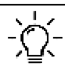
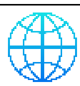
Chapter 7
Cross Section Elements

Legend

	Multimodal Application Example
	Context-Sensitive Solutions Application Example
	Performance-Based Practical Design Application Example
	Multimodal (MM)
	Context-Sensitive Solutions (CSS)
	Performance-Based Practical Design (PBPD)
	Web link for additional information
	AASHTO-Specific Information

Chapter

7

7 Cross Section Elements

7.1 Introduction

The development of roadway cross sections is often the building block for transportation decision-making and project development. Recognizing that Colorado's roadways serve a diverse set of travel modes and commerce needs, a balanced approach needs to be considered when developing a cross section and its elements that meets the purpose and need, project statement, local community's needs, and the Colorado Department of Transportation (CDOT) Region goal for the roadway. This often requires a high level of stakeholder outreach to understand the modal priorities on a particular corridor and how those priorities can be allocated within the limited roadway space.

7.2 General Description

The roadway cross sectional elements extend from vehicular travel lanes to include dedicated bicycle/transit lanes or shoulders, parking lanes, raised or flush medians, landscape buffers and pedestrian sidewalk and amenity zones. The allocation and design of the available space should be done with an understanding of both the cross section and the corridor. Cross sections will often vary throughout a project length to adapt to different context zones and identified constraints. Design of a cross section should also consider the longitudinal and crossing movements of all users, with the elements balanced to optimize functionality and safety within constraints and practicality.

There is no definitive minimum standard governing one or two-way roadway widths. As an example, on urban arterials, sufficient unobstructed width should be provided for oversized loads if they are known to use the facility. Determining if this is necessary should be based upon the frequency and number of oversized transports and/or the location of oversized transport generators in the area. The impacts of accommodating these transport types and anticipated volume should be weighed against the cost, speed, and safety advantages or disadvantages of a widened cross section. In general, urban and suburban roadway widths should be kept to a practical minimum necessary to accommodate the modes and volumes expected. This approach may require truck turns and oversized loads to encroach on adjacent and/or opposing lanes. If the volume of large vehicles is minimal, it may be acceptable to incur occasional encroachments.

In addition, during winter conditions, it is reasonable to assume there may be a small loss (e.g., 1 to 3 -feet) in usable width along each outside curb line to accommodate snow removal deposition and ice buildup. Designers should take this into account and understand how the facility will operate under such conditions. Alternatively, a wider landscape area between the edge of the roadway and the sidewalk could be used as a snow storage area in locations that experience more frequently higher snow accumulation totals.

General guidance and criteria include:

- For reconstruction and preservation on rural highways, begin with the existing total roadway section width as a starting point for design consideration. Reallocation of lateral space among lane and shoulder width should be investigated using the *AASHTO Highway Safety Manual* (AASHTO, 2010) to identify beneficial tradeoffs and potential performance improvement.
- Use locally calibrated *Highway Safety Manual* data, where available, when considering tradeoffs between lane and shoulder widths on rural highways.
- On urban and suburban streets, allocate lane and shoulder widths to balance the functionality and safety of all modes of travel. Wider is not necessarily safer.

7.2.1 Surface Type

The selection of pavement type is determined by the volume and composition of traffic, soil characteristics, recurring weather conditions, performance of pavements in the area, availability of materials, energy conservation, the initial cost and the overall annual maintenance and service life cost. The structural design of pavements is not included in this chapter but may be found in the CDOT *M-E Pavement Design Manual* (CDOT, 2021). Prior to the beginning of the pavement design process, it is highly recommended that the designer, at project inception, discuss the general scope of the project with the local CDOT materials engineer or pavement manager to begin the pavement design process. The materials engineer will provide guidance pavement type or pavement treatment selection.

Refer to Chapter 4, Section 4.2.1, of the American Association of State Highway and Transportation Officials (AASHTO) *A Policy on Geometric Design of Highways and Streets* (the Green Book) (2018 AASHTO GDHS) (AASHTO, 2018) for more information.

7.2.2 Reference Documents

CDOT *Mechanistic Empirical (M-E) Pavement Design Manual*. The *M-E Pavement Design Manual* (CDOT, 2021) provides a uniform and detailed procedure for designing pavements on CDOT projects. It is highly recommended that the designer work with the CDOT Region Materials Engineer to initiate a pavement design for a project early during the project scoping phase.

Use the following link to access CDOT's M-E pavement Design Manual: CDOT M-E Pavement Design Manual.

CDOT Standard Plans – M&S Standards. The CDOT Standard Plans - M & S Standards (CDOT, 2019) is a compilation of CDOT Standard Plans for CDOT construction projects. Standard Plans that are applicable to a specific project are identified on the project plans and are not physically attached to those plans. The designer specifying any of these Standard Plans for a specific project accepts the responsibility of determining their applicability. Additional information concerning the Standards Plans are available in the *CDOT Standard Specifications for Road and Bridge Construction* (CDOT, 2022). Standard Plans adopted or revised subsequent to the adoption of this Guide shall be listed on the index of the project plans and physically included in the plans. The designer should regularly check for new or revised standards at the link below as they are frequently updated.

Use this link to access CDOT Standard Plans – M&S: CDOT Standard Plans - M&S

7.2.3 Cross Slope

Design of the roadway cross slope often requires a balance between the need for reasonably steep cross slopes for drainage purposes and relatively flat cross slopes for user comfort. Pavement superelevation on curves is determined by the speed-curvature relationships given in Chapter 3 of this Guide and CDOT Standard Plans - M & S Standards (CDOT, 2019).

Two-lane and wider undivided highways on tangents have a crown or high point at the centerline and slope downward at an even rate outward. On higher speed and intermediate type undivided roadway, crowned at the center, the desired rate of cross slope is 2%.

An overlay typically will match the existing cross slope unless the safety assessment report indicates cross slope corrections need to be made. The profile grade and pivot point are generally located at the pavement crown.

On divided highways, typically each direction of roadway has a consistent cross slope across the entire width of pavement. At intersections, interchange ramps or in unusual situations, the crown position may vary depending upon the presence of medians, islands, auxiliary lane configurations, drainage, or other site-specific controls.

To avoid excessively close inlet spacing, hydroplaning, and other drainage problems associated with flat pavement slopes and wide typical cross sections, superelevation transitions and vertical curve lengths should be minimized in wide typical cross sections to reduce flat areas that may accumulate water.

On steeper cross slopes or super elevated cross sections, bicyclists and pedestrians using mobility devices may have trouble balancing or traveling along their intended path and therefore the roadway shoulder cross slope should be kept to 2% or less. See Chapters 12 and 13 for design guidance.

7.2.4 Skid Resistance

"Pavement types and textures also affect a roadway's skid resistance. The four main causes of poor skid resistance on wet pavements are rutting, polishing, bleeding, and dirty pavements. Rutting causes water accumulation in the wheel tracks. Polishing reduces the pavement surface micro-texture and bleeding can cover it. In both cases, the rough surface features needed for penetrating the thin water film are diminished. Pavement surfaces will lose their skid resistance when contaminated by oil drippings, layers of dust, or organic matter. Measures taken to correct or improve skid resistance should result in the following characteristics: high initial skid resistance durability, the ability to retain skid resistance with time and traffic, and minimum decrease in skid resistance with increasing speed." (2018 AASHTO GDHS).

CDOT's practice for concrete pavements is to use longitudinal tining. Tining is defined as pulling a specially designed rake across the finished uncured surface to create grooves in the pavement which aids in reducing hydroplaning and skidding. Tining is required for design speeds of 40 mph and greater. Transverse tinning is typically not installed as it increases road noise significantly.

Roadway shoulders used for bicyclists and pedestrians should be paved and of a consistent material with the vehicular travel lanes. Refer to Chapters 12 and 13 for design guidance.

7.2.5 Traveled Lane Texturing (Rumble Strips)

Transverse travel lane rumble strips may be considered for locations where unexpected roadway conditions cannot be corrected through traditional geometric or traffic control measures and supplemental audible and vibratory indications are necessary to inform a driver of the approaching condition. These transverse rumble strips are typically installed by saw cutting or grinding the pavement and only done so in locations where the noise from the rumble strips will not adversely affect nearby residents where the CDOT Region Traffic Engineer approves of the installation. Examples of where transverse rumble strips may be effective include:

- Advanced warning on a high-speed rural roadway approaching a stop-controlled intersection.

- Advanced warning for the dropping of a traveled lane on a high-speed roadway.
- Advanced warning for the existence of a horizontal curve that is well below the design speed for the rest of the roadway (i.e., a 25 mph curve on a 45 mph highway).
- Other locations as determined by the CDOT Region Traffic Engineer or a safety study.

The transverse rumble strips are typically installed in conjunction with other warning and regulatory devices to help increase driver awareness and understanding of the potential hazard or unexpected condition ahead.

If rumble strips are installed on a facility that is a bicycle route, a minimum of 4 feet of clearance should be provided between the outside edge of the rumble strips and the edge of pavement (or guardrail if applicable), and they should be intermittent to provide gaps for bicyclists to move between the shoulder and outside travel lane if needed to avoid obstructions or debris. If space is limited, edge line rumble strips can be used to maintain 4 feet of clear space on the shoulder. Refer to Chapter 13 of this Guide for design guidance.

Refer to CDOT Standard Plans – M & S Standards Project Special Detail M-614-1 (CDOT, 2019) for additional details.

7.3 Lane Widths

Before identifying the proposed travel lane width of the vehicular travel lanes, the context of the roadway, intended users and surrounding land use should be considered. Depending on these factors along with others, the roadway travel lane width can generally vary between 10 and 12 feet. For lower speed roadways in more urban or downtown land use contexts with less truck traffic and greater pedestrian and bicycle activity, 10-foot lanes may be appropriate. As a roadway transitions to more rural and high-speed contexts, 12-foot lanes might be more appropriate. Cross Sections in this Guide provides a general overview of the lane widths based on various context zones.

Refer to Chapter 4, Section 4.3, of the 2018 AASHTO GDHS for more information.

7.3.1 MM, PBPD, and CSS Considerations

- *Multimodal ((MM).* In more urban contexts, pedestrian and bicycle safety and operations may be prioritized over vehicular mobility and travel speed and thus may support narrower travel lanes to reinforce lower travel speeds and opportunities for shorter pedestrian crossings and wider bicycle facilities. Many studies have confirmed that there is no reduction in vehicle capacity by using 10-foot travel lanes and have proven a positive influence on reduced vehicle crashes and overall crash severity.
- *Context Sensitive Solutions (CSS).* Designing travel lanes and shoulders as wide as possible along with providing wider unobstructed roadway clear zones has the potential to encourage

higher travel speeds and result *in* roadway becoming a barrier to pedestrians trying to cross the roadway. Serious consideration and discussion should occur with the local community stakeholders to determine the desired priorities for the roadway that reflect the community, statewide safety strategies, and mobility goals.

- *Performance-based practical design (PBPD).* Engineers should use national best practice research found in AASHTO and NACTO guides for determining the appropriate lane width that reflects the various contextual elements of the roadway location. Context considerations should include modal priorities, land use context, regional and local roadway relevance, historic safety performance and community input. Furthermore, narrowing a travel lane may reduce right of way impacts, operation and maintenance costs, capital costs, and improve operations and performance, but this must be evaluated for each project.

7.4 Shoulders

7.4.1 General Characteristics

A shoulder is the portion of the roadway that is generally located to the left and/or right of the active travel lanes depending on the roadway orientation. Shoulders serve a variety of purposes including but not limited to allowing a space for stopped vehicles or slower moving vehicles to pull off, bicycle lanes, emergency use, lateral support of subbase, base, and surface courses and a recovery area in an avoidance maneuver.

Refer to Chapter 4, Section 4.4, of the 2018 AASHTO GDHS for more information.

7.4.2 Width of Shoulders

For purposes of this Guide, the shoulder shall be the minimum continuous usable width of shoulder that provides an all-weather surface and meets the purpose and need and/or project statement. The typical width will vary from 4 to 12 feet, depending on the roadway design vehicle, constraints, safety, and funding. Shoulders should be paved full width in accordance with the functional or physical characteristic of the roadway. The shoulder width will likely vary where speed-change lanes, auxiliary lanes, turn lanes, climbing lanes, or curb and gutter are used. Refer to Chapter 14 of this Guide for additional information for designing bicycle paths using shoulders.

7.4.3 MM, PBPD, and CSS Considerations

The needs of bicyclists and pedestrians should be considered when determining the appropriate shoulder width. Shoulders can generally range in width from 4 to 16 feet and should reflect the intended context, whether it be a bicycle uphill climbing lane or a truck chain up area. From a bicycling perspective, wider shoulders are generally preferred to provide increased separation from moving traffic, allow for side-by-side riding in compliance with state law, and provide opportunity to avoid roadway debris without having to travel into the adjacent travel lane (especially important along steeper downhill sections). In mountain locations where there is insufficient shoulder width to provide an appropriate width shoulder in both directions, consideration should be given to maximizing the width of the bicycle shoulder in the uphill direction where speed differential is greatest; and to utilize a narrower shoulder the downhill direction where bicyclists are more likely to be traveling a speed closer to that of vehicular traffic.

If determined appropriate, rumble strips located between the travel lane and shoulder should be installed in accordance with Standard Plan No. M-614-1 and should only be installed where a minimum of 4-foot of clearance between the outside edge of the rumble strip and outside edge of pavement can be maintained. When necessary to maximize the width of usable shoulder for bicyclists, the rumble strips can be located on the edge of the travel lane within the white edge line stripe. In accordance with the M-614-1 standard plan, gaps in the rumble strip should be provided to allow cyclists to transition between the shoulder and adjacent travel lane to allow for the avoidance of debris or stopped vehicles along with making a left turn at a downstream intersection.

The cross slope of the roadway shoulder should also be considered when evaluating the needs of bicyclists and pedestrians. Ideally a shoulder needs to be at least 4 feet wide to provide a level of confidence for a cyclist to use on a regular basis. Shoulders narrower than 4 feet reduce the comfort of the cyclist and the motorist alike when a car is overtaking a bicycle or group of bicycles.

