete barrier may be appropriate at cut locations as a retaining wall. A 2-foot offset must be added to the shoulder dimension as is done for guardrail. In cut sections a ditch of sufficient width must be provided behind the barrier to maintain drainage flow from the hillside and to retain rocks and debris which may fall from the hillside.

5.6.6 Ditch Sections

Roadside ditches divert and remove water from the surface and subsurface of the roadway. Chapter 8 discusses the types, hydraulic characteristics, and protective linings for ditches. Roadway ditch foreslopes steeper than 1v:6h are not desirable for safety reasons. In addition, 1v:6h or flatter foreslopes reduce the potential for snow drifts.

Roadside ditches can have several shapes: V, radial, trapezoidal or parabolic. The trapezoidal ditch is the preferred shape when considering safety and ease of design, construction and maintenance. Parabolic and circular ditch sections are used in special circumstances. Examples of these are provided in the *MassHighway Construction Standards*.

5.7 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.

5.7.1 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 in sequence with the construction of the roadway project so that disruption to the public is minimized.

In general, overhead utility poles should be located outside the shoulders, sidewalk, and roadside recovery areas (if provided). If utility poles can not be located outside of the sidewalk area, it is important that the minimum clear path of travel for pedestrians described in Chapter 5 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.

5.7.2 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 $\frac{1}{2}$ the width of the sign face plus one additional foot from the face of curb. Additionally, signage can not impede the "accessible route" defined under 521 CMR.

5.8 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 ROW impact on cultural and commercial features.
- Additional right of way is often required for wetland mitigation.

5.9 For Further Information

- *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, 2004.
- *Highway Capacity Manual, Special Report No. 209*, Transportation Research Board 1995.
- *Roadside Design Guide*, AASHTO, 2002.
- *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.
- *MassHighway Design Policy for Bridge R&R Program for Non-NHS Roadways*, October 1992.
- *Americans with Disabilities Act Handbook*, December 1991.
- *Architectural Access Board, Rules and Regulations*, 521 CMR 1.00 et seq.
- *AASHTO Guide for the Development of Bicycle Facilities*, 1999.
- *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.
- *NCHRP Report 350 - Recommended Procedures for the Safety Performance Evaluation of Highway Features*, 1993.
- *TCRP Report 19 – Guidelines for the Location and Design of Bus Stops*, 1996.
- *Accessibility Guidelines for Outdoor Developed Areas*, Architectural and Transportation Barriers Compliance Board, 1999.