APPENDIX D

Draft Chapter 10 for AASHTO Roadside Design Guide

Chapter 10 – Draft

Roadside Safety in Urban or Restricted Environments

10.0 OVERVIEW

Generally, the principles and guidelines for roadside design presented in the previous chapters of this Guide discuss roadside safety considerations for rural highways, Interstates, and freeways where speeds are generally higher, approaching or exceeding 80 km/h [50 mph], and vehicles are operating under free-flow conditions. This chapter presents the designer with considerations to enhance safety on uncontrolled access highways in urban or restricted environments. The following conditions are typical for these types of roads or streets:

- Lower or lowering speeds,
- Dense abutting development,
- Limited rights-of-way,
- Closely spaced intersections and accesses to properties,
- Higher traffic volumes, and
- The presence of special users including mass transit vehicles, delivery trucks, bicycles, and pedestrians (including the disabled).

These and other conditions influence the design and operation of highways in these areas.

Restricted environments are segments of roads and streets where conditions are different from adjacent sections of the road or street. These areas are not limited to urban environments, as they may also be found in rural or rural-urban transition areas. Examples include areas of restricted right-of-way, spot development, parks, playgrounds, or other facilities that increase or otherwise affect the vehicular or non-vehicular activity in the area.

Often there is no clear demarcation between rural and urban conditions. Operating speeds in these rural-urban transition areas may reduce, but in many cases speeds tend to remain high, especially in off-peak hours. The number of abutting property access points and intersections becomes more frequent. The density of roadside objects increases and these objects are often characterized by smaller lateral offsets to the travel lanes than observed in a rural setting. Bicycle and pedestrian activity is also likely to increase. Generally, traffic volumes increase and the levels of service decrease. As one leaves an urban area, the process reverses. In major metropolitan centers, these transitional corridor regions can radiate outward from the urban center for tens of kilometers [miles].

There may also be whole communities that are separated from the metropolitan center by rural-like conditions but function similar to an urban area. Often these "bedroom communities" do not display many of the characteristics of a true urban area. For example, these communities may have more than occasional pedestrian and bicycle activity. Consequently, roadside safety for both motorists and non-motorists becomes more of a consideration. The designer must be careful to design operational and safety treatments for highways in these communities and restricted environments based on their operating characteristics rather than requiring specific safety and operational treatments used in all urban areas.

In high-speed areas or on controlled-access facilities, protection for pedestrians from possible errant vehicles may be prudent as well as the placing of fencing or barrier to discourage pedestrians or bicyclists from entering the roadway.

Section 2.1.2 mentions that the highway designer has a significant degree of control over roadside geometry and appurtenances. This statement is more applicable for rural conditions and especially so for new rural highways. In urban or restricted conditions, however, the roadside environment (houses, businesses, trees, utility poles, signals, walkways, etc.) is already established and less flexible. Consequently, the designer has the challenge of providing roadside safety given the many pre-existing constraints at hand.

Existing road and street traffic volumes usually increase over the passage of time resulting in the need to make decisions regarding additional capacity. Designers must be cognizant that roadway widening may result in more potential conflicts for pedestrians and bicyclists that use the space both within and immediately adjacent to the facility. Appropriate measures should be considered to provide an adequate level of safety. A safe, efficient, and economical design is the goal.

The various appurtenances such as benches, trash barrels, and bicycle racks that accommodate pedestrians and bicyclists may be undesirable from a traffic safety perspective. Ideally, appurtenances should be located where they are not likely to be hit by an errant vehicle. In situations where appurtenances are likely to be hit, they should be of a yielding nature, where practical, to minimize damage to the striking vehicle and its occupants. Breakaway supports for signs should be used unless an engineering study indicates otherwise. However, concern for pedestrians has led to the use of fixed supports in some urban areas. Examples of sites where breakaway supports may be imprudent are adjacent to bus shelters or in areas of extensive pedestrian concentrations. Many situations may need case-specific analysis. Consideration should be given to using breakaway supports for post-mounted signals installed in wide medians.

10.1 EVALUATION OF CRITICAL URBAN ROADSIDE LOCATIONS

While the clear roadside concept is still the goal of the designer, there are likely to be many compromises in urban or restricted environment area. One misconception is that a curb with a 0.5 m [1.5 ft] lateral offset behind it satisfies the clear roadside concept. Realistically, curbs have limited re-directional capabilities and these occur only at low speeds, approximately 40 km/h [25 mph] or lower. Consequently, fixed objects located adjacent to the travel lane, even in the presence of curbs, pose a potential hazard. Achieving the recommended clear zone distances in Chapter 3 of this document may be unlikely in an urban setting. As a result, a secondary goal for roadside design in an urban setting is to identify locations that are more prone to urban roadside crashes and assure that these locations receive priority attention for roadside safety improvements. One way to achieve this improved safety is to establish specific lateral offsets for unique urban locations where the roadside is not shielded by features such as on-street parking.

Critical urban locations over represented by hazardous roadside crashes may be identified based on unique site characteristics at an individual location. The operating speed and functional purpose of the road also help to define the characteristics of these potentially hazards corridors. Finally, specific road features are known to be directly associated with a higher likelihood of roadside crashes and can further define candidate urban roadside locations that merit additional consideration.

10.1.1 Need for Individual Study of Sites

In an urban environment, the most hazardous roadside crashes occur when vehicles operate at higher speeds and are less constrained by prevailing traffic conditions. Consequently, regardless of curbing, the designer must strive for a wider clear zone that is more reflective of the off-peak operating speed (85th percentile) or design speed, whichever is greater. At the higher speed end of the rural-urban transition area or on medium to high-speed urban facilities, serious consideration should be given to providing a paved shoulder with widths ranging from 1.2 m [4.0 ft] up to 2.4 m [8.0 ft] or as required by regional standards. These shoulders can often be used to accommodate bicyclists and even the occasional pedestrian when sidewalks are not provided. The shoulder can be eliminated, if necessary, further into the urban area where off-peak speeds are lower and alternative bicycle facilities are available.

As always, for reconstruction or resurfacing projects, the crash history should be considered in determining the specific clear roadside treatment for each portion of a project.

The standard hierarchy of design options for the treatment of fixed objects should be considered for each location. They are, in order of preference:

- Remove the fixed object.

- Redesign the fixed object so it can be safely traversed.

- Relocate the fixed object to a point where it is less likely to be struck.

- Reduce impact severity by using an appropriate breakaway device or impact attenuator.

- Redirect a vehicle by shielding the obstacle with a longitudinal traffic barrier.

- Delineate the fixed object if the above alternatives are not appropriate.

10.1.2 Design Speed and Functional Use

Urban or restricted environment operating speeds vary more by time of day than their companion operating speeds in rural settings. During free-flow conditions, and especially during late night, speeds are much higher; often well beyond the speed limit. Higher speeds result in the potential for more severe crashes, as indicated by the data shown in Table 10.1. This table shows the percentage of single vehicle fixed-object crashes that occurred from 7:00 p.m. to 7:00 a.m. and from 7:00 a.m. to 7:00 p.m. on urban principal and minor arterials in one state. During the lower volume and higher speed period of 7:00 p.m. to 7:00 a.m., a somewhat greater percentage of injury and fatal crashes occur than during the other half of the day. While other factors such as alcohol, fatigue, and limited night-sight distance may contribute to this higher percentage, higher speeds and greater speed variance under free-flow conditions are likely to be significant contributing factors.

Consequently, roadside features need to be designed for the higher operating speeds that occur during free-flow conditions as the resulting crashes are likely to be more severe. This may mean that the estimated encroachment speed used to design for roadside features may be higher than the design speed for the roadway as a whole, especially if the off-peak operating speed (85^{th} percentile) was not used to determine the project design speed. Also, as stated in the Preface, "since the design speed is often determined by the most restrictive physical features found on a specific project, there may be a significant percentage of a project length where that speed will be exceeded by a reasonable and prudent driver." Therefore, "the designer should consider the expected operating speed at which encroachments are most likely to occur when selecting an appropriate roadside design standard or feature."

Table 10.1 Percentage of single vehicle fixed-object crashes by severity and time period for urban principal and minor arterials in Illinois (2001-2003)

Time Period	Property Damage Only Crashes	Possible Injury and Non-Incapacitating Injury Crashes	Incapacitating Injury and Fatal Crashes	Total
7 p.m. to 7 a.m.	38.0%	10.1%	3.4%	51.5%
7 a.m. to 7 p.m.	36.6%	8.9%	3.0%	48.5%
				100.0%

Source: Based on Data Provided by HSIS

10.1.3 Targeted Design Approach for High-Risk Urban Roadside Corridors

Section 10.1.1 indicated the need for the individual evaluation of sites while Section 10.1.2 emphasized the importance of speed and time-of-day evaluation. A third critical feature in achieving safer urban roadside conditions is identification of known high-risk locations common to the urban roadside. As a designer assesses potential high-risk locations along a corridor, these locations should be high-priority candidates for focused roadside safety treatments.

