

CAREC Road Safety Engineering Manual 3

# ROADSIDE HAZARD MANAGEMENT

APRIL 2018

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# Abbreviations



AASHTO	-	American Association of State Highway Transportation Officials
ADB	-	Asian Development Bank
CAM	-	chevron alignment marker
CAREC	-	Central Asia Regional Economic Cooperation (program)
m	-	meter
mm	-	millimeter
km	-	kilometer
MASH	-	Manual for Assessing Safety Hardware
NCHRP	-	National Cooperative Highway Research Program
RRPM	-	raised reflective pavement marker
vpd	-	vehicles per day
WRSB	-	wire rope safety barrier

# Purpose of this Manual



The Central Asia Regional Economic Cooperation (CAREC) countries committed to road safety at the 14th CAREC Ministerial Conference in Mongolia in September 2015. More recently, the CAREC Road Safety Strategy 2017–2030 during the 15th Ministerial Conference in Pakistan in October 2016. The strategy supports and encourages governments and road authorities to plan, design, construct, and maintain roads with road safety as a key and specific objective.

One important, but often forgotten, part of a highway is the roadside. Single-vehicle “run-off-road” crashes are a significant part of most national crash statistics. They are particularly severe, and can occur anywhere and at any time. The severity of these crashes is directly related to the nature of the roadside. It is the responsibility of highway engineers to provide “forgiving” roadsides that can safely accommodate drivers when they make a mistake. Highway agencies across the CAREC region acknowledge this problem, and are keen to build up expertise in this field.

This manual serves as a practical point of reference for roadside hazard management in CAREC countries. The principles contained in this manual are suggested to be adopted in all CAREC road projects. This manual was written to expand the understanding of, and to assist the implementation of, safer roadsides on CAREC roads. This information is essential for highway engineers, planners, designers, audit team members, project managers, and representatives of the client and/or project team. The main topics include:

- identification of roadside hazards;
- investigation of roadside hazards (the roadside hazard management strategy);
- the clear zone concept;
- the three groups of safety barriers; and
- safe treatments for roadside hazards on CAREC highways.

The most important message in this manual concerns the roadside hazard management strategy. Readers are encouraged to embrace the strategy; this manual details the key steps in it and explains how each step can help to improve roadside safety:

- Avoid locating hazardous objects within the clear zone (remove any existing objects).
- Relocate hazards beyond the clear zone to minimize the probability they will be struck by an errant vehicle.
- Redesign (or modify) hazards to reduce their danger. Use devices such as breakaway sign posts to reduce the severity of an impact.
- Shield hazardous objects that cannot be treated in any other way with safety barrier.
- Delineate the hazard and take steps to “keep vehicles on the road.”

This manual was prepared under a technical assistance grant for Enhancing Road Safety for CAREC Countries (TA 8804-REG) from the Asian Development Bank (ADB). The production of this manual was administered and managed by the CAREC Secretariat at ADB. The Secretariat team includes Ko Sakamoto, Oleg Samukhin, Ian Hughes, Charles Melhuish, Pilar Sahilan, and Debbie Gundaya. The principal author of this manual is Phillip Jordan.

# I. An Introduction to Roadside Hazard Management

1. It is well-known and appreciated that the road, together with the road user and the vehicle, plays a key role in the cause of crashes on the roads and highways of the world. The geometric design of new roads and the safe management of traffic on existing roads have been critical safety considerations in global efforts to reduce trauma on roads of the world. These efforts continue today. Safer roads are critical for everyone.

2. An important but often overlooked part of every road is its roadside. In recent decades, more attention has started to be given not only to the safety of the road but also to its roadside. It has been a concern for a long time that too many single vehicle run-off-road crashes have been resulting in too many deaths and serious injuries for road users globally. Indeed, several studies have revealed that run-off-road crashes are not only frequent, but are especially serious. They result in more severe casualties (injuries and deaths) than most other crash types.

3. These crashes have many reasons: driver fatigue, alcohol, speed, inattention, or reactions to other incidents. We can never be quite sure just where, or when, a vehicle will leave a road.