Shoulders can help reduce roadway departure crashes, but in a PBPD design this may not be best option based on the data, context, and purpose and need of the project. It may not be the most cost-effective decision to widen shoulders as this can increase earthwork, right of way, and pavement costs to the project. In a PBPD process, one of the first steps the engineer should take is to determine what users are frequenting the corridor. Are there bicyclists using the shoulders? Are farm and agriculture vehicles present that use the shoulder to move from field to field? Is there a bus route and stops? What is the crash history for the roadway, and is there a concentration of roadway departures at specific locations? If the recommended shoulder widths of the 2018 AASHTO GDHS are being used, why not consider providing wider shoulders where crash concentrations suggest this to be beneficial, but use a narrower shoulder to accommodate other uses where there is little or no crash history indicating the need for a widened shoulder?

Use this link to access information about CDOT's High Demand Bicycle Corridors:
https://www.codot.gov/programs/bikeped/high-demand-bicycle-corridors

7.4.4 Shoulder Cross Sections

In most cases, the shoulder cross slope should be the same as the cross slope of the adjacent travel lanes. However, in sag vertical curves in tangent horizontal alignments with narrow shoulder widths or where inlet spacing becomes excessive, the shoulder cross slope should be steepened up to 1% greater than the adjacent lane cross slope to increase the hydraulic carrying capacity of the shoulders. The designer also should consider breaking the uphill shoulder in the opposite direction on fully superelevated roadways to reduce water draining across the road and preventing icing conditions. The algebraic difference between the shoulder and travel lane cross slopes shall be 5% or less. Greater algebraic differences require rounding the travel lane slope to transition to the shoulder break and maintain the maximum 5% algebraic difference.

7.4.5 Shoulder Stability

Shoulders should be paved full depth in accordance with the functional or physical characteristic of the roadway. At certain locations, erosion of topsoil or shouldering materials adjacent to the pavement edge results in hazardous conditions for the motorist and a reduction in lateral support for the pavement. The use of a pavement safety edge is required on all projects having roadway pavement. The pavement safety edge shall be included on all resurfacing or reconstruction projects. Vertical pavement edge drop-off on highways has been linked to many serious crashes when errant vehicles attempt to steer back onto the roadway. Instead of a vertical drop-off, the safety edge shapes the edge of the pavement to 30 to 35 degrees. Research has shown this is the optimal angle to allow drivers to reenter the roadway safely. Refer to the CDOT Standard Plans - M & S Standards Project Special Detail D-614-1 (CDOT, 2019) for additional information.

Use this link to access the CDOT Safety Edge details: Project Special Safety Edge Detail D-614-1

7.4.6 Shoulder Contrast

Distinguishing paved shoulders from the mainline pavement is recommended to discourage the use of the shoulder as a travel lane and provide guidance and warning to drivers. This can be accomplished by pavement markings and differences in shoulder surface texture.

Shoulder texture treatments that provide an audible or vibrational warning to errant drivers have proven effective in keeping traffic off the shoulder and reducing crashes on long tangent or highway sections with a history of roadway departure crashes. Rumble strips may also be used to differentiate a shoulder and minimize roadway departure crashes and shall comply with the current CDOT Standard Plans - M & S Standards (CDOT, 2019).

This is a viable option that should be considered based on the purpose and need and/or project statement. This option needs to fit within the context and functionality of the project.

Rumble strips should always be considered for use in rural areas where flat or rolling terrain with long tangents and relatively flat curvature is predominant. These physical elements tend to result in increased driver inattentiveness or drowsiness. Under these circumstances, the use of shoulder rumble strips is highly recommended but should be discussed with the CDOT Region Traffic Engineer before being included in the design.

If there is any doubt on the use of rumble strips, further analysis should be conducted with input from the CDOT Region Traffic Engineer. The analysis shall include taking into consideration crash history, bicycle usage, and other pertinent risk factors that will help to decide the appropriate application of rumble strips. Suggested designs to accommodate rumble strips and a bicycle facility are found in Chapter 13 of this Guide.

Other textures or methods, such as chip seals, slurry seals, or cape seals, may be used in lieu of shoulder grooving on an experimental basis. Course chip seals (1/2-inch aggregate or larger) are not recommended in areas with regular bicycle traffic.

7.4.7 Turnouts

Refer to Chapter 6 of this Guide for information on turnouts.

7.5 Cross Section Templates

This section includes typical facility type cross section templates with common overlays, such as bicycle, pedestrian, and transit facilities, for the each of the six context classifications described in Chapter 1. These templates are meant to serve as a starting point, with modifications and overlays dictated by the CSS and PBPD processes.

Design influences begin before "design" begins. In other words, knowing who the users of the roadway prism are and evaluating the data analytics for the roadway (corridor vision plans, crash data, pedestrian data, truck, bike, and transit data) may directly influence the scope development of the project. Early project scoping and alternatives identification and evaluation efforts have a major influence on design outcomes. As a project moves from preliminary to final design, it becomes much more difficult to modify design configurations to achieve overall project outcomes. Future versions of the AASHTO GDHS will emphasize a performance-based process framework and a design model for identifying project contexts and developing and evaluating roadway configurations that meet intended project outcomes. Conducting these evaluations early in the project development process increases the opportunities for design flexibility. NCHRP Report 785: *Performance-Based Analysis of Geometric Design of Highways and Streets* conceptually depicts the influence and role geometric design performance measures have from project planning to final design.

Following good investigative scoping analysis into the current roadway users and characteristics is a major step to ensure that multimodal and context sensitive needs for the corridor are being considered. This is also the foundation of performance based practical design that will establish the roadway template that will meet the needs and vision of the users.

The dimensions of a typical cross section depend on several features that vary with the type of roadway and context. The design may be adjusted for specific conditions as indicated in the appropriate chapter of this Guide or for the specific classification of roadway.

CDOT includes Z slopes in typical sections. The Z slopes, which slope gently away from the edge of the pavement, provide for safety, drainage, snow storage, sign placement, and rockfall containment and shall be included in the design. The typical section also indicates the locations of the following points:

- *Hinge Point*. The point on the subgrade directly below the edge of the pavement from which the subgrade slopes downward to the point of slope selection.

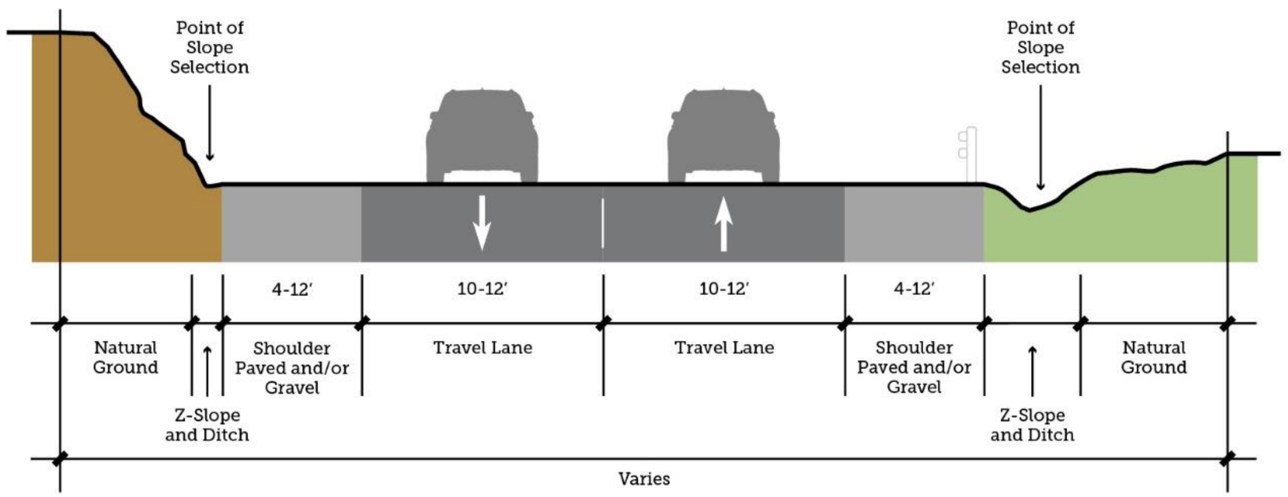
- *Point of Slope Selection.* The point at the toe of the Z slope that intersects with the subgrade. The point of slope selection is the point at which the embankment or excavation begins to slope away from the roadway prism.
- *Profile Grade.* The point on the pavement surface, defined by its location on the vertical alignment of the roadway, from which all other points and slopes on the cross section are determined.
- *Pivot Point.* The point on the pavement surface about which the cross slope of the roadway is rotated to effect superelevation. The pivot point may be at the same location as the profile grade.

Templates and renderings are provided on the following pages for:

- C1: Rural Mountainous Environment
- C2: Rural Places
- C3: Suburban Places
- C4: Traditional Neighborhood
- C5: Downtown Places
- C6: Urban Core
- Freeway

C1: RURAL MOUNTAINOUS ENVIRONMENT / CROSS SECTION EXAMPLES

TYPICAL SECTION



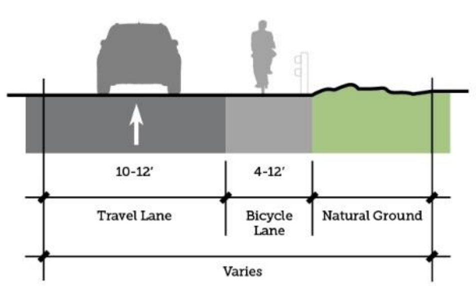
Rural Mountain Road: Ground Level

Rural Mountain Road: with Bike Shoulders

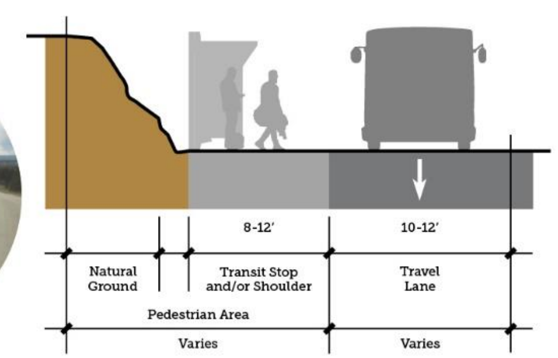
Rural Mountain Road: with Slow Vehicle Turn-outs at High Altitude