The strategies proposed within this section apply primarily to higher speed urban or rural-urban transition area corridors. Where feasible, increased lateral offset to rigid roadside objects is encouraged for all urban facilities; however, low speed facilities such as local roads or central business districts with twenty-four hour on-street parking may not be practical applications for these target lateral offsets due to constrained right-of-way and competing uses for the limited roadside space.

10.1.3.1 Obstacles in Close Proximity to Curb Face or Lane Edge

Historically a lateral distance value, referred to as an operational offset, of 0.5 m [1.5 ft] has been considered an absolute minimum lateral distance for placing the edge of objects from the curb face. This minimum lateral offset, though sometimes misinterpreted as such, was never intended to represent an acceptable safety design standard and should be reserved for the placement of frangible objects only. In a constrained urban environment there is still a need to position rigid objects as far from the active travelway as possible.

Research has shown that in an urban environment, approximately 80-percent of roadside crashes involved an object with a lateral offset from the curb face equal to or less than 1.2 m [4 ft] and over 90-percent of urban roadside crashes have a lateral offset less than or equal to 1.8 m [6 ft]. Objects located on the outside of curves are also hit more frequently than at other locations. It seems prudent, therefore, to achieve larger lateral offsets at these curve locations. As shown in Figure 10.1, a recommended goal is to achieve 1.8 m [6 ft] lateral offsets from the face of curb at these hazardous outside-of-curve locations while maintaining 1.2 m [4 ft] lateral offsets elsewhere. For urban locations without vertical curb, lateral offsets of 3.6 m [12 ft] on the outside of horizontal curves and 2.4 m [8 ft] at tangent locations are reasonable goals when clear zone widths recommended in Chapter 3 cannot be achieved.

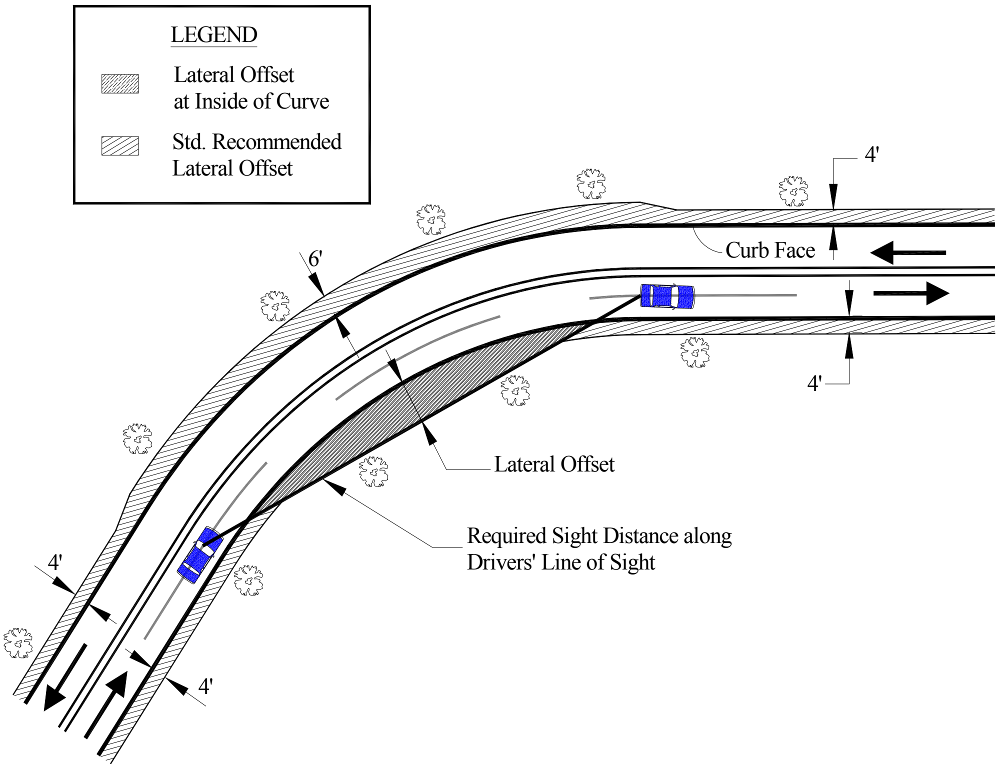

Figure 10.1 Lateral Offset for Objects at Horizontal Curves

In addition to creating a wider lateral offset on the outside of horizontal curves, sight distance at the inside of sharp horizontal curves can be obstructed by roadside objects. As indicated in Figure 10.1, a driver's line of sight that is suitable to permit the required stopping sight distance should be maintained.

Many urban corridors have auxiliary lanes available in addition to standard use lanes. Example auxiliary lanes include bicycle lanes, turn bays, extended length right-turn lanes, and bus lanes. At these locations lanes that function as higher speed lanes such as the extended length turn lanes or bus lanes should be treated as standard travel lanes and clear zone measurements would then begin at the right lane edge or curb face. Auxiliary lanes such as bicycle lanes can be included in the clear zone and the clear zone measurements begin at the right lane edge marking for the motor vehicle lane. At all of these auxiliary lane locations, however, lateral offset goals remain unchanged.

10.1.3.2 Lane Merge Locations

The placement of roadside objects in the vicinity of lane merge points increases the likelihood of vehicle impact with these objects. A lane merge can include the termination of an acceleration lane, a lane drop, or a bus bay exit point. Longitudinal placement of objects within approximately 6.1 m [10 ft] of the taper point increases the frequency of roadside crashes at this location. A wider lateral offset at taper points on urban roadways will eliminate or reduce roadside crashes at these locations and allow the driver to focus solely on merging into the traffic stream.

As shown in Figure 10.2, the recommended lateral offset in the immediate vicinity of the taper point 3.6 m [12 ft] from the lane merge curb face. This lateral offset permits errant vehicles that do not navigate the merge successfully to continue straight and stop without impacting a rigid object. Breakaway objects should have lateral offsets of 1.2 to 1.8 m [4 to 6 ft] at these locations.

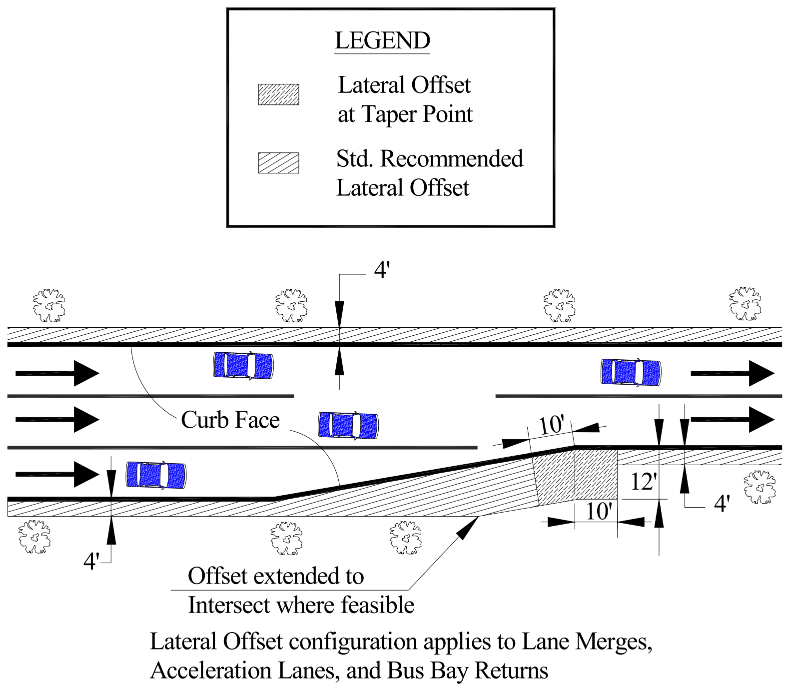

Figure 10.2 Lateral Offsets at Merge Points

10.1.3.3 Driveway Locations

Many rural roads have a white edgeline delineating the right edge of the travelway. In urban environments, a continuous white line is often not included at locations with curb as the curb itself functions to delineate the edge of the road. During night time or inclement weather conditions, the need for positive guidance along the right edge of the road may be heightened due to reduced visibility. In addition, impaired or fatigued drivers may depend more heavily on this delineation to help them keep their vehicles within the boundaries of the travelway. At driveway locations, the defined edge of road delineation and limited redirection capabilities of curb are no longer available resulting in increased roadside crashes for objects positioned on the far side of driveways.