4. Roadside safety is an important but overlooked part of road management in the CAREC region. The task of road safety engineers is to reduce the likelihood a vehicle will leave the road and, if one does, to minimize the consequences of that event. Therefore, engineers and others responsible for managing CAREC highways have an important role to play in reducing single vehicle run-off-road crashes and their consequences. This manual has been prepared to help in this task.

## A. Background to roadside hazard management

5. The roads and highways that connect the CAREC region contain many similarities, but also many differences. Some carry high traffic volumes; some carry few vehicles. Many are high-speed roads; on others, vehicle speeds are low due to geometric

or topographic constraints. Some highways are wide with duplicated carriageways, while some are narrow, single carriageway roads. Some CAREC highways cross deserts, while others pass through mountainous terrain, and many are found in undulating farmland. They experience severe weather conditions that are among the most extreme on the planet. One unfortunate and often fatal common link these roads share is that vehicles sometimes run off them and become involved in single-vehicle run-off-road collisions on roadsides.

6. Vehicles run off a road (and enter the roadside) for many reasons, including:

- driver fatigue (the driver is asleep or almost asleep);
- excessive speed for the conditions;
- driver is under the influence of alcohol or other drugs;
- driver distraction, inattention, or inexperience;
- ice, snow, heavy rain, or other weather conditions;
- a vehicle failure;
- poor geometric design of the road;
- a misleading and poorly delineated road; or
- a sudden change in traffic conditions (such as a vehicle ahead stopping suddenly, or an animal running onto the road unexpectedly).

7. Such incidents are common on CAREC highways as well as on roads and highways the world over. It is not possible to be sure where and when a vehicle will leave a road, but we do know such incidents often lead to severe injuries or death for the vehicle's occupants.

8. When drivers lose control of their vehicles and leave the road, they often collide with unyielding objects (such as trees and poles) or nontraversable features (such as drains, steep side slopes, or rough surfaces) that cause the vehicle to vault (become airborne), roll over, or stop abruptly.

9. Ideally, all roadsides should be free of potentially hazardous features so errant vehicles can be brought under control safely. We use the term "forgiving roadside" for such roadsides. This is a positive term



that means the roadside is free of roadside hazards that may kill or injure road users in errant vehicles that happen to leave the road at that point.

10. The roadsides of most CAREC highways at present are not “forgiving.” Too often, in urban areas, they contain many public utilities or local beautification schemes. On many urban roadsides, there are large poles, rigid light columns, advertising billboards, and trees. On rural roadsides, trees, undrivable side slopes, bridge parapets, and culvert headwalls comprise most of the hazards. On major routes, overpass, and interchange structures, large sign-supporting posts are common roadside hazards. Along CAREC roadsides, there are a multitude of roadside hazards. The photographs in this manual highlight many examples.

11. Identifying, investigating, and treating roadside hazards are significant road safety challenges along CAREC highways.

12. This manual’s readers face the challenge of what to do to reduce the frequency and/or severity of such crashes. For many engineers, their first thought is to install safety barriers. Their only consideration may be the cost. However, as detailed in this manual, other options are often safer and cheaper.

13. These other options are best considered in a careful and logical manner with the guidance of the roadside hazard management strategy. The strategy is an underpinning philosophy of this manual. It provides a clear and simple approach to follow to identify, investigate, and then successfully treat roadside hazards. It will help to reduce road trauma on roads and highways.

14. In addition to explaining the roadside hazard management strategy, this manual demonstrates how to create more forgiving roadsides along the CAREC network. It covers:

- how to identify a roadside hazard via the clear zone concept,
- how best to investigate a roadside hazard by using the roadside hazard management strategy, and
- selecting the most appropriate treatments for the site.

15. This manual also explains the three groups of safety barriers, as well as other useful items of roadside furniture such as slip base and impact-absorbent light columns, crash cushions, and drivable end walls. Although there are relatively few of these devices in use along CAREC highways at present, they will become more common in the future. It is



There are many different types of fixed roadside hazards. (Left to right) Trees, rocks, open drains, poles, piers, undrivable side slopes, culverts, and bridges are just some of the many hazards that exist along CAREC highways. The job of road safety engineers is to design and build safer new highways free of such hazards, as well as to reduce the risk that current hazards present today.

important for everyone responsible for managing CAREC highways to maintain up-to-date knowledge of new and innovative road safety devices that can reduce run-off-road crash severity.