TYPICAL SECTION OVERLAYS

Bicycle Lane: Type A



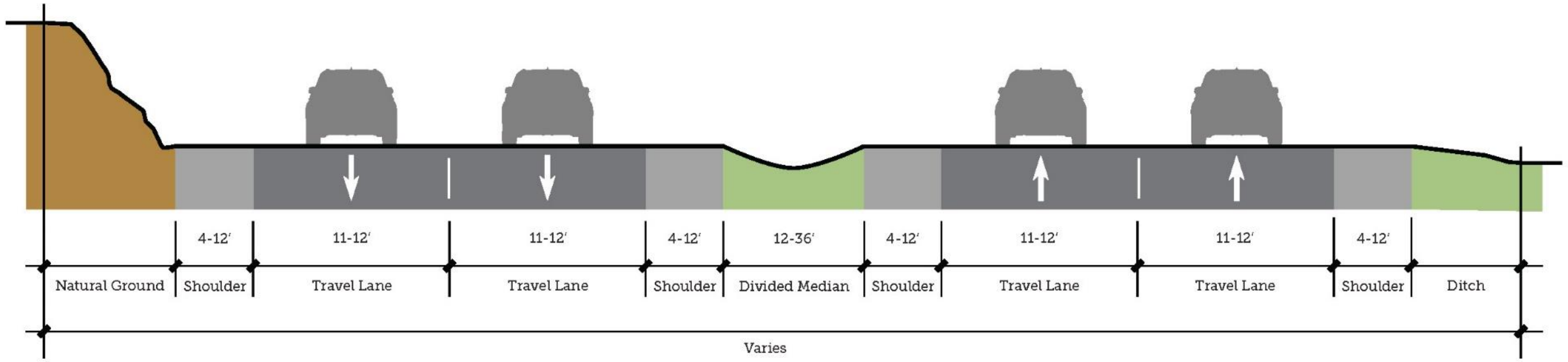
Transit Stop: Type B



C1: RURAL MOUNTAINOUS ENVIRONMENT / RENDERING EXAMPLE

C2: RURAL PLACES / CROSS SECTION EXAMPLES

TYPICAL SECTION



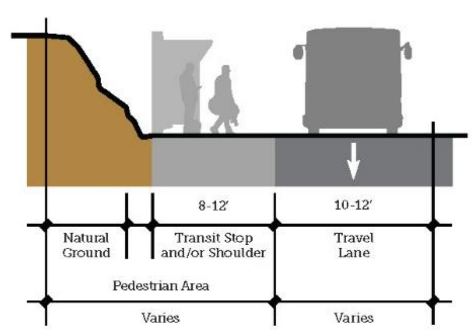

Rural Places:
Ground Level


Rural Places:
Aerial Level

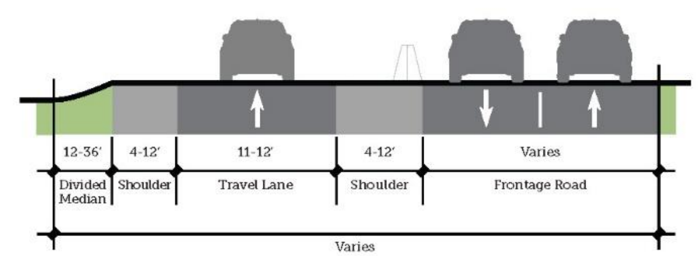
TYPICAL SECTION OVERLAYS

Transit Stop: Type B

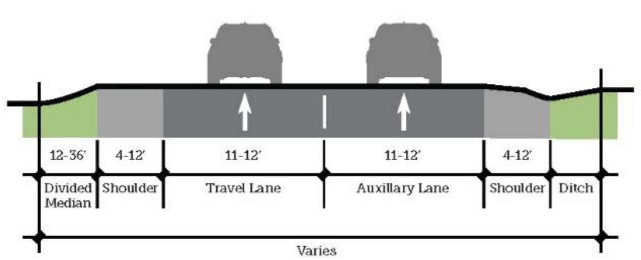




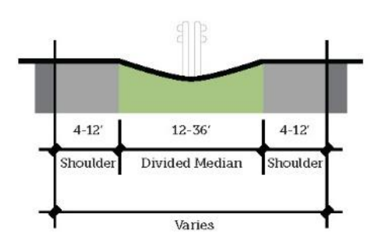
Frontage Road

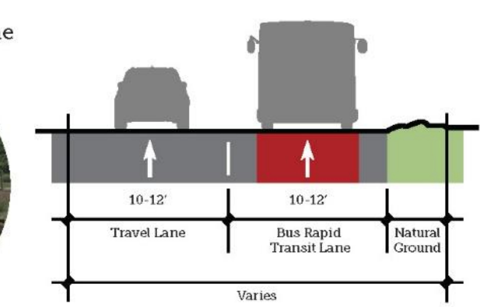
Auxiliary Lane

Median Guardrail/Barrier Divider

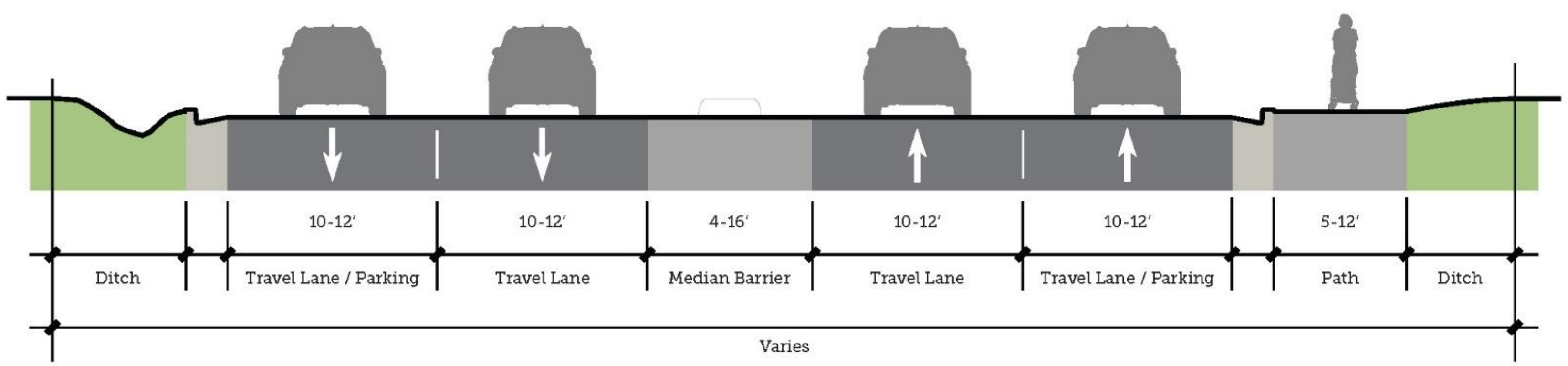
Bus Rapid Transit Lane

C2: RURAL PLACES / RENDERING EXAMPLE

C3: SUBURBAN PLACES / CROSS SECTION EXAMPLES

TYPICAL SECTION

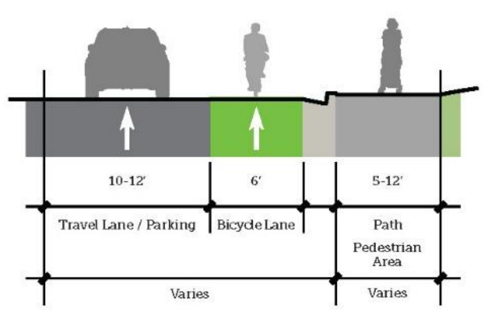


Suburban Places:
Ground Level

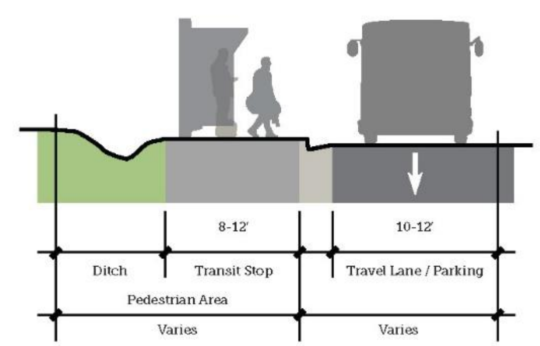
Suburban Places:
Ground Level

TYPICAL SECTION OVERLAYS

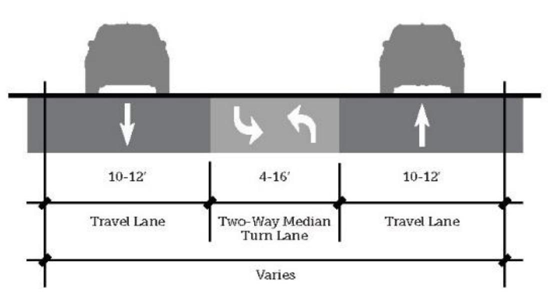
Bicycle Lane



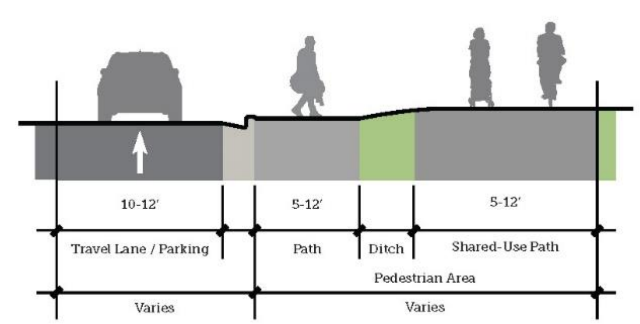
Transit Stop



Two-Way Turn Lane



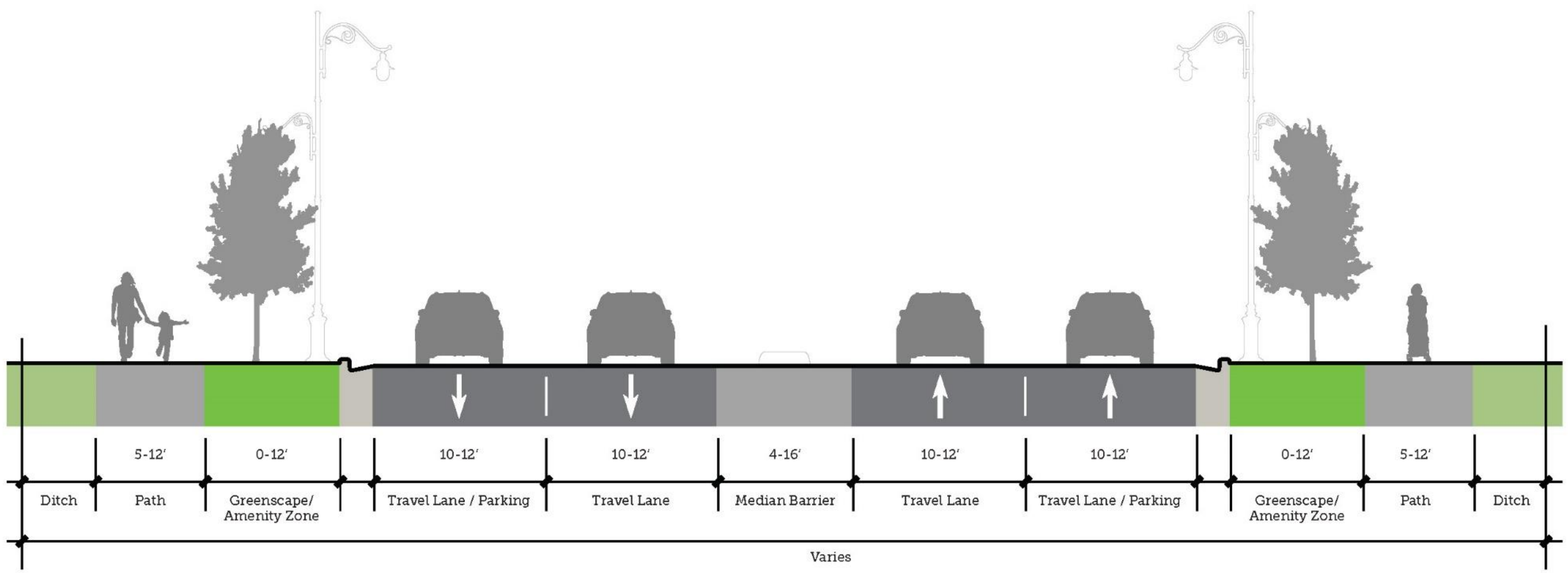
Shared-Use Path



C3: SUBURBAN PLACES / RENDERING EXAMPLE

C4: TRADITIONAL NEIGHBORHOOD / CROSS SECTION EXAMPLES

TYPICAL SECTION

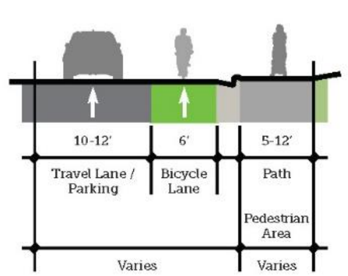


Traditional Neighborhood: Ground Level

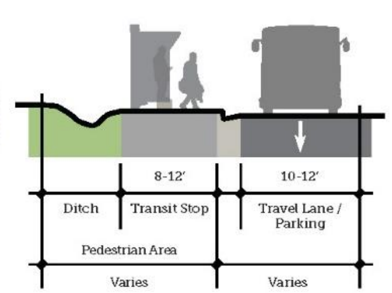
Traditional Neighborhood: with Bike Lane