The creation of a longitudinal offset 3.0 to 4.6 m [10 to 15 ft] beyond the edge of driveway prevents the placement of rigid objects in this high crash location. Since it is also not appropriate to locate roadside objects so that they adversely impact the line of sight for drivers exiting the driveway, these visibility triangles should also be maintained free of roadside objects. Figure 10.3 demonstrates the resulting lateral offsets appropriate for driveway locations. The driver's line of sight should be based on the expected speed of approaching vehicles.

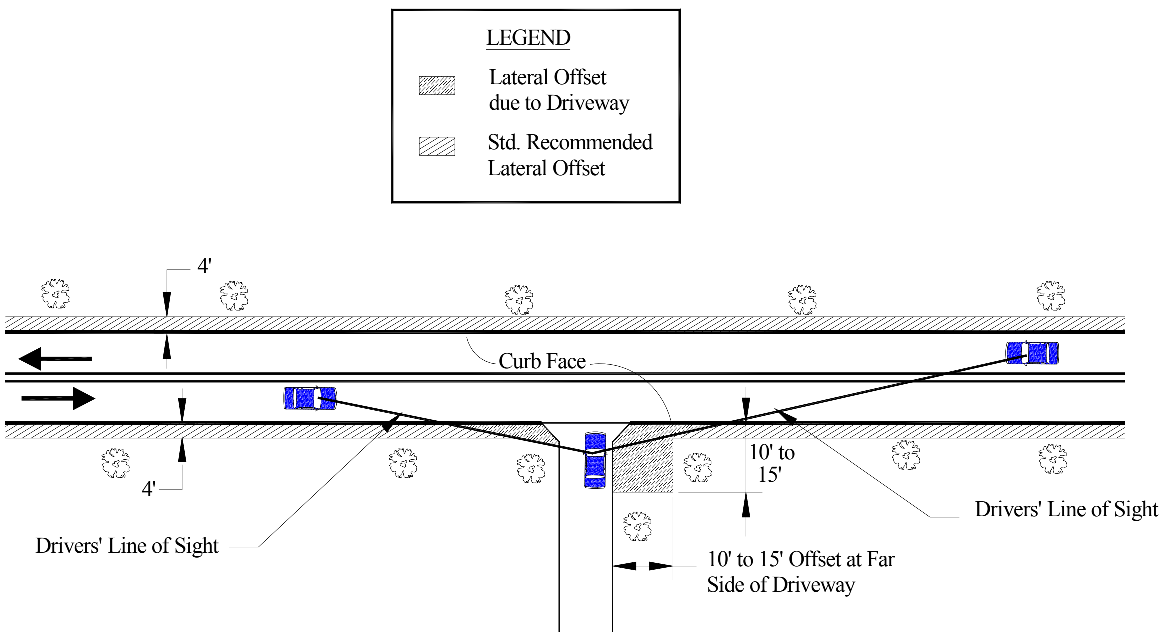

Figure 10.3 Roadside Lateral Offsets at Driveways

10.1.3.4 Intersection Locations

Crashes at intersections often occur between vehicles; however, intersection crashes where vehicles hit roadside objects are also common. In some cases, the crash occurs because a driver attempts to avoid hitting another vehicle; however, single vehicle crashes also occur frequently at intersection locations. The collisions can occur because of the presence of small channelization islands that are not noticeable by drivers, objects located too close to the curb in the curb return region, and objects located so that they are aligned opposite pedestrian access ramps. Roadside object placement strategies at intersections, therefore, can be addressed as follows:

- For intersection channelization islands (also known as corner islands), the island design should adhere to the AASHTO *Geometric Design of Highways and Streets* criteria. The island should be sufficiently designed so as to be conspicuous to approaching drivers and should not encroach on vehicle paths. Similarly median noses should be conspicuous and designed so as not to impede normal traffic operations. At both the corner islands and the median noses, the placement of rigid objects should be avoided completely. Only breakaway devices should be constructed at these locations.

- Often a turning vehicle does not successfully navigate the designated turn path and strays onto the adjacent curb return or shoulder. This situation often occurs for truck turning movements. Object placement at the inside edge of intersection turning movements should be as far as practical from the curb face or lane edge. A target lateral offset value for the intersection return should be 1.8 m [6 ft] for curbed facilities with an absolute minimum value of 0.9 m [3 ft]. Similarly, for locations without curb these values should be as far as possible from the edge of lane as these locations do not have a curb to help the driver realize that the vehicle has strayed from the designated turning path.

- Many urban intersections with curb include directional pedestrian access ramps at the intersection corners. For these locations, rigid objects should not be positioned so that errant vehicles are directed towards them along the path of the access ramp. As a result, placement of pedestrian buttons should be located on a breakaway pedestal pole adjacent to the directional ramp where possible rather than on a rigid traffic signal pole. This will enable the traffic signal pole placement to occur further away from the curb return region and will also position the pedestrian button immediately adjacent to the appropriate access ramp.

10.1.3.5 High Crash Locations

An individual site may be characterized by an unusually high number of crashes (often clustered in the same general region). If this trend is observed, it is likely that a feature of the road environment may be directly contributing to the number of roadside crashes. One example of high roadside crashes may be a large number of collisions with an underpass or structure. This type of crash would indicate that something about the underpass is confusing the drivers. Upon inspection, it may be observed that the underpass has an abruptly exposed end or a lateral placement that is not operationally compatible with the lane configuration. This issue can then be corrected using barrier transitions or travel lane re-configurations.

Each of these high crash locations should be individually evaluated and roadside enhancements should be identified to mitigate these observed crash trends.

10.2 ROADSIDE FEATURES FOR URBAN AND RESTRICTED AREAS

In addition to maintaining increased lateral offsets to rigid objects at select urban locations, several roadside features common to urban regions and restricted areas merit additional guidance about placement strategies of these specific features. The following sections address these objects and their placement in urban areas.

10.2.1 Safe Design for Common Urban Roadside Features

10.2.1.1 Curbs

Curbed sections are generally used at locations with design speeds of 70 km/h [45 mph] or less on roadways in urban or highly developed areas. Items that need to be considered are: delineation of the pavement edge, delineation of pedestrian walkways, control of access points, retention of water on the roadway, and vaulting or destabilization of vehicles.

The common practice in urban settings is to use curbs or curbs with gutters adjacent to the highway travel lanes or shoulders (when present) to provide separation of pedestrians from the traffic flow. Realistically, curbs have limited re-directional capabilities and these occur only at low speeds of approximately 40 km/h [25 mph] or lower. For speeds above 40 km/h [25 mph], the curb can influence driver behavior by providing positive guidance but does not provide a physical vehicle redirection function. Curbs alone may not be adequate protection for pedestrians on adjacent sidewalks or for shielding utility poles. In some cases, other measures may need to be considered.

When a vehicle strikes a curb, the trajectory of that vehicle depends upon several variables: the size and suspension characteristics of the vehicle, its impact speed and angle, and the height and shape of the curb itself. Where curb is needed for drainage, the use of a curb no higher than 100 mm [4 in.] is satisfactory; however, the use of 140 mm [6 in.] curb is more common in urban regions. Section 3.4.1 provides additional guidance for the use of curbs.

In urban conditions, a minimum lateral offset of 0.5 m [1.5 ft] should be provided beyond the face of curbs to any frangible obstructions. This minimum offset does not meet clear zone criteria, but simply enables normal facility operations which may help to:

- Avoid adverse impacts on vehicle lane position and encroachments into opposing or adjacent lanes,
- Improve driveway and horizontal sight distances,

- Reduce the travel lane encroachments from occasional parked and disabled vehicles,
- Improve travel lane capacity, and
- Minimize contact from vehicle mounted intrusions (e.g., large mirrors), car doors, and the overhang of turning trucks.

Designers should strive for lateral offsets more appropriate for the off-peak operating speeds. Example preferred lateral offsets are identified in Section 10.1.3.1 of this chapter. At the higher speed end of the rural-urban transition area or urban facilities, consideration should be given to providing a shoulder and offsetting any curbing to the back of the shoulder. The shoulders may be used to accommodate bicyclists and pedestrians where sidewalks are not provided.

Previous high-speed urban research determined that a lateral distance of approximately 2.5 m [8.2 ft] is needed for a traversing vehicle to return to its pre-departure vehicle suspension state (1). As a result, the placement of guardrails behind curbs should either be located in the immediate vicinity of the curb (per specifications for the particular guardrail) so as to shield critical roadside features or they should be located with a minimum lateral offset of 2.5 m [8.2 ft] to enable vehicles with speeds greater than 60 km/h [40 mph] to return to their normal suspension state and minimize the likelihood that they could vault the barrier.