## B. Safe design principles and the “forgiving roadside concept”

16. A well-designed road aims to keep vehicles safely on the road. Safe road design endeavors to provide safe road conditions, including:

- appropriate horizontal and vertical alignments;
- adequate road and lane widths, including sealed shoulders;
- suitable cross fall, as well as super elevation on curves;
- good sight distance;
- provision of appropriate signing, clear pavement markings, and delineation;
- a sound road surface;
- management of traffic conflicts at intersection; and
- appropriate management of vehicle speeds.

17. The fundamental principle for designing safe roadsides is based on the knowledge that drivers (or riders) will make mistakes; occasionally they will lose control of their vehicles and leave the road. We can never be sure exactly where or when this may occur. When a vehicle runs off the road, there is a real risk that it will either roll over or it will crash into a fixed object. Both can lead to severe injuries or death for the occupants (riders).

18. To minimize the consequences if a vehicle runs off the road, it is important to provide a forgiving roadside to minimize the severity of the driver’s mistakes. Safe design principles include provision of forgiving roadsides for occasions when a vehicle runs off the road. Forgiving roadsides are free of rigid poles, drains, structures, and steep slopes. Slopes should be drivable to enable an errant vehicle recover or come to a stop. All aspects of the roadside should be designed to minimize the possibility of an occupant of an errant vehicle being seriously injured or killed.

19. In short, a forgiving roadside forgives a driver for making the error. Our task is to provide the forgiving roadside as one of our main contributions to reducing road trauma.

20. But, to provide a forgiving roadside, we need to understand some basic concepts as well as many technical details. There are some key questions we must answer first, such as what is a roadside hazard and what is a clear zone, before we can move on to the range of effective treatments we can use to reduce this major road safety problem across CAREC highways.

21. This manual is structured into three key chapters: identifying roadside hazards, investigating those roadside hazards, and finally treating the roadside hazards. It has been prepared to give readers a clear and practical introduction to this important road safety issue.

## C. Engineers can make a difference

22. Whatever the cause, when an errant vehicle leaves the road, the occupants need a safe and forgiving area in which to safely recover and stop. Unfortunately, they are more likely to confront a solid pole, a large tree, a deep drain, or a steep slope on many sections of CAREC roads. Any of these can cause death or serious injury to the occupants of an impacting vehicle.

23. Roadside hazards are one of the largest killers on roads of the world. In the CAREC region as roads improve and more highways are built, speeds will increase and the problem of single-vehicle run-off-road crashes is sure to worsen. It is the right time for engineers in the CAREC region to begin to make a positive difference in roadside hazard management.

24. The roadside is an important but often forgotten part of a road. Roadsides provide space for parking, for landscaping, for services, for lighting, and for drainage. Roadsides are a place for natural flora and a home for native fauna. Throughout the CAREC region, however, the roadside is often a place occupied by roadside structures (culverts, bridges), stockpiles of materials, rigid poles, rocks, undrivable side slopes, and deep drains. The roadside is often an area that increases the severity of many run-off-road crashes.

25. Many engineers in recently motorizing countries, including most CAREC countries, underestimate the importance of their work in reducing road crashes. Some of them think crashes are due fully to the faults and mistakes of the driver and/or rider. They believe

the only way to improve road safety is for the police to take a stricter and more effective role in enforcement.

26. These engineers fail to realize that many of the human mistakes made on roads are due to an engineer's failings: a drain that is unnecessarily close to the road, a bridge that has inadequate barrier to shield its end walls, a sharp curve at the base of a steep slope with no delineation.

27. So, the good news is that engineers and other professionals engaged by road authorities across the CAREC region can improve safety of their roads, one small part at a time: by helping drivers (and riders) to avoid run-off-road crashes by providing clear delineation of curves; and helping to minimize the severity of run-off-road crashes by managing speeds, and by installing suitable crash protection, where needed.



A critical side slope (steeper than 1V:3H) increases the risk of rollover crashes. In turn, this increases the risk of serious injury or death for vehicles' occupants.

28. By appreciating that engineers and other professionals have a key role in road safety, and by applying the essential principles contained in this manual (as well as the other manuals in this series), engineers and other professionals can influence the design, construction, operation and maintenance of safer roads, and often at low cost. There are countless opportunities.