TYPICAL SECTION OVERLAYS

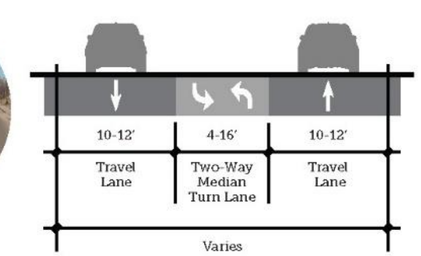
Bicycle Lane



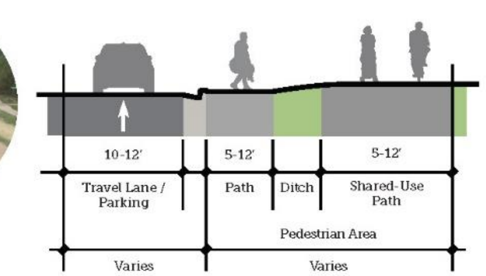
Transit Stop



Two-Way Turn Lane



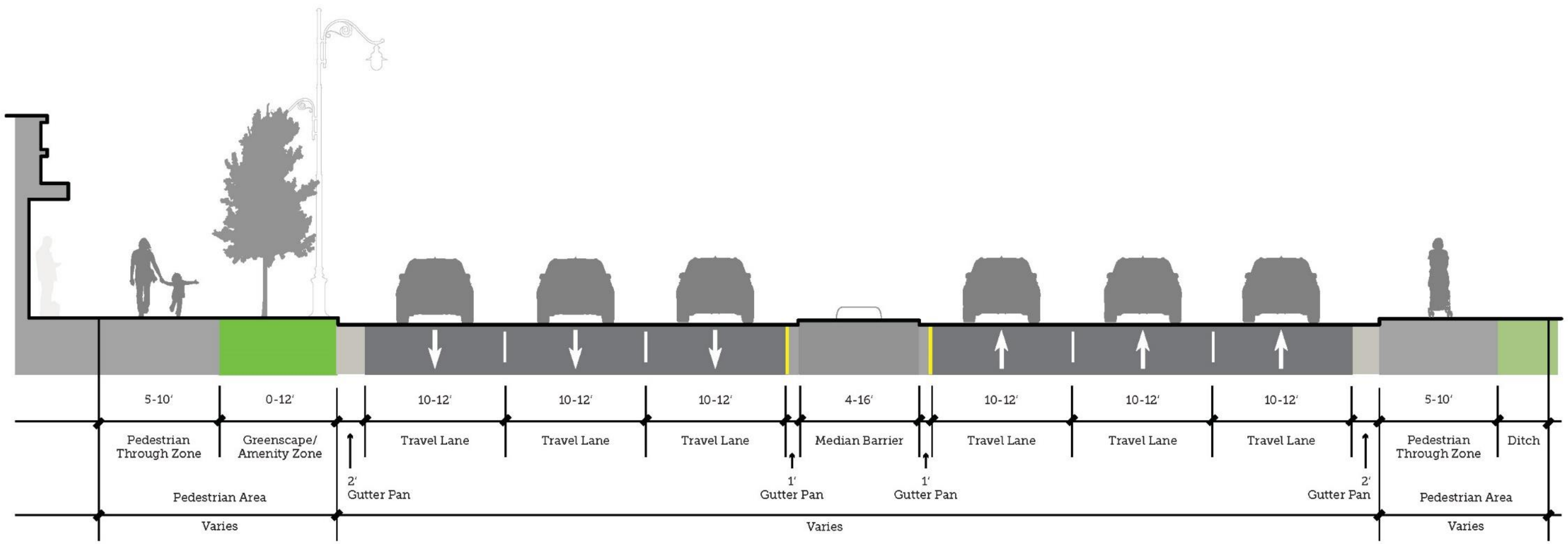
Shared-Use Path



C4: TRADITIONAL NEIGHBORHOOD / RENDERING EXAMPLE

C5: DOWNTOWN PLACES / CROSS SECTION EXAMPLES

TYPICAL SECTION

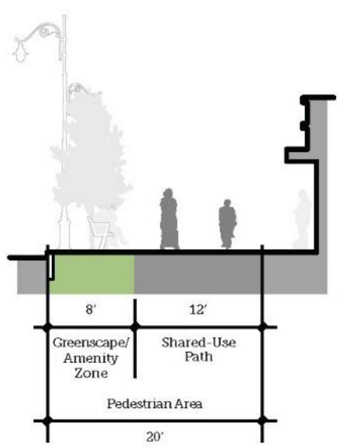


Downtown Places: Ground Level

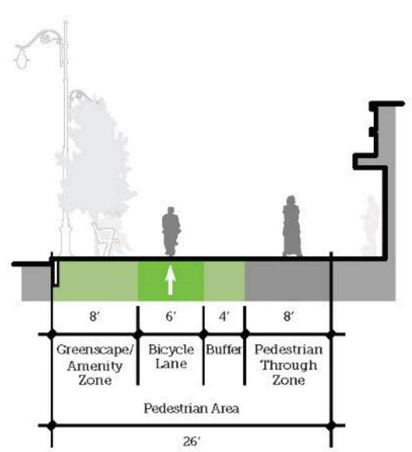
Downtown Places: Ground Level

TYPICAL SECTION OVERLAYS

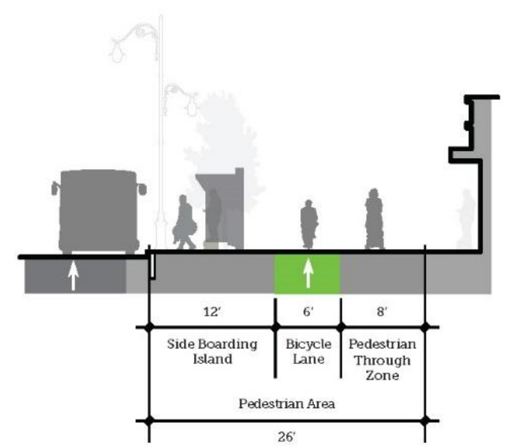
Shared-Use Path: Type A



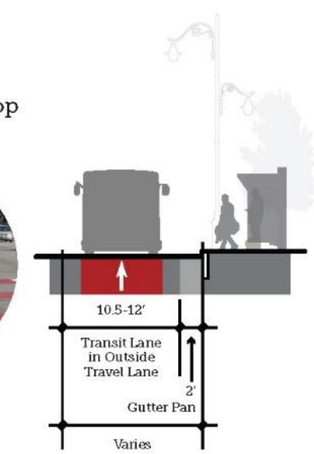
Protected Bicycle Lane: Type B



Bicycle Lane with Transit Stop



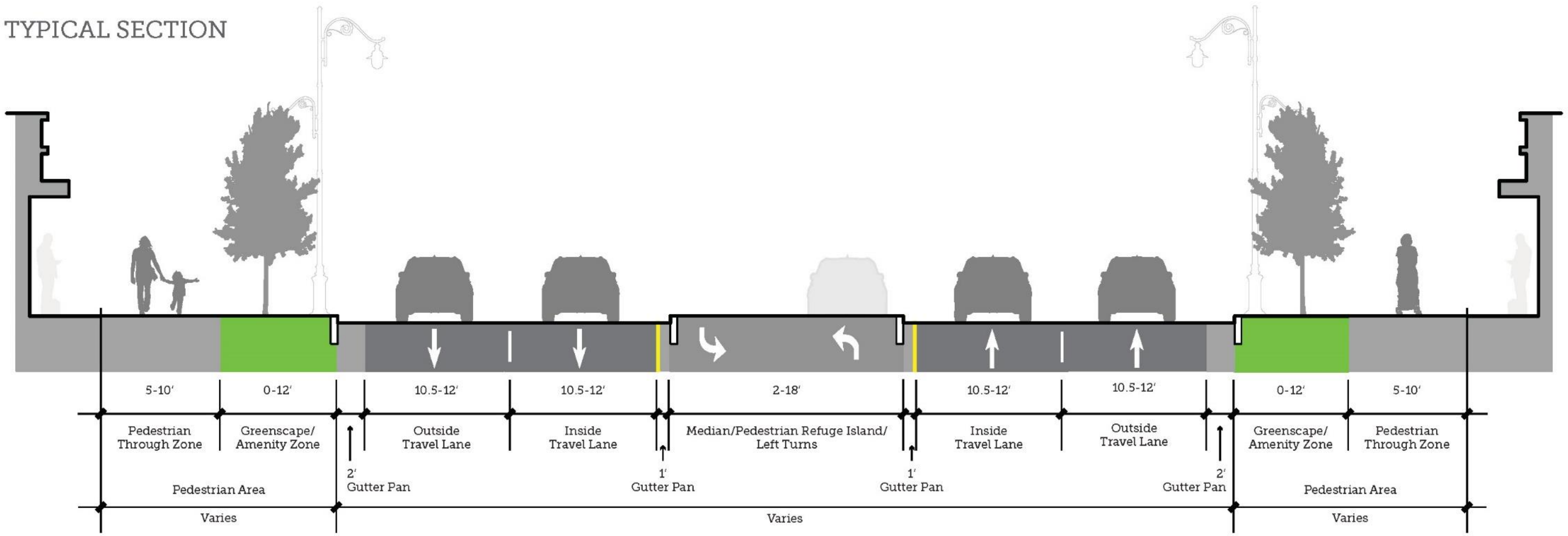
Transit Lane with In-Lane Stop



C5: DOWNTOWN PLACES / RENDERING EXAMPLE

C6: URBAN CORE / CROSS SECTION EXAMPLES

TYPICAL SECTION

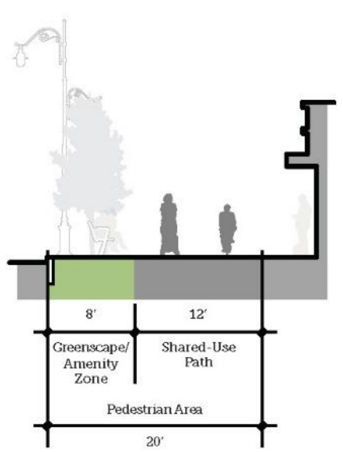


Urban Core: Ground Level

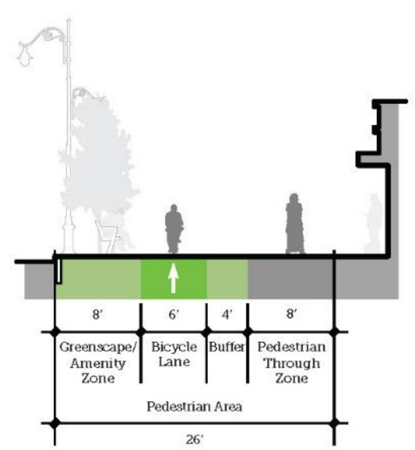
Urban Core: Ground Level

TYPICAL SECTION OVERLAYS

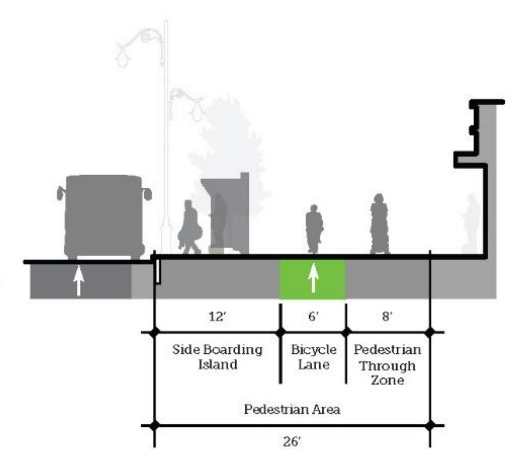
Shared-Use Path: Type A



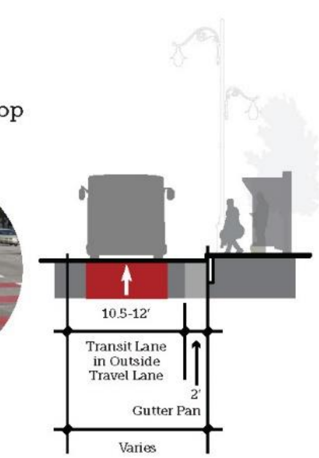
Protected Bicycle Lane: Type B



Bicycle Lane with Transit Stop



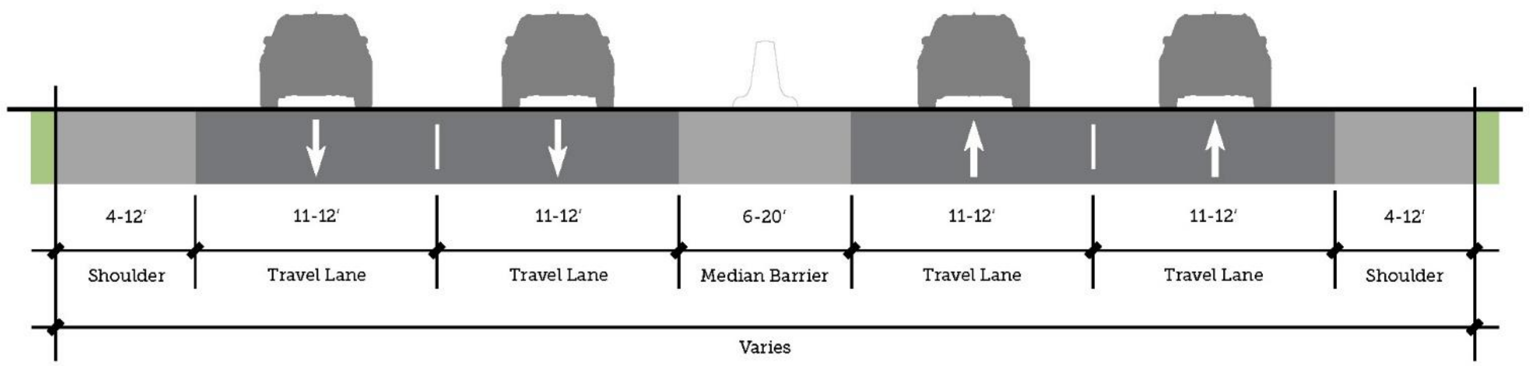
Transit Lane with In-Lane Stop



C6: URBAN CORE / RENDERING EXAMPLE

FREEWAY / CROSS SECTION EXAMPLES

TYPICAL SECTION



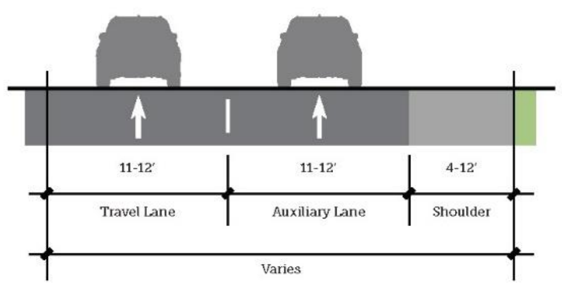
Freeway:
Ground Level

Freeway:
Overpass Level

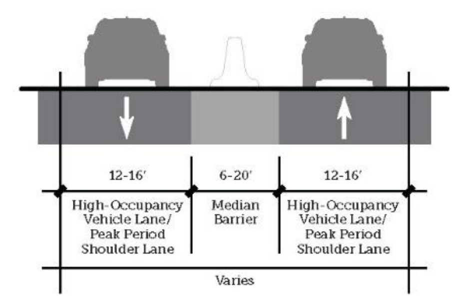
Freeway:
Aerial Level

TYPICAL SECTION OVERLAYS

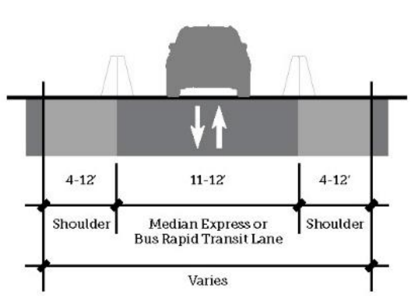
Auxiliary Lane

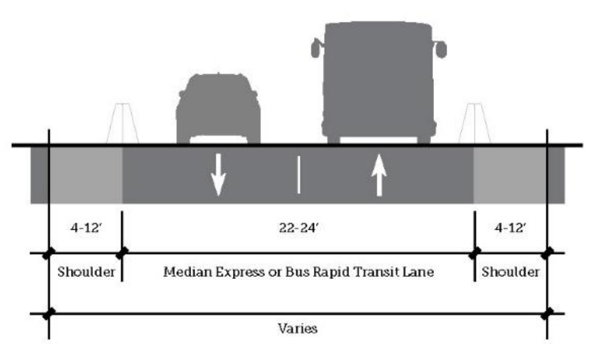


High-Occupancy Vehicle / Peak Period Shoulder Lane

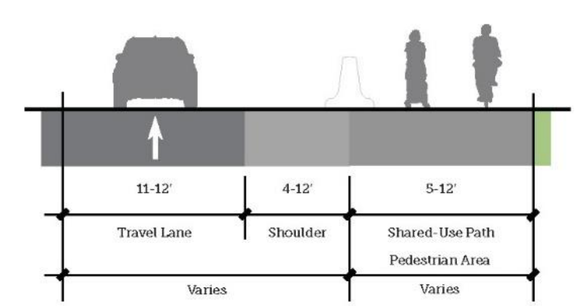


Median Express or Bus Rapid Transit Lane





Protected Shared-Use Path



FREEWAY / RENDERING EXAMPLE

7.6 Roadside Design

The term "clear zone" is used to designate the unobstructed, relatively flat area provided beyond the traveled way for the recovery of errant vehicles. The traveled way does not include shoulders.

The width of the clear zone is influenced by the traffic volume, speed, and embankment slopes as discussed in the AASHTO *Roadside Design Guide* (AASHTO, 2011). The AASHTO Guide should be used as a reference for determination of clear zone for freeways, rural arterials, and high-speed rural collectors.