A variety of strategies have been proposed, applied, and or tested for safe application of curb treatments as a means to enhance roadside safety. Common strategies are as follows:

Purpose:	Strategy:
Prevent curb from vaulting vehicles	• Use appropriate curb heights compatible with expected vehicle trajectories • Orient barriers with respect to curbs so as to improve curb-barrier interactions • Grade adjacent terrain flush with the top of curb

10.2.1.2 Shoulders

The common edge treatment for urban roads is a curb or curb with gutter; however, many roads exist in urban environments with a paved shoulder located between the travel lanes and curb or with a graded or paved shoulder and no curb. The purpose of a shoulder is to provide a smooth transition from the travelway to the adjacent roadside while facilitating drainage and promoting various other shoulder operational. The shoulder width should be included as part of the clear zone width. There are many recommendations regarding appropriate shoulder widths for lower speed roads. These values vary depending on the function of the shoulders as well as the available right-of-way and recommended widths should be determined using regional guidelines or standards.

Because right-of-way costs are high in urban environments, the use of paved or graded shoulders without curbs in these environments often is the result of previously rural roads having been incorporated into urbanized land use without the companion roadway improvements. Often the road with only a shoulder will have a drainage ditch located parallel to the road, so care must be taken to maintain traversable conditions in the event an errant vehicle exits the road, travels across the shoulder, and then encounters the roadside grading. In general, wider shoulders contribute to higher travel speeds; however, wider shoulders also result in fewer run-off-road crashes.

10.2.1.3 Channelization / Medians

The separation of traffic movements by the use of a raised median or turning island is often referred to as channelization. A flush or traversable median or island is considered part of the roadway, while a raised median or raised turn island are considered part of the roadside.

Channelized islands are generally used to reduce the area of pavement at an intersection while providing positive guidance to turning vehicles. These islands can be used for pedestrian refuge, traffic control device placement, and can also be planted with landscaping treatments that contribute to an improved visual environment (4). For a raised island to be visible, it should have a minimum size of 5 m^2 (50 ft^2) for urban conditions (5). The orientation of the curb on a raised island should be slightly skewed toward the adjacent travel lane to give an illusion of directing errant vehicles back into the travel lane. Other cross-sectional characteristics of raised islands are similar to those of raised medians. The raised median provides the primary function of separating opposing directions of vehicle travel. This physical separation has the added benefit of improving access management (restricting frequent left-turns into driveways), providing a location for pedestrian refuge (assuming median has adequate width), and providing road edge delineation during inclement weather conditions. A median may simply be raised using a vertical or sloped curb. In urban regions, a median width can vary dramatically depending on the proposed function of the median.

Many studies have resulted in the conclusion that raised medians have a negligible effect on crash frequency. Crash severity varies depending upon the median width (wider medians reduce the chance for head-on collisions), the use of median barrier, and the placement of rigid objects in the median area.

Common channelized island and median strategies are as follows:

Purpose:	Strategy:
Reduce likelihood of run-off-road collision	• Widen median
Reduce crash severity	• Place only frangible items in channelized island or median • Shield rigid objects in median

10.2.1.4 Gateways

The traffic calming strategy known as a gateway is defined as

> *"a physical or geometric landmark on an arterial street which indicates a change in environment from a major road to a lower speed residential or commercial district."* (6)

Gateways can be a combination of street narrowings, medians, signs, arches, roundabouts, or other unique features. One common objective of a gateway treatment is to make it clear to a motorist that he or she is entering a different road environment that requires a reduction in speed.

Drivers need a certain transitional speed zone with explicit guidance and roadway features to inform and encourage them to slow down gradually before they reach the urban area. Meanwhile, the transitional speed zone will also help drivers to speed up in a certain time period when leaving an urban area. This transition area is important for drivers who are not familiar with the urban region. They rely on the roadway features to give them enough indication to be aware of the surrounding changes and to adjust their corresponding driving speed and behavior, yet gateway placement in this transitional area must carefully adhere to safe roadside design principles.

Roundabouts are another commonly recommended gateway treatment. They can serve as safe traffic calming alternatives to conventional intersections as they function as both psychological and physical indicators of a transition from a rural high-speed environment to the lower-speed urban street (7, 8). The center islands of the roundabouts are often landscaped and sometimes include sculptures or monuments. The application of street art in roundabouts is generally hazardous if these items are placed in the center of the first roundabout encountered by the rural driver. The use of a series of roundabouts as a transition with the street art located in the subsequent roundabouts, however, is common international practice and a reasonable safety strategy for these transitional regions.

Common roadside safety gateway strategies are as follows:

Purpose:	Strategy:
Reduce likelihood of run-off-road crash	• Apply speed reduction signs, pavement markings, and other gateway treatments
Reduce severity of run-off-road crash	• Construct roundabouts with traversable island centers in initial islands

10.2.1.5 Roadside Grading

The terrain adjacent to an urban road should be relatively flat and traversable. In general, the placement of common urban roadside features such as sidewalks and utilities tends to create a flatter urban roadside. The primary risk for irregular terrain adjacent to the travelway is that an errant vehicle will either impact a rigid obstacle or that the terrain will cause the vehicle to rollover. Rollovers were responsible for 20-percent of the fatal crashes in 2002, and the largest number of rollovers occurred after a vehicle impacted an embankment or a ditch (9, 10). The principal cause of rollovers is a vehicle "tripping" on an element of the roadside environment, such as a ditch or an embankment, although sharp pavement drop-off on the shoulder may also lead to vehicle tripping for roads without curb. To prevent vehicle tripping, the grade of ditches, slopes, and embankments should be minimized as much as possible, and pavement drop-offs must be kept to a minimum.

These strategies are potentially more relevant to rural or unrestricted environments than to urban ones, however. In urban areas, the roadside is typically characterized not by shoulders and embankments, but by curb and gutter applications and by adjacent roadside development.

The sideslope of an urban road should, in general, slope from the edge of the right-of-way towards the curb of the road. This slope will prevent any road drainage from encroaching on adjacent property and enables the drainage to be contained within a closed drainage system. As a result, the slope is often quite flat (1 V : 6 H typically) for curbed urban roads. For roads without curb, the design guidelines for rural roadside conditions should be applied. That is, the terrain including drainage channels, should be safely traversable by a motor vehicle and the placement of obstacles such as headwalls must be flush with the ground surface and designed to be navigated by an errant vehicle.

Common roadside grading strategies are as follows:

Purpose:	Strategy:
Minimize Crash Likelihood	• Maintain traversable grades that are free of rigid obstacles
Minimize Crash Severity	• Flatten grades to reduce chance of vehicle rollover • Create an object setback policy

10.2.1.6 Pedestrian Facilities

Sidewalks and pedestrian facilities, in general, do not pose a particular hazard to motorists. The safety concern for locating these facilities adjacent to the road is the risk to the pedestrians using the facilities. Providing safe facilities for pedestrians to walk is an obvious strategy for increasing pedestrian safety. The AASHTO *Green Book* (5) recommends the use of sidewalks on urban streets, with sidewalk widths ranging between 1.2 and 2.4 m [4 and 8 ft] in width, depending on the roadway classification and nearby land use characteristics (see Table 10.2).

Table 10.2 AASHTO Green Book Sidewalk Specifications

Road Class	Side of Street	Specification
Arterial	Both	Border area (buffer plus sidewalk) should be a minimum of 2.4 m [8 ft], and preferably 3.6 m [12 ft] or more
Collector	Both sides of street for access to schools, parks, shopping Both sides of streets desirable in residential areas	1.2 m [4 ft] minimum in residential areas 1.2 to 2.4 m [4 to 8 ft] in commercial areas
Local	Both sides of street for access to schools, parks, shopping Both sides of streets desirable in residential areas	1.2 m [4 ft] minimum in residential areas 1.2 to 2.4 m [4 to 8 ft] in commercial areas, although additional width may be desirable if roadside appurtenances are present.

Source: Developed from AASHTO (5)

Of the roughly 75,000 pedestrian-related crashes that occur each year, almost half occurred while the pedestrian was at a non-intersection, on-roadway location (11). This statistic suggests that designing roadsides to support pedestrian activity use may go a long way towards improving pedestrian safety.

An additional feature of the roadside environment is a pedestrian buffer area (often referred to as a buffer strip). The pedestrian buffer is a physical distance separating the sidewalk and the vehicle travelway. Buffer areas often accommodate on-street parking, transit stops, street lighting, planting areas for landscape materials, and common street appurtenances including seating and trash receptacles. Buffer strips may be either planted or paved and are encouraged for use between urban roadways and their companion sidewalks.

Figure 10.4 depicts the recommended placement of roadside objects in a buffer strip 1.2 m [4 ft] wide or less. Figure 10.5 demonstrates recommended roadside object placement when the buffer strip width exceeds 1.2 m [4 ft].