29. Engineers and others responsible for managing roads in the CAREC network can make a positive difference to road safety, to save lives and prevent injuries.

A key message underpinning this manual is that engineers have a vital role to play in providing safer roads and roadsides, for all road users in the CAREC region.



Run-off-road crashes are especially serious. They lead to a higher percentage of fatalities and serious injuries than other types of crashes.

## II. Identifying Roadside Hazards

30. The safe management of roadsides is an important responsibility of road authorities. It is becoming an increasingly important task as more efforts are directed toward reducing the cost of road crashes across the world.

31. The first step toward making a roadside safer is to identify the roadside hazards along it. This task requires judgment and experience. One engineer may have a very different opinion from another about what constitutes a roadside hazard. Is every tree on a roadside a hazard? Are bus shelters hazards? Is that bridge parapet a roadside hazard? What about the piers supporting the overpass? Are they hazards too?

32. Government road agencies need to agree on a definition for roadside hazards to ensure they treat the high-risk hazards first. They are responsible for spending public funds in an efficient manner.

33. As a profession, therefore, we need to seek uniformity and consistency in the definition of a roadside hazard. We need to be able to agree on a definition of a roadside hazard before we can move forward to making decisions about how best to treat these hazards.

### A. What is a roadside hazard?

34. A roadside hazard is any feature or object beside the road that may adversely affect the safety of the roadside area should a vehicle leave the road at that point.

35. In our profession, a roadside hazard is more specifically defined as any fixed object with a diameter of 100 millimeters (mm) or more. From this definition, one can easily imagine fixed poles (sign-supporting poles, power poles, lighting columns) and large trees as roadside hazards. But roadside hazards also include other features too, such as large rocks or undrivable side slopes that can cause serious injuries to the occupants of a vehicle that runs off the road.

36. There are two groups of roadside hazards: (i) point hazards, and (ii) continuous hazards.

### 1. Point hazards

37. Point hazards are individual hazards or roadside hazards of limited length. They include:

- trees (over 100 mm diameter),
- bridge end posts,
- large planter tubs,
- monuments,
- landscape features,
- nonbreakaway sign posts (over 100 mm diameter),
- interchange supporting piers,
- driveway headwalls,
- culvert headwalls,
- utility poles (more than 100 mm diameter),
- solid walls, and
- pedestrian overpass piers and/or stairs.

38. An isolated pole, for instance, presents a risk to an errant vehicle. But increasing numbers of poles along that road will increase the risk. An errant vehicle may be lucky enough to miss a single pole, but with more poles comes increased risk that one will be struck.

39. Because of their individual nature and limited length, the preferred treatment for point hazards is to remove them from the clear zone, rather than to shield them with a barrier. Barrier has a minimum length for structural strength (see later in this manual), and using 40 meters (m) or more of steel barrier to shield, say, a pole is not always the most suitable nor safe option.

40. Note that while trees less than 100 mm in diameter within the clear zone are not considered point hazards, still consider their removal from the clear zone, if they are expected to grow to that size or larger in the future.

### 2. Continuous hazards

41. Continuous hazards differ from point hazards in that they extend for a considerable length along a



road. Therefore, it is generally less practical to remove or relocate them. When located within the clear zone, these continuous hazards are roadside hazards. The length of the hazard increases the likelihood an errant vehicle will strike it, and some hazards (such as cliffs) have a high crash severity regardless of the speed of the errant vehicle.

42. Examples of continuous hazards include:

- rows and forests of large trees;
- uncovered longitudinal drains;
- retaining walls;
- steep embankments;
- rock cuttings;
- cliffs;
- areas of water (such as lakes, streams, channels over 0.6 m deep);
- unshielded hazards (such as cliffs) beyond the clear zone, but within reach of an errant vehicle;
- curbs with a vertical face more than 100 mm high on roads with operating speeds above 80 kilometers per hour (km/h); and
- fences with horizontal rails that can spear vehicles.

## B. Clear zone concept

43. A forgiving roadside reduces the consequences for vehicles' occupants of a run-off-road crash. The safety of the roadside area can be maximized by providing a clear area where vehicles can slow down without hitting a fixed object, allowing the driver time to regain control. But how large do we need to make this clear area beside the road? Is a couple of meters acceptable? Or do we need a very wide and clear area? Do we have any figures available to guide us or do we simply guess? What if the road reservation is very constrained, and we simply cannot get any more land?