For urban arterials, collectors, and local streets where curbs are utilized, space for clear zones is generally restricted. Where right of way is not restricted, a desirable clear zone area would be 4 feet behind the curb on tangent sections and 6 feet behind the curb on the outside of curve sections. In constricted right of way conditions, a minimum clear zone offset distance of 18 inches or more should be provided beyond the face of the curb to the face of the obstruction. The designer should consider large pole foundation diameters to avoid interference with back of curb. Where shoulders are provided rather than curbs, a clear zone commensurate with the AASHTO *Roadside Design Guide* (AASHTO, 2011) should be provided.

At signalized intersections, there are instances to have curbed medians with traffic signal poles located in the medians. The designer should discuss signal pole placement with the traffic engineer. Placing signal poles too close to the traveled lanes to reduce mast arm length is contrary to good safety practices. The cost of a longer mast arm to position the pole as far away from high-speed traffic should be exercised to provide the largest safety margin to avoid crashes with the poles.

Additionally, when considering pole placement in curbed median areas the designer must consider Public Rights of Way Accessibility Guidelines (PROWAG) (U.S. Access Board, 2011) requirements for accessibility-impaired pedestrians. Good thoughtful design of these elements and how they work together is critical to meet these requirements.

Use this link to access CDOT's ADA Resources for Engineers, including policy information, scoping and design resources, construction resources, measurement resources for curb ramps and push buttons, and training materials *https://www.codot.gov/business/civilrights/ada/resources-engineers*

7.6.1 Clear Zone Requirements with MM, PBPD, and CSS

It is important to understand the relationship that clear zone has on drivers' perceived level of safety and its influence on travel speed. Generally, as drivers perceive less risk when traveling along a roadway, they feel more comfortable traveling at higher rates of speed as is often found in more urban or mountain conditions. This should be considered when accounting for clear zones and the context of the project area. In many cases, designers and the community are looking to achieve travel speeds closer to the posted speed limit to improve safety, increase comfort of multimodal facilities, and reduce wildlife-vehicle collisions.

7.7 Curbs

"The type and location of curbs affects driver behavior and, in turn, the operation of a highway. Curbs serve any or all of the following purposes: drainage control, roadway edge delineation, right of way reduction, aesthetics, delineation of pedestrian walkways, reduction of maintenance operations, and assistance in orderly roadside development. A curb, by definition, incorporates some raised or vertical element." (2018 AASHTO GDHS)

The use of curbs on higher-speed roadways is discouraged in the interest of safety and because storm water runoff can be accommodated through natural runoff into the surrounding environment. In urban situations, curbs are more commonly used. In suburban contexts with higher travel speeds, judgment must be used, and the land uses should be considered, such as availability of closed drainage systems (storm sewers) and associated safety aspects.

Curbs can be configured in a number of ways and may be sloped to allow mounting by vehicles and bicycles or more vertical to discourage drivers from mounting the area outside of the roadway edge. Vertical curbs shall be used only on roadways where speed is 45 mph or less, with sloping curb being used where speeds are greater than 45 mph. Curbs should be avoided in front of the face of guardrail as the curb vaulting of the vehicle could affect the proper restraint the barrier is attempting to provide. Refer to CDOT Standard Plans - M & S Standards M-606-1 (CDOT, 2019) for guidance and alternatives to curb placement with guardrail systems. Vertical curbs should not be used along freeways or other high-speed arterials; but if a curb is needed, it should be of the sloping type and located as far from the active traveled way outside of the shoulder as possible. Refer to the CDOT *Drainage Design Manual* (CDOT, 2019) for minimal longitudinal slope requirements.

A 1-foot gutter is used with a curb where drainage control is not required, e.g., medians and islands. Sloping curb may be used on islands and medians where vehicle encroachment is expected based on the surrounding land use and desire lines. Sloping curb can also be used where there is a desire to limit general purpose traffic but accommodate larger design vehicles such as in the case of a truck apron of a roundabout or a mountable median cut through for emergency vehicles. Vertical curb should be used wherever a more physical deterrent to restricting access is desired.

Areas that require drainage control should have a curb with an integrated 2-foot gutter. Cross slope of gutter varies depending on whether the water is to flow toward or away from the curb. Refer to CDOT Standard Plans - M & S Standards (CDOT, 2019). Inlets and storm drains are favored over valley gutters for carrying drainage across intersections based on the potential impacts on safety and operations from navigating the depressed gutters. Radii of curbs in intersections are generally dictated by the type of roadway, intended design vehicle and the surrounding land use context. Larger radii should be used sparingly and should be kept as small as possible to control travel speeds and improve safety for all modes at the intersection.

Normally, the curb and gutter are not considered to be part of the usable travel lane width as drivers and bicyclists prefer to not operate in the gutter area based on the proximity to the curb face and the presence of a longitudinal joint. However, there may be exceptions in areas where lane width is constrained or a monolithic concrete pavement surface with consistent cross slope across the travel way and gutter are used. A 2-foot offset from the edge of travel way to the face of curb is preferred because placement of the curb may affect driver perception of the roadway, causing shying away from the curb.

Certain special circumstances occur with curb:

- Special curb types, such as curb without gutter or bituminous curbing, may be required.
- 10-foot transitions between different curb styles may be necessary.
- In high snow areas with frequent plowing operations, leading edge tapered median curb approaches are beneficial to prevent plow and curb damage.

Refer to CDOT Standard Plans - M & S Standards (CDOT, 2019) for further specific information on curbs.

7.8 Drainage Channels and Sideslopes

7.8.1 General Considerations

Current highway drainage design should incorporate safety, aesthetics, good appearance, ecology and control of pollutants, and economy in maintenance and construction. The above may be direct benefits of using flat sideslopes, broad drainage channels, and liberal warping and rounding. These features avoid obsolescence, improve appearance, and invite favorable public reaction.

The interrelationship between the drainage channel and the sideslope is important for safety because of the great influence they have on the sequence of events that can occur when a vehicle leaves the traveled way.

7.8.2 Drainage Channels

Drainage channels perform the vital function of collecting and conveying surface water from the highway right of way. Drainage channels, therefore, should have adequate capacity for the design runoff, should accommodate unusual storm water runoff conditions to minimize potential damage to the highway, and should be located and shaped to avoid creating a hazard to traffic.

Design flows and channel capacities can be determined based upon the CDOT *Drainage Design Manual* (CDOT, 2019). Side ditches should be used in all cut sections. Steep-sided channels are more desirable from a hydraulic point of view, but hydraulic performance shall be carefully evaluated if it introduces a steep slope hazard to errant vehicles within the clear zone of the highway. Channels shall be designed in accordance with the AASHTO *Roadside Design Guide* (AASHTO, 2011).

The depth of channel should be sufficient to remove the water while preventing saturation of the pavement subgrade. The depth of water that can be tolerated, particularly on flat channel slopes, depends upon the soil characteristics. In flat and low-lying areas with poor drainage and soil characteristics, a built-up roadway section or other means to move water well away from the roadway will help to prevent wicking of moisture back into the roadway subgrade prism.

Refer to Chapter 4, Section 4.8.3, of the 2018 AASHTO GDHS for more information.

7.8.3 Sideslopes

Sideslopes should be designed to ensure the stability of the roadway and to provide a reasonable opportunity for an out-of-control vehicle to regain control and return to the roadway safely. Three regions of the roadside are important when evaluating the safety aspects: the top of the slope (hinge point), the foreslope, and the toe of the slope (intersection of the foreslope with level ground or with a backslope, forming a ditch). In many situations, the toe of the slope is within the clear zone and the probability of reaching the ditch is likely, in which case safe transition between foreslope and backslope should be provided.

Rounded slopes reduce the chances of an errant vehicle becoming airborne, thereby reducing the hazard of encroachment and affording the driver more control over the vehicle. Foreslopes steeper than 4:1 are not desirable because their use severely limits the choice of backslopes. Slopes 3:1 or steeper are recommended only where site conditions do not permit use of flatter slopes. Clear runout space at the base of non-recoverable slopes is desirable. When foreslopes steeper than 3:1 must be used, consideration should be given to the installation of a roadside barrier. The designer should keep in mind that the introduction of a roadside barrier is actually adding a hazard to the roadway. Will this barrier hazard be more or less safe than the hazard protected by the barrier?

Normally, backslopes should be 3:1 or flatter to make it easier for motorized equipment to be used in maintenance. In developed areas, sufficient space may not be available to permit the use of desirable slopes. Backslopes steeper than 3:1 should be evaluated with regard to soil stability and traffic safety.

- Slopes that are 4:1 or greater are considered to be recoverable.
- Slopes that are between 3:1 and 4:1 are considered non-recoverable but traversable.
- Slopes that are steeper than 3:1 are considered to be non-traversable.

Design of a safe roadside depends upon design speed, traffic volumes, horizontal and vertical alignment of the roadway, type of highway, and other factors. For a thorough discussion of safety in design of side slopes, highway clear zones, and drainage channels, refer to the AASHTO *Roadside Design Guide* (AASHTO, 2011).

7.8.4 Cut Slope Standards

Cut slopes should not be steeper than 3:1 unless material is encountered that will stand on steeper slopes. Flatter slopes should be used in shallow cuts or in soils highly susceptible to erosion.

Geotechnical Considerations

Geotechnical strata in Colorado are highly variable and can be solid rock structure, glacial till (loose sandy rock) cobble and boulders, heavy clays, sandy soils, weak volcanic rock, or sedimentary shale deposits. Whenever a design is considering large cut or fill sections, it is advisable to make the initial investment to explore the existing geotechnical conditions. For large cut sections, identifying the angle of repose and presence of moisture in the cut slope will affect final cut slope stability and help to identify final slope grade to avoid slope stability issues later. For large fill sections, determining the load bearing capacity of the in-situ soils and water table conditions may help to avoid settlement issues and fill slope stability problems later.

7.8.5 Fill Slope Standards

Fill slopes are determined by a combination of terrain, height, and template type. The other chapters have specific information on desired fill slopes and CDOT practices for different highway types. Where 3:1 slopes or steeper are used, a comparison of costs of these slopes with any guardrail required vs. flatter slopes should be made. Refer to the AASHTO *Roadside Design Guide* (AASHTO, 2011) for guardrail guidelines.

Table 7-1 gives the standards for fill slopes to be used for different types of highways. Flatter slopes should be used in soils highly susceptible to erosion.

The minimum clearance from the right of way line to the catch point of a cut or fill slope should be 10 feet for all types of cross sections, but the desirable clearance is 20 feet. Access for maintenance activities should be considered.

Table 7-1 Fill Slopes

Highway Type	H*	Terrain: Plains Slope Ratio**	Terrain: Rolling and Mountainous Slope Ratio**
4 or more lanes (Z=12'@ 6:1)	≤4 ft	Z, then 6:1	Z, then 6:1
	>4 ft to 10 ft	Z, then 4:1	Z, then 4:1
	>10 ft to 15 ft	Z, then 4:1	Z, then 3:1
	>15 ft	Z, then 3:1	Z, then 3:1
▲ 2 lanes (Z=8'@ 6:1 or 6'@ 6:1 or 4'@ 6:1)	≤4 ft	Z, then 6:1	Z, then 4:1
	>4 ft to 10 ft	Z, then 4:1	Z, then 4:1
	>10 ft to 15 ft	Z, then 4:1	Z, then 3:1
	>15 ft	Z, then 2:1	Z, then 2:1

* H is the vertical distance between outside edge of top layer of pavement and catch point where fill meets natural ground.

Slopes 3:1 or steeper should be reviewed for safety and guardrail warrants.

** May be steep in special cases.

▲ In constrained situations on a 2-lane roadway, the Z slope may be constructed as steep as 4:1.

7.8.6 Clearance from Slope to Right of Way Line

It is desired to maintain a minimum of a 10-foot clearance from the slope to the existing or proposed right of way line. This provides an adequate distance that is needed for maintenance of slopes, walls, fences, etc.

7.8.7 Slope Benches

The necessity for benches, their width, and vertical spacing should be determined only after an adequate geotechnical materials investigation has been completed. The designer should contact the Materials and Geotechnical Branch.

For ease of maintenance, a 20-foot width of bench is satisfactory. Benches slope approximately 20:1 towards the roadway to prevent ponding of moisture behind the bench, thus creating additional slip plane problems. Benches should be constructed to blend with geologic strata rather than conforming to any set grade.

7.8.8 Cut Slope Treatment

The tops of all cut slopes should be rounded where the material is other than solid rock. A layer of earth overlying a rock cut also should be rounded. Refer to the Slope Rounding details on the typical sections and Subsection 203.05 of *CDOT Standard Specifications for Road and Bridge Construction* (CDOT, 2022).

Refer to Chapter 4, Section 4.8.4, of the 2018 AASHTO GDHS for more information.