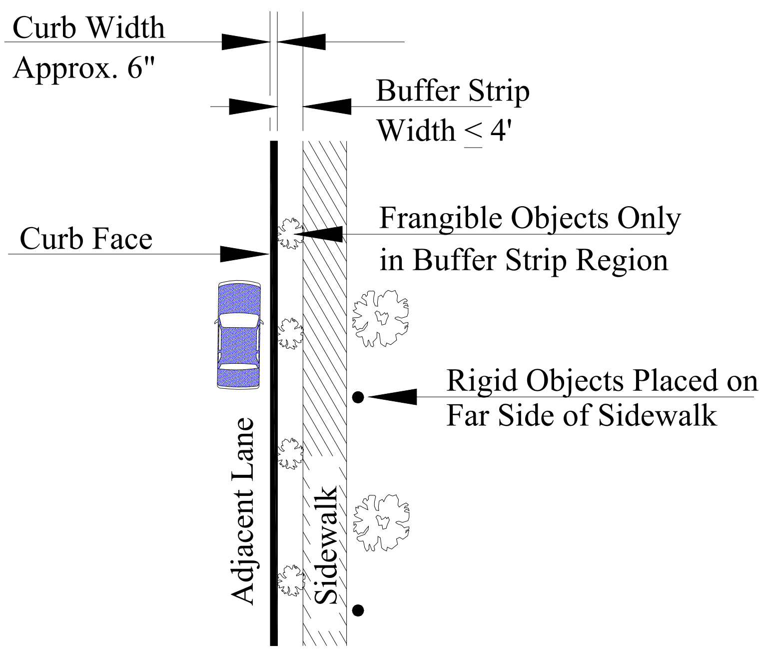

Figure 10.4 Landscape and Rigid Object Placement for Buffer Strip Widths ≤ 4’

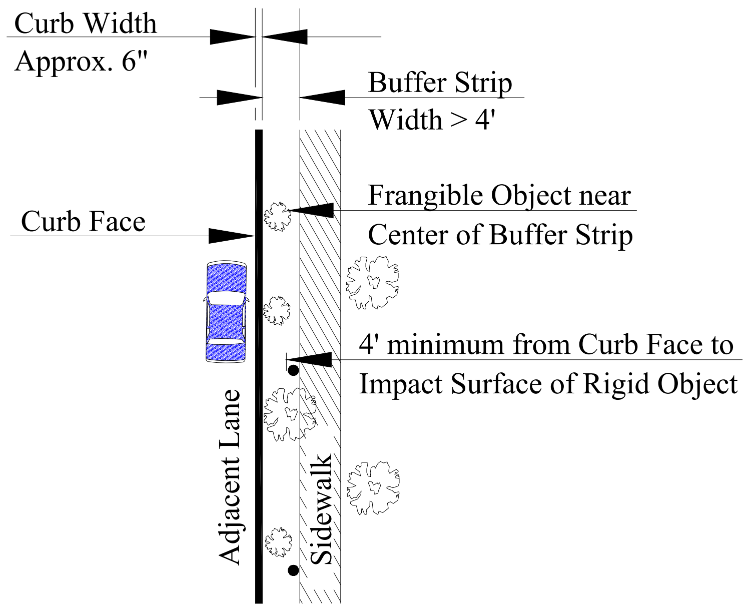

Figure 10.5 Landscape and Rigid Object Placement for Buffer Strip Widths > 4'

Common strategies for eliminating or minimizing motor vehicle-pedestrian crashes at roadside locations are as follows:

Purpose:	Strategy:
Reduce motor vehicle-pedestrian crash likelihood at roadside locations	• Provide continuous pedestrian facilities • Install pedestrian refuge medians or channelized islands (see previous section on medians and islands) • Offset pedestrian locations away from travelway with pedestrian buffers • Physically separate pedestrians from travelway at high-risk locations • Improve sight distance by removing objects that obscure driver or pedestrian visibility
Reduce severity of motor vehicle-pedestrian crashes at roadside locations	• Reduce roadway design speed / operating speed in high pedestrian volume locations

10.2.1.7 Bicycle Facilities

Bicycle facilities consist of road and roadside features intended for bicycle operation. These facilities may include standard lanes, wide outside lanes, bicycle lanes, and off-road bicycle paths. Accompanying bicycle facilities may be bicycle hardware often located along the roadside such as bicycle racks. Wide shoulders and bicycle lanes provide an additional "clear" area adjacent to the travel way, so these features could potentially provide a secondary safety benefit for motorists, provided bicycle volumes are low, and can be included as part of the clear zone. These bicycle facilities will also further separate the motor vehicle from any roadside obstructions and improve the resulting sight distance for motor vehicle drivers at intersecting driveways and streets.

Bicycle racks are commonly made of steel or other metals, and are typically bolted to the ground to secure locked bicycles from potential theft. These features are not designed to be yielding should a run-off-road event occur. Making such features yielding would potentially minimize the core function of these features, to provide a secure location for locking up bicycles. Thus, a potentially more desirable alternative may be to encourage the placement of these features outside of the clear zone.

In the past the use of barrier-delineated bicycle lanes was popular as it provided a perceived safety buffer between the more vulnerable bicyclists and the motor vehicles. In recent years, however, this treatment has diminished for the following reasons:

- Raised barriers limit the movement of entering or exiting bicycles in the bike lane;
- Motorists at side streets essentially block the bike lane in the driver's effort to pull forward to determine if it is safe to enter the motor vehicle travelway;
- Barrier separated bicycle lanes may collect debris or be blocked by snow removed from the motor vehicle lanes;
- The separated bicycle lane configuration can be confusing and is often used incorrectly by the bicyclists; and
- The bicyclists turning left or proceeding straight at an intersection are in direct conflict with right turning motor vehicles (12).

It is helpful to understand the magnitude of the safety risk to cyclists as they encounter roadside environments. One FHWA report using hospital emergency department data noted that 70-percent of reported bicycle injury events did not involve a motor vehicle and 31-percent occurred in non-roadway locations. For bicycle-only crashes, a total of 23.3-percent of the recorded crashes occurred at sidewalk, driveway, yard, or parking lot locations (13).

Strategies to improve bicycle safety as well as bicycle-motor vehicle interactions are as follows:

Purpose:	Strategy:
Reduce likelihood of crash	• Use wider curb lanes • Increase operational offsets
Reduce severity of crash	• Locate bicycle racks as far away from road as possible

10.2.1.8 Parking

In many urban environments, limited off-street parking often necessitates the use of on-street parking to address the needs of local businesses and stakeholders. As noted in the AASHTO *Green Book* (5), cars typically park 150 to 305 mm [6 to 12 in] from the curb, and have a normal width of roughly 2.1 m [7 ft]. Thus, approximately 2.4 m [8 ft] is needed to comfortably accommodate on-street parking. One common strategy in larger cities is to design wider outside parking lanes, such as 3 m [10 ft], and convert them to travel lanes during peak periods and anticipated high volume conditions.

On-street parking can potentially have mixed results on a roadway's safety performance. On one hand, these features narrow the effective width of the roadway, and may result in speed reductions, thereby leading to a reduction in crash severity. Conversely, on-street parking may also lead to an increase in collisions associated with vehicles attempting to pull in or out of an on-street parking space.

In addition to vehicle conflicts, on-street parking serves as a physical buffer between the motor vehicle path and pedestrian facilities. The parked vehicles may act as a shield to prevent proper sight distance for the drivers of adjacent motor vehicles, often resulting in new conflicts between motor vehicles and pedestrians stepping between parked cars. There is an inherent conflict between the motor vehicle and drivers exiting or entering their parked vehicles on the traffic side of the roadway.

The severity of a roadside hazard constituted by a collision between a parked vehicle and a moving vehicle is minimal. Since on-street parking is generally parallel to the moving vehicles, the impact by a moving vehicle is likely to be a sideswipe crash. This is one of the less severe crash types. For locations with head-in parking, the crash severity likelihood is increased as the moving vehicle may impact a vehicle in reverse. On-street parking is generally not considered appropriate for higher speed roads such as rural to urban transitional arterials.

On-street parking strategies are as follows:

Purpose:	Strategy:
Reduce likelihood of crash	• Restrict on-street parking to low-speed roads
Reduce crash severity	• Where parking is appropriate, use parallel parking rather than angular (head-in) parking

10.2.2 Safe Placement of Roadside Objects

10.2.2.1 Mailboxes

Chapter 11 reviews mailbox recommendations and their placement adjacent to roads. While making mailboxes crashworthy will satisfy safety associated with mailbox-related crashes, it is important to recognize that the placement of mailboxes may have an important impact on the overall safety of the roadway. Mailboxes should not obstruct intersection sight distance, nor should they be located directly on higher-speed roadways where stopping associated with mail delivery and collection can lead to substantial speed differentials between vehicles on the travelway, thereby increasing the possibility of a rear-end collision. In urban settings a commonly observed placement of the mailbox is adjacent to a driveway (to make it easy for the home owner to retrieve mail). Since the curb has a secondary function of delineating the edge of the roadway, a mailbox placed on the departure side of a driveway (where a curb cut interrupts the roadway delineation) is particularly vulnerable for errant vehicles that exit the road to the right.