44. Such questions are common and reflect real issues confronting project managers during the development of road projects. They are best answered by adopting the clear zone concept.

45. The clear zone concept allows engineers to design and provide a drivable roadside area clear of hazards. This concept does not prevent run-off-road crashes, but it reduces their consequences. Safety is maximized by providing a clear area where an errant vehicle can slow down, avoid hitting a fixed object, and where the driver can regain control.



This CAREC highway crosses a large desert. It has wide open and flat roadsides, which provide a good level of roadside safety here. The most obvious safety improvement here would be to include delineation and paved shoulders to keep vehicles on the road.



Although there is much flat roadside, care needs to be taken with man-made structures such as culverts (in the photo) and bridges. We can never be sure where or when a vehicle will leave a road.

46. Because an actual recovery area can be quite large, the concept of a clear zone was developed to define an area which reflects the probability of a severe crash occurring at a site. The clear zone concept and principles provide a risk management approach to prioritize the treatment of roadside hazards at different locations. The clear zone distance provides a balance between a sufficient recovery area for errant vehicles, the cost of providing this area, and the probability of an errant vehicle encountering a roadside hazard.

47. Early studies in the United States found that on high-speed open roads with flat side slopes, 85% of

vehicles could recover within 9 m from the edge of the roadway. In the field of roadside hazard management, we aim to provide a safe roadside for those 85% of vehicles that recover within this width.

48. Of course, this means that 15% of errant vehicles do not recover within that width, and some travel a much greater distance before recovering (or coming to a stop). The width required for recovery of 100% of vehicles is substantially wider. In fact, this width is so wide that it is generally impracticable to achieve. The clear zone concept is, therefore, based on figures for 85% of errant vehicles.

49. However, if a major hazard (such as a high cliff) lies just outside the clear zone, and the certain consequences of an errant vehicle leaving the road are severe, consider protecting all vehicles that may run off the road at that location. That is, act to include the last 15% of road vehicles that would theoretically travel beyond the normal clear zone.

### 1. What is a clear zone and how is it calculated?

50. A clear zone is the area beside a road (measured at right angles from the edge line or the edge of the nearest traffic lane) that needs to be kept free of fixed roadside hazards to give an opportunity for drivers of errant vehicles to recover.

51. The width of the required clear zone should be an early consideration in designing a new road or upgrading an existing one. The required width of the clear zone will also be an important consideration during a road safety audit of an existing road. Knowing the necessary clear zone for an existing highway is an important starting point when investigating a blackspot that features many run-off-road crashes. It is important to know how wide the clear zone should be, to make the right decisions to provide it.

52. The clear zone width for any road (proposed or existing) is determined by a process that considers a range of four key factors:

- **The operating speed of the traffic.** The operating speeds of the traffic will dictate how far off a road an errant vehicle may travel. At 60 km/h, 85% of errant vehicles will recover within 3 m from the edge of the traffic lane but at 100 km/h, 85% of vehicles will require 9 m to recover. Faster equals further.

- **The traffic volume.** A higher volume of traffic results in greater exposure and an increased likelihood that one of those vehicles will run off the road. Thus, the traffic volume factor is a budgetary matter; it requires providing larger clear zones for busier roads. It allows smaller clear zones if traffic volumes are low. For low-traffic roads, with few motorists exposed to a roadside hazard, it is less cost-effective to provide the same clear zone as high-volume roads.
- **The curve radius of the road.** The clear zone is wider on the outside of a curve because errant vehicles travel further off the outside of a curve before recovering. A curve adjustment factor is available to increase the clear zone width as necessary.
- **The steepness of the side slope.** This factor influences how far an out-of-control vehicle will travel from the road. If the side slope is very steep (more than the critical slope), it is not counted as a part of the clear zone. The clear zone must extend beyond the slope, sometimes into neighboring fields. Steep slopes are not drivable, not recoverable, and they increase the risk an errant vehicle will overturn. Overturning crashes often result in serious injuries or fatalities. Adjustment factors are provided for adjusting the clear zone for roadside slope. Steep side slopes need wider clear zones.