7.9 Multimodal Accommodations

Developing a cross section template is not a one-size-fits-all approach. It requires an analysis of various factors including the contextual and functional classifications. These site conditions will help to determine the appropriate design elements and treatments to be considered. Many factors may be applicable in deciding the correct template needed. Those factors may include:

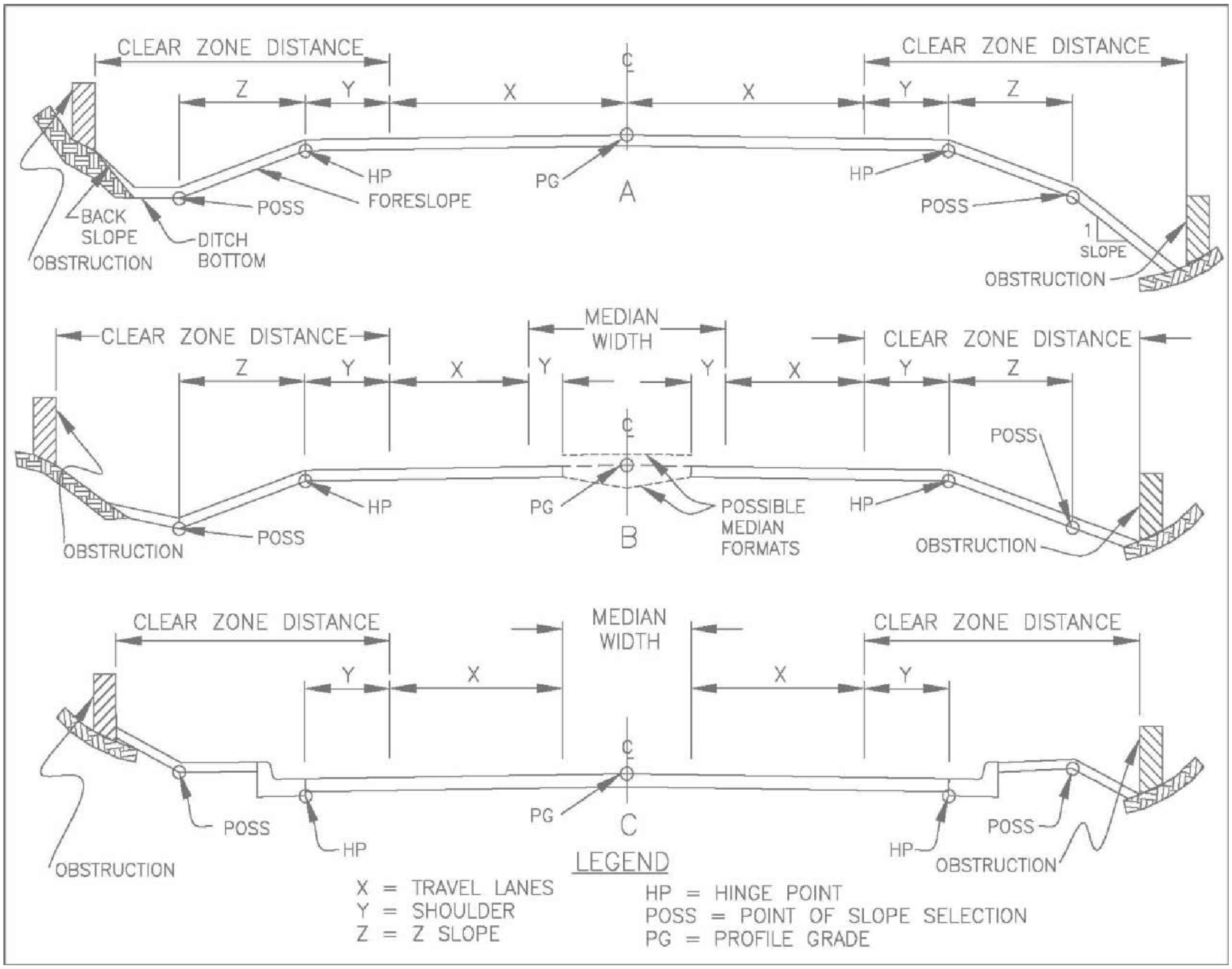
- Physical characteristics.
- Land use and roadway context classifications.
- Functional roadway classifications.
- Crash history.
- Expected pedestrian, bicycle, and motor vehicle demand.

There is not a single set of templates for a multimodal roadway. A multimodal roadway template is made of various zones (or elements) that need to be considered both independently and collectively to understand how they can best be balanced and stitched together to reflect the project goals. The appropriate accommodation for each mode of travel is dependent on a number of factors including transportation demands and conditions, traffic volume (by mode), traffic speed (by mode), and context and functional classification. The goal is to balance the needs of each mode based on these factors.

7.10 Illustrative General Cross Section

Figure 7-1 illustrates typical combinations of the highway elements: travel lanes, shoulders, side-drainage channels/landscaping areas, sidewalks, curbs, and side slopes.

Figure 7-1 General Cross Section Information



7.10.1 Normal Crown Sections

Figure 7-1 shows cross sections commonly used in CDOT highway practice, undivided and divided highways. Shoulder widths and Z slopes are included on both the fill and cut sections. The embankment or fill sections on the right side of the sections are composed of the Z slope and fill slopes.

The drainage channels shown on the left side of the sections are formed by the Z slope on the roadway side and the cut slope or backslope on the outer side. The Z slope and backslope combination should be selected to produce a cross section that can be safely traversed by an errant vehicle. Any hazardous object should be located outside of the clear zone.

What is a Z-slope?

When developing a roadway cross section, the designer starts with the centerline/profile grade (PG) and works outward by carrying a uniform cross slope for the pavement section. Typically, this cross slope for the pavement is a decreasing 2% grade, but it can be flatter or steeper depending upon superelevation or contextual constraint that require a flatter or steeper cross slope. The uniform cross slope away from the profile grade generally ends at the hinge point, which also corresponds to the outside edge of the roadway pavement.

The z-slope is the gravel area outside of the pavement edge that provides a strong traversable area. The intent of the z-slope is purely safety related as it provides an area for a driver to recover an errant vehicle, to safely traverse off the road and to recover back to the road. Generally, the z-slope has a 6:1 slope and can vary in width depending upon the terrain or right of way constraints.

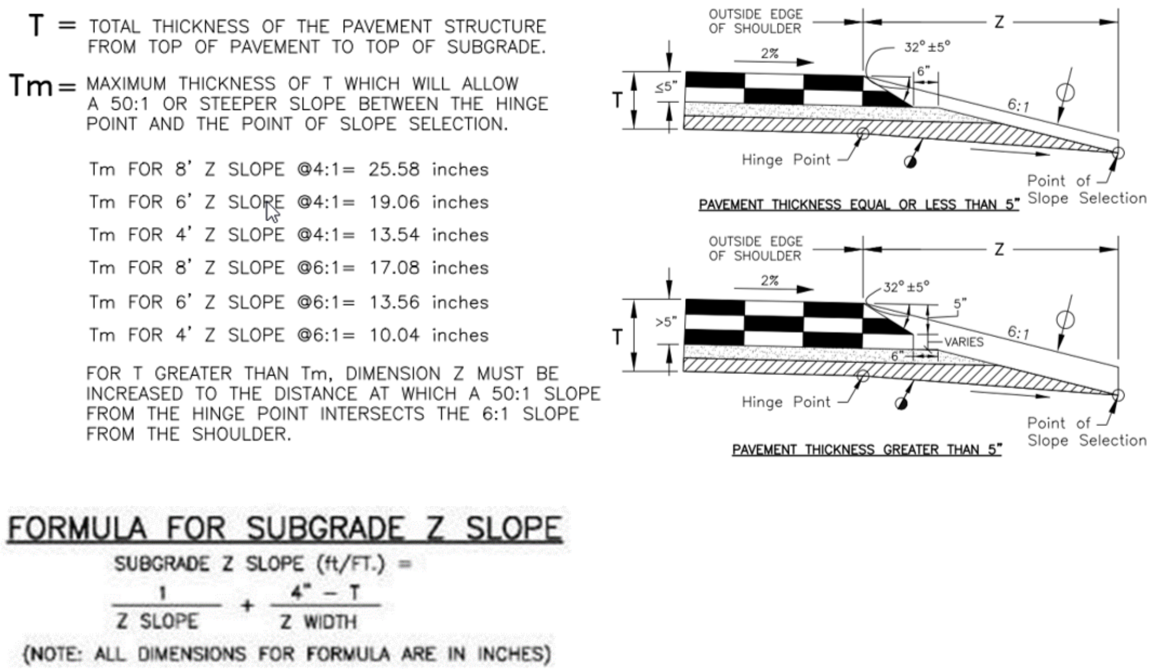
The far outside edge of the z-slope is called the Point of Slope Selection (POSS). The POSS is where the designer begins developing a varying slope to connect to the existing terrain. The POSS slope can vary before it catches with the natural ground. If the POSS is still within the clear zone area, the slope may need to be maintained at 4:1 or flatter to provide a recoverable slope, or no less than 3:1 if the slope can be maintained down to the catch with natural ground for a traversable slope. If the POSS needs to be steeper than 3:1. the designer should investigate if roadside barrier installation is required. For example, if the Truck DDHV exceeds 250 veh/hr, then use 12 feet and then it can vary between 8 feet and 4 feet depending on lane and shoulder width.The designer should reach out to the Region Traffic Engineer to discuss the need for barrier installation.

For further information on traversable and recoverable slope, refer to the AASHTO *Roadside Design Guide* (AASHTO, 2011).

Z-Slope for Subgrade Drainage

Another advantage of the Z-slope is to extend it sufficiently enough away from the pavement section to allow the layers of the pavement subgrade to drain moisture away from under the pavement. By developing a Z-slope, with a grade sloping away from the roadway, this avoids the “bathtub” effect that could trap moisture under the roadway and weaken the pavement structure.

Figure 7-2 Z Slope Formula



7.10.2 Superelevated Sections

Although superelevation is advantageous for traffic operations, various factors such as wide pavements, abutting properties, drainage, intersections, and access points may make it impractical in built-up areas. Therefore, superelevation is not usually provided on low-speed urban streets in residential and commercial areas. It should be considered in industrial areas or streets where operating speeds are above 40 mph. A maximum superelevation of 4% to 6% is commonly used. A detailed discussion of superelevation is found in Chapter 3.

Refer to Chapter 4, Section 4.9.2 of the 2018 AASHTO GDHS for more information.

7.10.3 PBPD, MM, CSS Geometric Example

The development of a roadway cross section will generally follow an iterative process that involves a review and analysis of existing data sets and continuous outreach with project stakeholders to arrive at a series of options that best balance the project area constraints and context, intended users, and available budget. In many instances the cross section will not be a one size fits all and will need to vary throughout the project area. It is important to keep the main cross section consistent through the context of the project to improve safety and minimize user confusion.

Generally, as part of the project goal setting or purpose and need development, thoughtful conversations should be had with project area stakeholders to understand the priorities of the project and intended users that are looking to benefit. Realizing that CDOT has limited right of way and funding, tradeoffs will need to be discussed to develop a solution that best meets the project goals. This tradeoff discussion will likely further discussions around using design minimums to fit all the various modal needs into the project area limits.

Where practical to do so, general best practice is to focus on one or two modes and provide good quality facilities for those modes, then look for alternate corridors to accommodate some of the modes that were not catered to as much on the original project.

The use of design minimums should be avoided, especially when it comes to bicycle and pedestrian travel since they are the most vulnerable facility users. If needed, a balanced approach should be applied to reducing facility width across the roadway cross section. For example, this could involve reducing travel lane widths down to 11 feet to allow for a more useable 8-foot bicycle shoulder or more comfortable 6-foot sidewalk that allows two people to comfortably walk side by side.

7.11 Traffic Barriers

7.11.1 General Considerations

Traffic barriers are used to minimize the severity of potential crashes involving vehicles leaving the traveled way, where the consequences of errant vehicles striking a barrier are less severe than leaving the roadway. Barriers are a source of crash potential themselves, and their use should be carefully considered. For more detailed information regarding traffic barriers, refer to the CDOT *Safety Selection Guide* (CDOT, n.d.) and the AASHTO *Roadside Design Guide* (AASHTO, 2011).

The designer should request a safety analysis to determine crash patterns, including vehicle types, when discussing traffic barriers.

Use this link to access the CDOT Safety Selection Guide and resources: [CDOT Safety Selection Guide]

Performance level, or barrier capability, lateral deflection characteristics, and the space available to accommodate barrier deflection are important factors in the selection of a longitudinal barrier system. To accommodate the deflection, Guardrail Types 3 and 7 should be placed so that the back of the barrier is at least the minimum distance shown in the CDOT Standard Plans - M & S Standards (CDOT, 2019) from the obstruction.

In the C3 through C6 context classifications where there may be pedestrian and shared-use facilities adjacent to a general traffic lane warranting a Type 3 guardrail, a double block and rail median barrier or a railing should be considered to protect a bicyclists or pedestrian from injury if a collision with the guardrail occurs from the path side.

Consideration should be given to the adaptability of the system to operational transitions, end treatments, and to the initial and future maintenance cost.

Evaluation of the roadside environment entails six options in priority order:

- Remove or redesign the obstacle so it can be safely traversed.
- Relocate the obstacle to a point where it is less likely to be struck.
- Reduce impact severity by using an appropriate break-away device.
- Redirect the vehicle by shielding the obstacle with a longitudinal traffic barrier and/or crash cushion.
- Delineate the obstacle if the above alternatives are not appropriate.
- Make no change to existing. Refer to the CDOT *Project Development Manual* Section 2.09 (CDOT, [2013] 2022).

The sixth option would normally be cost effective only on low-volume and/or low-speed facilities or where engineering studies or safety evaluations show that the probability of a crash occurring is low. Clear documentation of this decision shall be completed and added to the project design file.

Site preparation is an important consideration in the use of traffic barriers. To ensure maximum barrier effectiveness, site conditions should be tailored to the performance characteristics of the particular barrier.

Roadway cross section significantly affects traffic barrier performance. Curbs, dikes, drainage inlet structures, sloped shoulders, and stepped medians can cause errant vehicles to vault or undermine a barrier or to strike a barrier so that the vehicle overturns. Optimum barrier system performance is provided by a relatively level surface in front of the barrier and, for semi-rigid and flexible barriers, beneath and behind the barrier. Where curbs and dikes are used to control drainage, they should be located directly in line with or behind the face of the barrier. Some barrier manufacturers have very specific details on the location of curbs or dikes to ensure they still meet crash test criteria in AASHTO's *Manual for Assessing Safety Hardware* (MASH) (AASHTO, 2016). The designer should investigate the proper placement of curb or dikes relative to the barrier that will be used.

7.11.2 Longitudinal Barriers

Longitudinal barriers are generally denoted as one of three types: flexible, semi-rigid, or rigid. The major difference between the types is the amount of barrier deflection that takes place when the barrier is struck.

Consider the following:

- Height of the barrier affecting driver sight distance, e.g., glare screen or offset barrier affecting sight distance on curves.

- Barrier transitions from different types of rail.