Mailbox placement for urban commercial locations is not included in Chapter 11 and is a less common problem. In addition to yielding mailbox support design, some jurisdictions promote the placement of reflective object markers on the mailbox or post to improve nighttime visibility (14).

Urban mailbox roadside safety strategies are as follows:

Purpose:	Strategy:
Minimize Crash Likelihood	• Remove or relocate mailboxes to safe locations • Add reflective object markers to improve nighttime visibility
Minimize Crash Severity	• Develop policies to require crashworthy mailboxes in urban environments • Shield rigid mailboxes

10.2.2.2 Street Furniture

In many urban areas the use of street furniture is a common approach to improving the aesthetic quality of a street. Street furniture includes items placed adjacent to the road that are there to improve the adjacent land use or to improve the transportation operations. In some jurisdictions, street lights and signs are included in the category of street furniture; however, for the purposes of this review street furniture is considered to be supplemental items such as benches, public art, trash receptacles, phone booths, fountains, kiosks, transit shelters, planters, bollards, bicycle stands, etc. Many street furniture items are placed along the right-of-way by the property-owners themselves, as in the case of the placement of a sidewalk cafe in front of a restaurant, and are thus largely outside the engineer's control. Transit shelters such as the one depicted in Figure 10.6 are provided to protect transit riders from inclement weather and must be located close to the curb to facilitate short bus dwell times.

Street furniture can potentially create sight distance obstructions when located near an intersection, particularly when large numbers of people congregate as a result of the street furniture. It is also important that the sight distance of pedestrians be maintained when placing street furniture proximate to the roadway.

Safe roadside street furniture strategies are as follows:

Purpose:	Strategy:
Minimize likelihood of crash	• Locate street furniture as far from street as possible • Restrict street furniture placement to avoid sight distance issues for road users
Minimize crash severity	• Develop street furniture that meets basic crashworthy standards

Figure 10.6 A Transit Shelter Located Curbside

10.2.2.4 Utility Poles, Sign Posts, and Lighting and Visibility

Both nationally and internationally, the placement of utility poles, light poles, and similar vertical roadside treatments and companion hardware are frequently cited as common urban roadside hazards. In Melbourne, Australia, for example, while impacts with trees are more common outside the metropolitan area, single-vehicle crashes with poles or posts are more common within the metropolitan region (15). A 1998 study by the European Transport Safety Council (16) identified collisions with utility poles or posts as one of the top two roadside hazards for Finland, Germany, Great Britain, and Sweden.

Utility Poles

Utility poles are prevalent in urban environments and can pose a substantial hazard to errant vehicles and motorists. The frequency of utility pole crashes increases with daily traffic volume and the number of poles adjacent to the travelway (17). Utility poles are more prevalent adjacent to urban roadways than rural highways, and demands for operational improvements coupled with limited street right-of-way often lead to the placement of these poles proximate to the roadway edge. In fact, utility poles are second only to trees as the object associated with the greatest number of fixed-object fatalities (18). Though utility poles are often impacted directly, the placement of guy wires that stabilize the pole can themselves pose a hazard as vehicles can impact them directly as well.

In general, utility pole-related crashes are considered to be principally an urban hazard, with urban areas experiencing 36.9 pole crashes per 100 miles of roadway, compared to 5.2 per 100 miles for rural areas (19). One study determined that the variable that had the greatest ability to explain utility pole-related crashes was the average daily traffic (ADT) along the roadway (20). The significance of ADT as the critical variable explains the importance of vehicle exposure to understanding run-off-road crashes with utility poles.

A common recommendation for addressing the utility pole safety issue is to place utilities underground and thereby remove the hazardous poles. The removal of all poles in the urban roadside environment is not practical as these poles often function as the supports for street lights and other shared utilities. There are, however, several known utility pole hazardous locations that should be avoided when feasible. In general, utility poles should be located (21, 22):

- As far as possible from the active travel lanes;
- Away from access points where the pole may restrict sight distance;
- Inside a sharp horizontal curve (as errant vehicles tend to continue straight towards the outside of curves); and

- On only one side of the road.

Researchers observed that in metropolitan Melbourne, poles involved in fatal crashes were most often less than 2 m [6.6 ft] from the edge of the road (23). The Georgia utilities clear roadside committee suggests that for curbed sections, poles should be as far as practical from the face of the outer curbs with the following goals:

- Lateral clearance of 3.6 m [12 ft] from face of curb to face of pole is desirable.
- For speed limits greater than 56 km/h [35 mph] but not exceeding 72 km/h [45 mph], a lateral clearance of 2.4 m [8 ft] is acceptable.
- For roads with posted speed limits less than or equal to 56 km/h [35 mph], a lateral clearance of 1.8 [6 ft] is acceptable (*24*).

Similar to the Georgia setback policy, the Maine Utility Pole Location Policy suggests offsets should be greater than 2.4 m [8 ft] for roadways with posted speed limits of 40-55 km/h [25-35 mph], and the offset should be greater than 4.3 m [14 ft] on roadways with posted speed limits of 65-70 km/h [40-45 mph] (*25*).

Lighting and Visibility

An important issue in addressing roadside safety is the role of lighting in making potentially hazardous roadside environments visible to the road users (motor vehicle drivers, bicyclists, and pedestrian), particularly during nighttime hours.

The North Carolina Department of Transportation's *Traditional Neighborhood Development (TND) Guidelines* (26) recommends that for a TND designed to accommodate "a human scale, walkable community with moderate to high residential densities and a mixed use core", more and shorter lights should be used rather than less frequent, tall, high-intensity street lights. This dense light spacing will provide adequate coverage for both pedestrian and vehicular activity.

Chapter 4 of this document briefly describes the various recommended luminaire supports.

Sign Posts and Roadside Hardware

The design of sign posts is directed by NCHRP 350, and there has been substantial research devoted to designing these features to be traversable. Multiple designs for these features are included in the current edition of the *Roadside Design Guide*, and specifications for evaluating these features are contained in AASHTO's *Standard Specification and Structural Supports for Highway Signs, Luminaires and Traffic Signals* (*27*).

Roadside safety strategies for utility poles, light poles, and street sign posts are as follows:

Purpose:	Strategy:
Treat individual poles or posts in high risk locations	• Remove or relocate poles • Place poles on inside of horizontal curves and avoid placement on outside of roundabouts or too close to intersection corners • Use breakaway or yielding poles • Shield poles • Improve pole visibility
Treat multiple poles or posts in high risk locations	• Establish urban clear zone offset guidelines for pole setback distances from curb • Place utilities underground while maintaining appropriate nighttime visibility • Combine utilities/signs onto shared poles (reduce number of poles) • Replace poles with building-mounted suspended lighting (where suitable)
Minimize Level of Severity	• Reduce travel speed on adjacent road

10.2.3 Placement of Landscaping, Trees, & Shrubs

Along most urban streets, some type of landscaping exists. Trees, shrubs, lawns, decorative rock, and other materials are used to provide a pleasing setting for drivers, pedestrians, bicyclists, and abutting land owners. The presence of roadside landscaping is known to have a positive influence on the health of drivers or motor vehicles as well as other users of the facility. Roadside landscaping can also aid in providing visual cues to drivers regarding the road environment. Maintenance of urban forestry can similarly aid in improving environmental quality in the region. The design process, therefore, should balance the benefits of landscaping with the requirements for roadside safety where ever possible.

The designer should always be consulted in the decisions regarding landscaping, particularly as they relate to sight distance and possible future lane needs. Considerations in the design of landscaping include:

- The mature size of trees and shrubs, and how this will affect safety, visibility, and maintenance cost.

- Sufficient border area to accommodate the type of landscaping planned. If parking is allowed along the curb, will the landscaping allow curbside access to parked vehicles?

- Potential future changes in roadway cross section. For example, the addition of a second left-turn lane at major intersections by taking approximately 3 m [10 ft] of additional space from the median island is becoming a common practice. Landscaping in the affected area should be minimal or should not be included in the plan.

Visibility restrictions resulting from landscaping are of principle concern to the designer. Points that must be considered include the following:

- Border area landscaping should allow full visibility at driveways and intersections for drivers and pedestrians.

- A clear vision space from 1 m to 3 m [3 ft to 10 ft] above grade is desirable along all streets and at all intersections. This allows drivers in cars, trucks, and buses to have good sight distance. Many cities have ordinances regarding sight restrictions at corners which incorporate this "clear space" idea.

- Landscaping very small islands should be avoided to reduce maintenance needs.

- Large trees or rocks should not be used at decision points (e.g., gore areas, island noses) to "protect" poles and other appurtenances. Rather, each of the design options stated in Section 10.1.1 (in the order listed) should be considered to improve safety.

- Longitudinal placement of trees and landscaping should separate these items from underground utility lines, power poles, street lights, existing trees, light standards, fire hydrants, water meters, or utility vaults to assure root systems do not conflict with utilities.

- Canopy trees should not be positioned under service wires and, where present, should be of sufficient height to provide clearance for taller vehicles including buses and trucks.

With respect to pedestrians, it is desirable to have a grass strip separating the sidewalk from the curb, thus further separating the pedestrian from vehicular traffic. The strip also provides room for snow storage and trash collection.

Another planting strategy that can improve roadside safety is the layering of plants so that rigid plants are shielded by smaller, more frangible plants. This plant layering creates an attractive roadside landscaping while also naturally creating energy dissipation in an accident through the creative use of plants.

10.2.4 Use of Roadside Barriers

A roadside barrier is a longitudinal barrier used to shield motorists from natural or man-made obstacles located along either side of a roadway. The primary purpose of roadside barriers is to prevent a vehicle from striking a fixed object or roadside feature that is less forgiving than the barrier itself. This is accomplished by containing and redirecting the impacting vehicle. Barriers are also used to separate pedestrians and bicyclists from vehicular traffic when appropriate. Refer to Chapter 5 for a discussion of application, performance, structural, and safety characteristics of crashworthy roadside barriers.

A blunt end of a roadside barrier is not desirable since it may penetrate the passenger compartment or stop the vehicle too abruptly when hit. A crashworthy end treatment is therefore considered essential if the barrier terminates within the clear zone or in an area where the barrier is likely to be hit head-on by an errant vehicle. The selection of the proper treatment should be in accordance with the proposed test levels, warrants, and availability of maintenance. Refer to NCHRP Report 350 for more information regarding crashworthy end treatments.

Intersections and driveways complicate the selection and use of end treatments. A major factor in selecting and locating end treatments is obtaining the necessary corner sight distance at these locations. Refer to Chapter 8 for further guidance on the subject of barrier end treatments and crash cushions.

Aesthetic concerns can be a significant factor in the selection of a roadside barrier in environmentally sensitive locations such as recreational areas, parks, or many urban or restricted environments. In these instances, a natural-looking barrier that blends in with its surroundings is often selected. It is important that the systems used be crashworthy as well as visually acceptable to the highway agency.

Having decided that a roadside barrier is warranted at a given location and having selected the type of barrier to be used, the designer must specify the exact layout required. The major factors that must be considered include the following:

- Lateral offset from the edge of pavement,
- Deflection distance of the barrier,
- Terrain effects,
- Flare rate,
- Length of need,

- Corner sight distance,
- Pedestrian activity including the needs of the disabled, and
- Bicycle activity.

Generally, a roadside barrier should be placed as far from the traveled way as conditions permit while ensuring that the system performs properly. Such placement gives an errant motorist the best chance of regaining control of the vehicle without striking the barrier. It also provides better sight distance, particularly at nearby intersections.

It is desirable that a uniform clearance be provided between traffic and roadside features such as bridge railings, retaining walls, roadside barriers, utility poles, and trees, particularly in urban areas where there is a preponderance of these elements. The placement of roadside barriers is covered in Chapter 5.

10.2.4.1 Barrier Warrants

Barrier warrants are based on the premise that a traffic barrier should be installed only if it reduces the severity of potential crashes. It is important to note that the probability or frequency of run-off-the-road crashes is not directly related to the severity of potential crashes.

Typically, barrier warrants have been based on a subjective analysis of certain roadside elements or conditions. If the consequences of a vehicle striking a fixed object or running off the road are believed to be more serious than those resulting from the vehicle hitting a traffic barrier, the barrier is considered warranted. While this approach can be used often, there are instances where it is not immediately obvious whether the barrier or the unshielded condition presents the greater risk. Appendix A presents an analysis procedure that can be used to compare several alternative safety treatments and provides guidance to the designer.

A barrier may be warranted if:

1. There is a reasonable probability of a vehicle leaving the road at that location, and
2. The cumulative consequences of those departures significantly outweigh the cumulative consequences of impacts with the barrier.

Note that there will generally be many more impacts with a shielding barrier than there would otherwise be with the unshielded object.

Highway conditions that warrant shielding by a roadside barrier can be placed in one of two basic categories: embankments or roadside obstacles. Warrants for the first category are found in previous chapters. Low-profile barriers 600 mm [24 in] high for speeds of 70 km/h [45 mph] or less have been developed. They shield without obstructing visibility. The presence of pedestrians and bystanders may justify protection from errant vehicular traffic.

10.2.4.2 Barrier to Protect Adjacent Land Use (for Access Management)

In urban or restricted environment areas, more consideration should be given to protecting pedestrians who are using adjoining properties from risks posed by errant vehicles. Schools, playgrounds, and parks located on the outside of sharp curves or across T-intersections are examples of where barrier systems may be appropriate. At these locations, the probability of a vehicle leaving the roadway and striking a person or persons in these areas is greater than on tangent stretches of roadway. Because there are not any specific warrants or guidelines for these situations, design judgment should be used.

Barriers intended to protect adjacent land use must prevent an errant vehicle from entering a specific area. A barrier that is not structurally adequate may be less desirable for the area it was intended to protect than having no barrier at all. Flying debris resulting from the impact of a vehicle into a deficient barrier can injure people in the area.

Consideration should also be given to installing a barrier to shield businesses and residences that are near the right-of-way, particularly at locations having a history of run-off-the-road crashes. This use of barrier is based on the need for individual study of sites as described in Section 10.1.1 and may be independent of conventional barrier warrants.

10.2.4.3 Common Urban Barrier Treatments

Roadside and Median Barriers

A median barrier is a longitudinal barrier most commonly used to separate opposing traffic on a divided highway. It is also used along heavily traveled roadways to separate through traffic from local traffic or to separate special use lanes from other highway users. By definition, any longitudinal barrier placed on the left side of a divided roadway may be considered a median barrier. For median barriers on high-speed, controlled-access roadways that have relatively flat and traversable medians, refer to Chapter 6.

The use of standard highway median barriers on urban facilities with a design speed of 70 km/h [45 mph] or less with street intersections, regardless of access control, generally is not warranted. Alternate methods of separating opposing traffic are encouraged, such as the use of medians (in some cases raised medians). Flush medians are preferred over raised medians on highways with design speeds greater than 70 km/h [45 mph], since raised medians can cause errant vehicles to vault. Intersection sight distance should be considered when designing a raised median with plantings or barrier.

Guardrails

There are a large variety of available guardrail treatments. Though these barriers may be impacted by errant vehicles, they are generally positioned at locations where they shield a much greater hazard than that posed by the guardrail itself. Chapter 5 reviews available guardrails and information regarding their performance upon impact.

Bridge Railings

The local variables regarding the placement of urban guardrail, bridge railing, and other barriers become more challenging. The primary reasons are the need to design these features around intersecting ramps and streets, to provide access to properties, and to maintain access for pedestrians, including persons with disabilities.

As detailed in Chapter 7, appropriate bridge railings need to be selected by considering roadway design, traffic volumes, percent of heavy vehicles in the traffic stream, and the volume of pedestrian traffic. The performance requirements of bridge railings for urban areas are no different from any other highway system. However, bridges carrying low traffic volumes at greatly reduced speeds may not need bridge railings designed to the same standard as railings used on high-speed, high-volume facilities. The railing should have adequate strength to prevent penetration by passenger vehicles, while the transition rail section approaching the bridge should be considered with the same selection considerations discussed in previous sections. Transitions that meet Test Levels 1 and 2 in accordance with NCHRP Report 350 are generally acceptable for cases with low roadway speeds. The bridge rail and transition section, nevertheless, must function effectively for the location and conditions selected. Standardization of urban bridge rail systems improves availability of replacement parts for maintenance departments. The FHWA requires a minimum TL-3 bridge railing on NHS projects unless supported by another rational selection procedure.

Highway structures, regardless of location and traffic volume, normally warrant rigid railing. A rigid bridge railing may require an approach guardrail and transition section. When a bridge also serves pedestrians, a barrier to shield them from vehicular traffic may be warranted. Placement of the bridge railing between traffic and the sidewalk affords maximum pedestrian protection. A pedestrian railing would then be needed at the outer edge of the bridge structure. The need for a bridge railing adjacent to the pedestrian walkway should be based upon the volume and speed of the roadway traffic, lane width, curb offset, and alignment. Other considerations include the number of pedestrians crossing the bridge, the crash statistics (if available), and the conditions on either end of the structure. The use of a bridge railing may create a problem unless the railing is terminated in an acceptable manner. Flaring the end section away from the roadway is often not practical because it would encroach upon the sidewalk requiring the walkway to meander around the transition section and terminal unit.