- Barrier transitions and end treatments used based on the context of the area involving multimodal applications.
- Wildlife being able to make passage under or over barriers.
- Maintenance concerns with snow drifting, ease of maintenance, immediacy of making repairs, and continuity of type and material.
- Height of the barrier in relation to a bicyclist's center of gravity in the case of barrier strike and potential overturning.
- Drainage concerns and icing (barrier shadows).
- Adequate room for entrance gating.
- Context-sensitive solutions (CSS). Refer to the Federal Highway Administration (FHWA) *Flexibility in Highway Design* document (FHWA, 1997).
- Materials selection such as wood vs. steel posts and galvanized vs. corrosion-resistant steel.
- Aesthetics and CSS considerations. Consider visual impact of selected barrier type and any memorandum of agreement that may apply to a specific corridor. Refer to the AASHTO *Roadside Design Guide* (AASHTO, 2011).

7.11.2.1 Roadside Barriers

A roadside barrier is a longitudinal system used to shield motorists from natural or manmade hazards located along either side of a roadway. It may occasionally be used to protect pedestrians, bystanders, and bicyclists from vehicular traffic. Temporary barriers are also used to protect workers in work zones.

Height and slope of the embankment are the basic factors in determining the barrier need through a fill section. Refer to the AASHTO *Roadside Design Guide* (AASHTO, 2011) for determination of barrier needs.

A clear, unobstructed, flat roadside is desirable. The objective of a barrier is to enhance safety. Therefore, a barrier should be installed only if it is clear that the barrier will have lower crash severity potential than the roadside obstacle it is shielding.

Short lengths of roadside barriers are discouraged. Where needed in two or more closely spaced locations, the barrier should be continuous. The designer should also be sure to communicate with the CDOT Region traffic staff to ensure proper calculations for length of need to adequately shield the greater hazard have been completed.

7.11.2.2 Median Barriers

"A median barrier is a longitudinal system used to minimize the possibility of an errant vehicle crossing into the path of the traffic traveling in the opposite direction."

"Special consideration should be given to barrier needs for medians separating traveled ways at different elevations. The ability of an errant driver leaving the higher elevated roadway to return to the road or to stop diminishes as the difference in elevations increases. The potential for crossover, head-on crashes increases in these situations."

"For all divided highways, regardless of median width and traffic volume, the median roadside must also be examined for clear zone hazards."

"Barriers should also be considered on outer separations of 50 feet or less adjacent to frontage roads." (2018 AASHTO GDHS)

Common types of median separation barrier include:

- Cable barrier.
- Double-faced steel W-beam (blocked-out) installed on strong posts.
- Concrete barrier.

Some use is also made of a three- or four-cable barrier installed on light steel posts, a double-faced steel W-beam installed on weak posts, a double-faced steel thrie beam (blocked-out) installed on strong posts, and a cable-chain-link-fence combination. When cable barrier is considered, the designer should fully investigate the maximum deflection of the cable barrier when struck so that the deflection does not encroach oncoming traveled lanes.

Use this link to access the CDOT Cable Barrier Guide: CDOT Cable Barrier Guide — Colorado Department of Transportation (codot.gov)

During the selection and design of a median barrier, consideration should be given to the possible effect of the barrier on horizontal sight distance.

Precast concrete median barrier and other CDOT approved barriers can be used for temporary positive protection of work areas and for guiding traffic during construction.

Refer to Chapter 4, Section 4.10.2.2, of the 2018 AASHTO GDHS for more information.

7.11.3 Bridge Railings

When designing bridge rail, the designer should consider the protection of pedestrians and bicyclists. In accordance with the AASHTO *Guide for the Development of Bicycle Facilities* (AASHTO, 2012b), bridge railing heights should be a minimum of 42 inches, with a preference of 48 inches, where pedestrians and cyclists are anticipated, and a more serious injury is likely to occur if either user were to fall over the edge. In addition, a bicycle handlebar rub rail that spans a height of 36 inches to 48 inches should be provided where bicyclists are expected to be traveling adjacent to the bridge railing.

The need for traffic barriers generally does not stop at the end of the bridge. The need must be filled by extending the bridge railing with a roadside barrier, which in turn must have a crash-worthy end terminal.

At the juncture between a bridge railing and roadside barrier, there is nearly always incompatibility in the stiffness of the two barrier types. This stiffness must be transitioned over a transition length that will prevent the barrier system from pocketing or snagging an errant vehicle. Refer to the CDOT Standard Plans - M & S Standards (CDOT, 2019).

Refer to Chapter 14 of this Guide for more information on bridges.

7.11.4 Crash Cushions

"Crash cushions are protective systems that prevent errant vehicles from impacting roadside obstacles by decelerating the vehicle to a safe stop when hit head-on or redirecting it away from the obstacle. A common application of a crash cushion is at ramp gores where a bridge-rail end exists in the gore. Where site conditions permit, a crash cushion should also be considered as an alternative to a roadside barrier for shielding rigid objects, such as bridge piers, overhead sign supports, abutments, and retaining wall ends. Crash cushions may also be used to shield roadside and median barrier terminals." (2018 AASHTO GDHS)

Design of new highways should consider alternatives to a crash cushion where possible. Where a crash cushion is the best alternative, adequate level space free from curbs or other physical features should be provided. Site preparation is important in using crash cushion design. Site conditions not compatible with the cushion design can compromise cushion effectiveness.

Refer to the CDOT *Safety Selection Guide* (CDOT, n.d.) for guidance in selecting crash cushions.

7.12 Medians

Use of medians will vary according to the type of highway and future developments expected on the highway. Medians may be used to:

- Separate opposing traffic.
- Provide an area for emergency stopping and recovery of errant drivers.
- Allow for left turns and U-turns.
- Provide width for future lanes or other alternate travel modes.
- Provide an area for snow storage.
- Minimize headlight glare.
- Provide a refuge area for pedestrians or bicyclists (refer to Chapters 9 and 14 of this Guide).
- Provide area for landscaping and lighting.

Median width is measured as the distance between the edges of traveled way and includes inside shoulders. The width of median should be appropriate to its purpose. The primary determinant of required median width is the type of facility. Width may be limited by right of way limitations, economics, pedestrian crossing distance, topography, aesthetic concerns, and at-grade intersection signal operations.

Roadways with opposing directions of travel less than 4 feet should be considered separators, not medians. When designing separators, sign width and location should be considered, and placement discussed with the CDOT Region Traffic Engineer.

Medians may be flush, depressed, or raised. Advantages of depressed medians include improved drainage and opportunities for snow storage. Depressed medians should be sloped downward on a 6:1 slope to a central valley with adequate median drainage provided. Where profile grades differ, engineering judgment must be used to provide a median that will drain properly and be as safe as possible.

Raised medians have application on arterial streets where it is desirable to regulate left-turn movements and control access. Raised medians are typically used in urban settings especially if medians are to provide an area for pedestrians to stand or be planted with landscaping. Consider that plantings and other landscaping features in median areas may constitute roadside obstacles and may limit sight distance. However, these vertical features have been shown to positively influence a reduction in travel speeds as drivers tend to slow down when traveling near vertical objects that are closer to the travel way edge.

Flush (or painted) paved medians are often used where two-way left-turn lanes are desired to improve capacity and reduce rear-end crashes resulting from left turning vehicles having to stop in active through travel lanes. Dedicated left-turn lanes may also be placed in the median area. In these cases, the turn lanes are not considered to be part of the median but are designed as an auxiliary lane.

Normally, the turn lane should be the same width as the travel lanes. Conditions with high numbers of truck or bus movement or conditions with limiting geometry may warrant different widths. Slightly wider turn lane widths, when width is available, provide an offset from opposing turning traffic and can improve sight distance for the motorist for a safe turning movement.

Refer to Chapter 4, Section 4.11 of the 2018 AASHTO GDHS for more information.

7.12.1 MM, PBPD, and CSS Considerations

In urban and suburban areas, or key rural areas (such as where a shared-use path crosses the highway/roadway), medians are highly beneficial to facilitate pedestrian or bicyclist crossings. In this case, a “refuge” or cut-out in the median is provided to allow for a two-stage crossing. This provides a waiting area in between bi-directional traffic to help cross streets with wider cross sections and allow pedestrians or bicyclists to judge gaps in traffic one direction at a time rather than trying to judge both directions simultaneously. Refuge areas must meet ADA compliance requirements. Refuges can be sited at intersections or at midblock locations depending on the pedestrian desired lines and adjacent activity generators. In general, if the logical crossing occurs midblock, and the crossing can be accommodated and controlled with signage, striping, and other traffic control devices, such as pedestrian hybrid beacons, it should be considered in that logical location rather than providing the crossing at adjacent intersections and expecting pedestrians or bicyclists to travel out-of-direction to cross the street.

7.13 Frontage Roads

A frontage road is a local auxiliary road generally located adjacent to more rural and higher speed roadways. It is primarily used in conjunction with expressways and freeways, although it may be used with any roadway.

Among the functions of frontage roads are controlling access, segregating high-speed through traffic from lower-speed local traffic, and keeping traffic generated by development in the surrounding area from directly affecting the safety and operations of the higher speed regional roadway.

Frontage roads provide an opportunity to allow bicycle and pedestrian connectivity adjacent to high-speed facilities that are not suitable for these modes of travel. They also provide opportunities to encourage travel by transit with transit hubs and/or access to park-n-ride facilities.

Specific applications of frontage roads vary with the type of roadway. One disadvantage of frontage roads is that they increase the complexity of the roadway operations, possibly leading to driver confusion, particularly at night when cars on frontage roads could be perceived as driving on the wrong side of the highway. Additional complexity is also found at crossroad intersections and how two very closely spaced intersections on both sides of the roadway are signalized.

Frontage road alignment may be parallel or divergent, continuous or broken, one-way or two-way, and on one or both sides of the main roadway. The connection at the frontage road and the main roadway is one of the more important aspects of frontage road design. Its cross section is dependent on geometric constraints, traffic characteristics and often intersection operations.

Traffic operations are improved if the frontage roads are located a considerable offset distance from the main roadway at the intersecting crossroads, in order to lengthen the spacing between successive intersections along the crossroads. In urban areas, a desirable spacing is approximately 150 feet (edge of shoulder to edge of shoulder) between the main roadway and the frontage road.

At the intersection, for satisfactory operation with moderate-to-heavy traffic volumes on the frontage roads, the outer separation should be 150 feet or more in width. However, wider separations can enhance operations significantly. Outer separations of 300 feet accommodate turning movements and provide a minimal amount of vehicle storage.

When a frontage road approaches a cross street that also connects to the mainline (highway), the minimum separation should be 300 feet between intersections, but the desired separation of these intersection should be investigated through a traffic analysis to determine current and future traffic queue impacts and storage requirements for all turning operations.

Narrower separations are acceptable where frontage-road traffic is light, where the frontage road operates one-way only, or where some movements can be prohibited. In these situations, outer separations as narrow as 16 feet may operate satisfactorily with barrier separation on roadways greater than 45 mph. For narrower separations on roadways less than 45 mph a 4-foot separation for barrier and a minimum of a 6-foot shoulder area for both roadways can be prohibited

Refer to Figures 4-7 through 4-10 in the 2018 AASHTO GDHS for schematics of frontage roads.

Refer to Chapter 4, Section 4.12, of the 2018 AASHTO GDHS for more information.

7.14 Outer Separations

The area between the outside edge of the main roadway and inside edge of traveled way of any street or frontage road is designated as the outer separation (Table 7-2). The separation functions as a buffer between the highway and local traffic and may be landscaped for improved aesthetics. The width of the outer separation is dependent on the highway classification and the type of street from which it is being separated. Plantings and other landscaping features in outer separators may constitute roadside obstacles. Separations should also be designed to prevent unauthorized access between main line and frontage roads.

Outer separations must meet clear-zone criteria. Refer to the 2018 AASHTO GDHS and AASHTO *Roadside Design Guide* (AASHTO, 2011).

Refer to Chapter 4, Section 4.13, of the 2018 AASHTO GDHS for more information.

Table 7-2 Width of Separation for Frontage Roads

Type of Frontage Road	Separation Width Minimum	Separation Width Desirable*
Two-Way Frontage Roads	24 ft	≥ 40 ft
One-Way Frontage Roads	20 ft	≥ 30 ft
Arterial Streets With Frontage Roads	8 ft	

**Use on non-urban highways.*

7.15 Noise Control

7.15.1 General Considerations

Roadway noise is generally defined as unwanted sound. Motor vehicles generate traffic noise from the motor, aerodynamics, exhaust, and interaction of tires with the roadway. Efforts should be made to minimize the radiation of noise into noise-sensitive areas along the roadway. The designer should coordinate with the CDOT Region Planning/Environmental Manager to evaluate noise levels and the need for reducing highway traffic noise through location and design considerations.

The physical measurement of human reaction to sound is difficult because there is no instrument that will measure this directly. A close correlation can be obtained by using the A-scale on a standard sound-level meter. The meter yields a direct reading in A-weighted decibels (dBA).

Traffic noise produces varying human reactions. The physical factor of noise is not, in itself, a good predictor of the level of public displeasure; the reaction is usually less if the noise source is hidden from view. The type of development in an area is another factor that affects the displeasure level. Higher traffic noise levels are usually more tolerable in industrial areas than in residential areas.

Other factors that influence human reactions to sound are pitch and intermittency. The higher the pitch or the more pronounced the intermittency of the noise, the greater the degree of annoyance.

For more information, refer to Chapter 16 of this Guide.

Refer to Chapter 4, Section 4.14, of the 2018 AASHTO GDHS for more information.

Refer to *CDOT Noise Analysis and Abatement Guidelines* (CDOT, 2020).

Use this link to access the CDOT Noise Analysis and Abatement Guidelines: CDOT Noise Analysis & Abatement Guidelines

7.16 Roadside Control

7.16.1 General Considerations

The efficiency and safety of a roadway depend greatly upon the amount and nature of roadway access points to the surrounding land uses. The designer should consult the State Highway Access Code (State of Colorado, 2002) and coordinate with the CDOT Region Access Manager for questions related to property owner right of access. Increased turbulence resulting from indiscriminate roadside development and uncontrolled driveway connections results in lowered capacity, increased hazards, and early obsolescence of the highway.