In some instances, a crash cushion or metal beam barrier terminal can be used to shield the end of a barrier at the edge of a curb. However, the presence of a raised curb may adversely affect the performance of this type of end treatment. In low-speed situations, a concrete tapered end section parallel to the roadway may be the best compromise. Concrete bridge railing should be extended a sufficient length beyond the end of the bridge to protect drop-offs yet not extend so far as to intrude on the sight distance of adjacent street intersections. Recommended taper lengths are 6 m [20 ft] minimum, with 10 to 13 m [30 to 45 ft] desirable.

Retrofitting existing bridge railings is a challenge. Typically, bridges designed to AASHTO specifications prior to 1964 may have deficient railings (based on current criteria). If the adequacy of a railing appears questionable, further evaluation should be made to ensure the design meets the current specifications. In many older railing systems, the presence of curbs defines the walkway between the driving lane and the bridge railing. This curb may cause an impacting vehicle to go over the railing or to strike it from an unstable position contributing to the possibility of roll over; however, several concrete railings installed on raised sidewalks have been successfully crash tested.

While some retrofit designs for a bridge railing that does not comply with current guidelines may not bring the railing to full AASHTO specifications, significant improvements can nevertheless be obtained. Chapter 7 outlines a number of retrofit concepts that can be adapted to different types of deficient railings. The metal post and beam retrofit functions well as a traffic barrier separating vehicles from pedestrians that are using an adjacent sidewalk on a bridge. In most cases, the metal post and beam system allows the existing bridge railing on a wide raised walkway to be used or converted to a pedestrian rail. Other retrofit means are also available and should be reviewed to determine their appropriateness for the conditions that exist.

Protective Screening at Overpasses

An object or debris that is thrown, dropped, or dislodged from an overpass structure can cause significant damage and injuries. Protective screening might reduce the number of these incidents; however, it should be noted that screening will not stop a determined individual. In many cases, increased enforcement may provide a more effective deterrent.

While the most common protective screening in use is for pedestrian type overpasses, other types of screening are used, such as glare screens, to protect oncoming traffic on overpasses. Splash or debris screens are used to protect commercial or residential properties that are beneath or adjacent to the structure.

At present, it is not possible to establish absolute warrants as to when, where, or what type of barriers or screens should be installed. The general need for economy of design and desire to preserve the clean lines of the structures, unencumbered by screens, must be carefully balanced against the requirement that the highway traveler, overpass pedestrian, and property be provided maximum protection.

Various types and configurations of screens, usually of a chain-link fence type, have been installed on overpasses throughout the country in areas where it has been determined that the problem of throwing or dropping objects exists.

The simplest design for use on pedestrian overpasses is a vertical fence erected on the bridge railing of the structure. While this type of design has been effective in keeping children from playing on the railing, the design has proven somewhat ineffective in combating the problem of objects being thrown from the structure. An object large enough to cause serious damage to passing vehicles can still be thrown over a vertical structure with some degree of accuracy. On pedestrian bridges, a semicircular enclosure has been placed on top of the two vertical walls to discourage this type of vandalism. This design has further evolved into a design with a partially enclosed curved top, which is used in some areas. Objects generally cannot be thrown over the top of a partially enclosed screen with any degree of accuracy.

Care should be taken in the design of chain-link type screens to ensure that the opening at the bottom of the side screens, through which object can be pushed or dropped, is eliminated or kept to a minimum. Where aesthetics are important, decorative type screening has been used.

Installation of protective screening should be analyzed on a case-by-case basis at the following locations:

- On existing structures where there have been incidents of objects being dropped or thrown from the overpass and where increased surveillance, warning signs, or apprehension or a few individuals has not effectively alleviated the problem;

- On an overpass near a school, playground, or other locations where it would be expected that the overpass would be frequently used by children not accompanied by adults;

- On all overpasses in urban areas used exclusively by pedestrians and not easily kept under surveillance by law enforcement personnel;

- On overpasses with walkways where experience on similar structures indicates a need for such screens; and

- On overpasses where private property that is subject to damage, such as buildings or power stations, is located beneath the structure.

In most cases, the erection of a protective screen on a new structure can be postponed until such time as there are indications of need.

Impact Attenuators

Impact attenuators are ideally suited for use at urban locations when fixed objects cannot be removed, relocated, or made breakaway, and cannot be adequately shielded by a longitudinal barrier. In urban situations, the increase in roadway maintenance mileage, the tight right-of-way constraints, and the varying traffic flow conditions create situations that limit available options for removing or relocating fixed objects. The use of impact attenuators, as opposed to longitudinal barriers, becomes more appropriate to shield fixed objects such as those at exit ramp gores, ends of median barriers, and bridge piers and abutments, to name only a few.

The width available for the placement of impact attenuators can be restricted in urban areas. However, a number of impact attenuators are available for narrow width conditions. The systems outlined in Chapter 8 should be reviewed to determine the appropriateness of the system for the proposed site location.

A curb's tendency to cause vaulting can reduce the effectiveness of an impact attenuator. Therefore, impact attenuators should not normally be installed behind curbs. Where necessary for drainage, an existing curb no higher than 100 mm [4 in.] can be left in place, unless it has contributed to poor performance in the past.

Impact attenuators are not intended to reduce crashes, but to lessen the severity of the impact. If a particular crash cushion is struck frequently, it is important to determine why the collisions are occurring. Improved use of signs, pavement markings, delineation, reflectors, and luminaires may help to reduce the number of occurrences.

Pedestrian Restraint Systems

Crashes involving pedestrians account for almost one out of every five traffic fatalities. Pedestrian crashes in some cities have accounted for as many as one-half of the traffic fatalities.

A large percentage (almost 40 percent) of pedestrian deaths occurs while the pedestrians are crossing streets between intersections; the injury rate shows the same trend. A pedestrian barrier prevents these crashes. Fences or similar devices that separate pedestrian and vehicular traffic have been used successfully to channel pedestrians to safe crossing locations. It is critical when considering a pedestrian barrier that crossings be located within a reasonable walking distance. The feasibility of restricting pedestrian crossings should be determined on a case-by-case basis.

Sidewalk pedestrian barriers are located along or near the edge of a sidewalk to channel pedestrians to a crosswalk or grade-separated facility, or to impede their crossing at undesirable locations. Barriers may also be used outside school entrances and playgrounds. Often it is advisable to contain pedestrians at public transportation stops to prevent pedestrians from encroaching onto the roadway.

Common construction materials for pedestrian barriers include chain-link fencing, pipe and chain/cable, planters or other sidewalk furniture, and hedges. Planters are not recommended if they would be an additional fixed object in a roadside area otherwise free of obstacles. Planters are also not recommended on narrow sidewalks where they may impede pedestrian circulation.

Median pedestrian barriers can significantly reduce the number of midblock crossings. Median barriers are frequently chain-link fences located along a median, which prevent pedestrians from crossing at non-intersection locations. They can be installed exclusively as pedestrian barriers or be incorporated with vehicle-separating median barriers. Intersection sight distance should be considered when designing a barrier.

Roadside pedestrian barriers are generally high chain-link fences located along a highway or freeway to prevent pedestrians from crossing the road. Pedestrian barriers should be crashworthy designs. For example, top longitudinal pipe cross bracing should not be used on chain-link fence.

Useful guidance may be found in the latest version of the *Uniform Federal Accessibility Standards* (28). Additional guidance may also be found in the *British Standard Specification for Pedestrian Restraint Systems* (29).

10.3 DRAINAGE

On those urban or restricted environment roadways where operating speeds are generally lower, ditches are less of a safety problem to the errant motorist. Where practical, a closed drainage system should be considered. Curbs and drop inlets are common drainage elements in these cases.

Drainage inlets, grates, and similar devices should be placed flush with the ground surface and must be capable of supporting vehicle wheel loads. In addition, slots should be spaced and oriented so they will not be an obstacle to pedestrians or bicyclists.

Even though drainage ditches may be located outside the nominal clear zones in urban or restricted environment areas, there may be a likelihood that errant vehicles that reach the ditch could be led down the ditch and could strike parallel culvert ends at driveways or intersecting roads. Traversable designs should be considered at these locations. Section 3.4.3.2 provides information on traversable designs.

10.4 URBAN WORK ZONES

Construction work zones in urban areas have varying degrees of traffic control and work-zone protection needs. Conditions can vary from low-speed, low-volume urban streets to highway construction zones in high-volume arterial and interstate locations. The type of traffic control under consideration needs to be reviewed for the site conditions, operating speeds, and traffic flows within the construction zone. The *Manual on Uniform Traffic Control Devices* (30) establishes the principles to be observed in traffic control, design, installation, and maintenance of traffic control devices in work zones.

Chapter 9 details a number of available traffic barriers and traffic control devices for work zones. Effective use and implementation of these barriers and devices in urban conditions remains extremely important and must be given full consideration on an individual project basis, including provisions for bicyclists and pedestrians.

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