Refer also to Chapter 11 of this Guide and the State Highway Access Code (State of Colorado, 2002) for further information on access.

7.16.2 Driveways

Driveway terminals are, in effect, low-volume intersections; thus, their design and location merit special consideration.

In general, driveways should be consolidated whenever possible after consulting with the Region Access Coordinator. Full movement driveways should naturally be oriented to the adjacent local roadways that are primarily meant to serve more local-access-oriented streets. Especially on more regional and arterial and higher volume collector roadways, access control should be considered where possible to limit the number of driveways and the number of movements that are allowed. On higher roadway classification, access should be limited to right-in/right-out and with left turns restricted and limited to only discrete locations that may provide proper traffic control devices. Cross access agreements between adjacent property owners should be pursued whenever possible. Another important consideration is to eliminate large graded or paved areas adjacent to the traveled way that are uncontrolled access points. Driveway width should be reduced and made as narrow as possible to accommodate the average design vehicle and limit entry or exit speeds to reduce potential conflicts with pedestrians and bicyclists that may be crossing through the driveway. The driveway cross slope shall accommodate ADA PROWAG regulations for pedestrians.

Refer also to Chapter 11 of this Guide for further information on access.

7.16.3 Mailboxes

Most vehicles stopped at a mailbox are clear of the traveled way when the mailbox is placed outside an 8-foot-wide usable shoulder or turnout.

For guidance on mailbox installations, refer to the latest edition of AASHTO *Roadside Design Guide* (AASHTO, 2011), and the CDOT Standard Plans - M & S Standards (CDOT, 2019). Local postal regulations should be consulted for additional criteria. Refer to Chapter 4, Section 4.15 of the 2018 AASHTO GDHS for more information.

7.17 Tunnels

7.17.1 General Considerations

Sections of streets or highways may be constructed in tunnels to carry them under or through a natural obstacle or to minimize the impact of the freeway on the community.

It may be necessary to engage a consultant to design the tunnel and associated lighting, fire prevention, and electrical and ventilation systems.

7.17.1.1 Shared Roadways

Depending on the nature of the roadway, width of shoulder and lighting levels within the tunnel, bicycle and pedestrian accommodations should be considered where necessary. Based on the confined nature of tunnels, any bicycle and pedestrian accommodations should be well thought out to ensure the safety and comfort of those users. If bicycle lanes or shoulders are provided, they should be wide enough to allow a bicyclist the space to maneuver around any debris or water collecting in the tunnel. Lighting levels should provide adequate illumination that is consistent with national best practice to allow a bicyclist to be seen by a driver and for a bicyclist to see any potential hazard in the roadway. Drainage grates and manhole covers should be reviewed to ensure that they are oriented to prevent any bicycle tires from becoming stuck in them and leading to a potential crash. If bicycle lanes or shoulders cannot be provided and bicyclists must share the roadway with moving traffic, passive or actuated warning devices should be considered to be installed on the approaches to the tunnel portals to alert drivers to the presence of bicyclists in the tunnel.

7.17.2 Types of Tunnels

Tunnels can be classified into two major categories: tunnels constructed by mining methods, and tunnels constructed by cut-and-cover methods. Of particular interest to the highway designer are the structural requirements of these construction methods and their relative costs.

7.17.3 General Design Considerations

The feeling of confinement in tunnels is unpleasant, and traffic noises are magnified. Because tunnels are the most expensive highway structures, they should be made as short as practicable.

Keeping as much of the tunnel length as possible on tangent will minimize the length and improve operating efficiency.

7.17.4 Tunnel Sections

From the standpoint of service to traffic, the design criteria used for tunnels should not differ materially from grade separation structures. The same standards for alignment, profile, and vertical and horizontal clearances generally apply.

Full left- and right-shoulder widths of the approach roadway should be carried through the tunnel. The need for added lateral space is greater in tunnels than under grade separated structures because of the greater likelihood of vehicles becoming disabled in the longer lengths and the natural desire to shy away from the walls of the tunnel and potential oncoming traffic.

Normally, pedestrians are not permitted in roadway tunnels; however, space should be provided for emergency walking and for access by maintenance personnel. Raised sidewalks, a minimum of 4 feet wide, are desirable beyond the shoulder areas to serve the dual purpose of a safety walk and an obstacle to prevent the overhang of the vehicles from damaging the wall finish or the tunnel lighting fixtures.

7.17.5 Examples of Tunnels

Figure 7-3 includes examples of tunnels in Colorado.

Figure 7-3 Tunnels in Colorado

Left to right: US 550 Bear Creek, I-70 Veterans Memorial Tunnels, and I-70 Eisenhower-Johnson MemorialTunnel.

7.18 Pedestrian Facilities

Consistent with CDOT Procedural Directive 1602.1, "Elevating Bicycle and Pedestrian Opportunities in Colorado" (CDOT, 2017), roadway designers shall accommodate pedestrians and bicyclists during planning, programming, design, construction, operation, and maintenance of the state highway system. Appropriate provisions must be made to provide accessible walking routes where pedestrians are expected. The type of facility can vary between a raised or separated sidewalk to a multiuse path or grade separated pedestrian bridge. Similar to the development of roadway cross sections, the context of the surrounding land use, expected pedestrian volume, vehicular traffic conditions, intersection configurations, separation between the pedestrian and vehicular facilities, and other general study area constraints play a part in determining the type of facility provided.

Based on the scale and resource implications to developing any grade-separated pedestrian structures, decisions regarding pedestrian overpasses and underpasses should be coordinated with the local agencies and the public. Care must be exercised to ensure access to persons with disabilities at pedestrian crossings. Refer to CDOT Standard Plans - M & S Standards (CDOT, 2019), and the requirements of the Public Rights of Way Accessibility Guidelines (PROWAG). For more information, contact CDOT's Civil Rights and Business Resource Center.

The project design shall also maintain ADA-compliant access during construction for the safety of pedestrian and bicyclists.

7.18.1 Sidewalks

Sidewalks are most often located where there is identified pedestrian demand such as schools, residential and commercial areas. Sidewalks should be considered in rural areas that have land use that support pedestrian activity. In project locations that presently do not have sidewalks, engineers can frequently identify historic pedestrian activity through defined "goat paths" or worn areas of grass where pedestrians have been traveling. Sidewalks should be considered for bridges especially in locations where sidewalks are provided on the approach and departure ends to the bridge.

Sidewalk width may vary due to physical limitations but generally should be a minimum of 5 to 6 feet of unobstructed width. It should be noted that two people need at least 6 feet to walk side by side comfortably. In constrained locations sidewalks can be reduced down to 4 feet but would require 5-foot-by-5-foot-wide passing zones every 200 feet to allow wheelchair users to pass one another. The width of the sidewalk generally should increase as the pedestrian volume increases up to 8 feet and often can expand to from 8 to 12 feet wide in denser commercial areas categorizing it as a shared use path. Where available the sidewalk should be separated from the moving traffic lane through a landscaping strip that varies in width from a minimum of 2 feet depending on the available right of way and type of landscaping being provided.

The designer should check with local agencies for design considerations.

For more information refer to Chapter 13 of this Guide.

7.18.2 Sidewalk Curb Ramps

In general, curb ramps within the project limits shall be brought into compliance with CDOT Standard Plan M-608-1 Curb Ramps. Most projects with curb ramps are required to upgrade ramps that do not meet the minimum requirements for functional accessibility, as defined in CDOT's *ADA Transition Plan* (CDOT, 2017). Additional guidance can be found in CDOT's *ADA Transition Plan*; Chapter 12 of this Guide; and CDOT Procedural Directive 605.1, "ADA Accessibility Requirements in CDOT Transportation Projects" (CDOT, 2017).

Questions about project-specific ramps should be directed to the CDOT ADA Regional Representative. Refer to Chapter 12 of this Guide.

Refer to Chapter 4, Section 4.17, of the 2018 AASHTO GDHS for more information.

7.19 Bicycle Facilities

Bicyclists should be expected on all state roadway facilities and should be accommodated to varying degrees unless there is an insurmountable constraint or safety reason for prohibiting bicycles from a section of roadway or highway. Generally, bicycles can share the roadway with vehicular traffic, utilizing shared lanes, paved shoulders, dedicated bike lanes, or protected bike lanes (also called separated bike lanes). Off-street trails or shared-use paths provide the highest-comfort bicycle facility for bicyclists of all ages and abilities and are ideal when there is sufficient right of way to provide them. The criteria for evaluating how best to accommodate the appropriate bicycle facility include land use context, traffic speeds, traffic volumes, the presence of on-street parking, the frequency of driveways or intersections, and the street's importance within the larger local, regional, or statewide bicycle network.

Specific information on warrants and construction requirements for bicycle facilities can be found in Chapter 14 of this Guide.

Refer to Chapter 4, Section 4.18, of the 2018 AASHTO GDHS for more information.

7.20 Bus Turnouts

Bus travel is an increasingly important mode of public transportation. Bus turnouts are safe areas for buses outside of the traffic lanes. The location and design of turnouts should be readily accessible in the safest and most efficient manner possible. The designer should coordinate details with the local transit agency. Intergovernmental Agreements may be required.

7.20.1 Freeways

A bus turnout off of the freeway must accommodate the deceleration, standing, and acceleration of buses on pavement areas clear of and separated from the through-traffic lanes. Speed-change lanes should be long enough to enable the bus to leave and enter the traveled way at approximately the average running speed of the highway without undue discomfort to the passengers. Refer to Section 4.19 of the 2018 AASHTO GDHS.

7.20.2 Arterials

The operations between buses and other traffic on arterial roadway should be considered in the context of the frequency of the bus headway, average stop duration, number of travel lanes and overall impact on traffic operations. In some conditions an in-lane stop might be acceptable and in higher volume roadway conditions with available right of way a bus turn out might be appropriate. It should be noted that bus operators often have trouble reentering the stream of traffic resulting in additional delay to bus riders and thus generally prefer in-lane stops. The designer should coordinate details with the local transit agency.

Use this link to access the Colorado Transit Directory Map: Colorado Transit Directory Map - Colorado Association of Transit Agencies

Refer to the AASHTO *Guide for Design of High-Occupancy Vehicle and Public Transportation Facilities* (AASHTO, 2004) for more information on bus turnouts.

7.20.3 Park-and-Ride Facilities

Park-and-Ride facilities are designed to accommodate:

- Bus loading and unloading.
- Taxis and ride share companies.
- Bicycle parking.
- Parking for bus passengers including persons with disabilities.
- Drop-off facility, plus holding or short-term parking area for passenger pickup. Coordinate details with CDOT's Division of Transit and Rail and local transit agency.

Refer to the AASHTO *Guide for Design of High-Occupancy Vehicle and Public Transportation Facilities* (AASHTO, 2004).

7.21 Transit Facilities

"Public transportation provides high passenger capacities in heavily traveled corridors, and allows high employment concentrations in city centers. It permits compact urban developments that are pedestrian and bicycle friendly and provides mobility for people that are unable to drive or do not have access to motor vehicles.

Transit vehicles operate in a wide range of environments, both on-street and off-street. Commuter rail and rapid transit operate in exclusive rights-of-way that are frequently grade-separated from intersecting roadways. However, bus routes on public streets and roadways and light rail or streetcar operations often share or intersect with the street environment.

Streets and roadways often must accommodate transit vehicles as well as motor vehicles, bicyclists, and pedestrians. Transit provisions are best accomplished when incorporated into all phases of street planning, design, and operation. This is essential especially where agencies at the state, county, and municipal level are required to plan, design, or modify streets and roadways to accommodate public transportation vehicles and facilities.

Planning and design guidelines, standards, and practices for transit accommodation have evolved over the past decade. Most of this guidance, however, encompasses a specific mode, such as buses, rapid transit, and light rail transit (LRT) and are sometimes prepared in response to specific agency needs. Recognizing that situation, AASHTO has developed the *Guide for the Geometric Design of Transit Facilities on Streets and Highways* (AASHTO, 2018) to provide design practitioners with a single, comprehensive resource that documents and builds upon past and present experience in transit design in streets and roadways.

The dominant form of public transportation in most urban areas is bus transit. Most bus transit operates in mixed traffic on streets. Generally, designs that make traffic move faster and more safely will improve bus speeds and service reliability. Roadway geometry should be adequate for bus movement, and pedestrian access to stops should be convenient. There are situations where preferential treatment for transit (dedicated lanes, stations, and priority at traffic signals) may be desirable. In those cases, the benefits to transit riders should typically be balanced with the effects on roadway traffic. Treatments and priorities for bus transit can vary depending upon specific traffic, roadway, and environmental conditions. Regardless of the type of treatment, the geometric design and traffic control features should adequately and safely accommodate all vehicles, pedestrians and bicyclists that would use a street or roadway. Where a street facility will be limited to bus use only, design features can generally be modified easily from those that apply for general traffic use.

This section addresses bus transit turnouts on freeway and arterial facilities. For guidance on other elements of transit facility design, including other types of transit facilities operating in and adjacent to streets and roadways, refer to AASHTO's *Guide for the Geometric Design of Transit Facilities on Streets and Highways* (AASHTO, 2018). Guidelines for high-occupancy vehicle (HOV) facilities on arterial streets are addressed in NCHRP Report 414, *HOV Systems Manual (NCHRP, 1998)*." (2018 AASHTO GDHS)

7.22 On-Street Parking

On-street parking is generally found in locations where local commercial and residential land uses support this application. In many urban and residential areas, on-street parking can be seen as essential to support the commerce of local businesses and the community. Where there is current or future demand for its use, parking should be considered where applicable. While parking does often create additional roadway turbulence and slows through vehicles in these areas, this does present the opportunity to help calm traffic.

Parking can be provided in a variety of parking configurations. Generally, it most commonly oriented in a parallel layout. Recently, variations of these parking layouts have been introduced through the inclusion of parking protected bicycle lanes where parking is located in between active vehicular travel and bicycle lanes. As is noted previously, the surrounding land use context and corridor transportation needs should be considered when determining where parking should be provided and in what configuration.