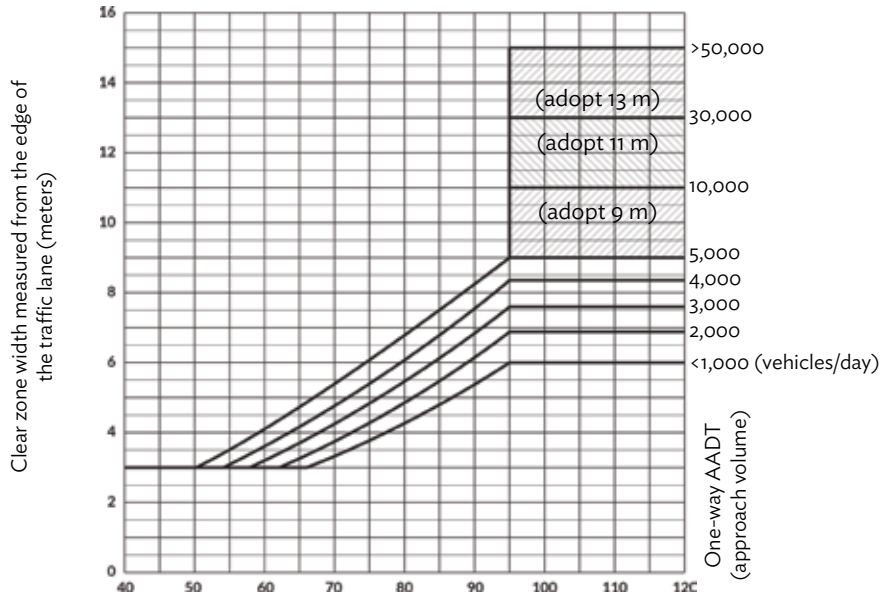
### 2. Calculating the clear zone

53. Figure 1 is used to determine the required basic clear zone required for a straight length of CAREC road. It is based on American Association of State Highway Transportation Officials (AASHTO) guidelines that originated in the 1960s and continue to be revised as required by various leading road authorities.

54. Use this figure to calculate the required clear zone for a road (proposed or new) in a few simple steps:

- Estimate the operating speed of the traffic (the estimated operating speed, not the design speed, and not the speed limit).
- Estimate the daily traffic volume (note that the graph is for one direction flow only; double the figure for a two-lane, two-way highway).
- Take these two figures from Figure 1 to calculate the clear zone.

**Figure 1: Clear Zone for Straight Roads**



Example 1: If the operating speed is 80 km/h and the one-way AADT is 4,000 vehicles/day, the clear zone width is 6 m.

Operating Speed (km/h)

Example 2: If the operating speed is 100km/h and the one-way AADT is 20,000 vehicles/day, the clear zone width is 11 m (adopt range 10,000–30,000 vehicles/day)

AAADT = annual average daily traffic, km/h = kilometer per hour, m = meter.

Source: VicRoads. 2011. *Supplement to Austroads Guide to Road Design – Part 6 (Roadside Design, Safety and Barriers)*. Sydney, Australia.

#### Clear zone example:

The highway is straight, with operating speeds estimated at 80 kilometers per hour, and a one-way traffic volume of 4,000 vehicles per day. Using Figure 1, the required clear zone for the highway is 6 meters.

55. Not all roads and highways are straight. There are factors other than operating speed that affect the distance an errant vehicle will travel from a road. The two most important of these are the horizontal and vertical geometries of the site.

56. An errant vehicle will travel further off the outside of a curve than off a straight due to the inertial

forces involved. An errant vehicle will travel further down a fill slope than on flat ground (or a gentle cut slope) due to gravitational forces.

### 3. Curve adjustments for the clear zone

57. The horizontal alignment of a road (curve) can influence vehicle behavior and the potential for running off the road. The laws of physics will cause an errant vehicle to travel further off a road on the outside of a curve than on a straight. Therefore, the clear zone distance indicated in Figure 1 for straight roads should be adjusted where the part of the road is on a horizontal curve by multiplying the clear zone distance by the appropriate curve correction factor from Figure 2. Multiply the clear zone with this adjustment factor; it will give a wider clear zone, remembering that errant vehicles go further off a road on the outside of curves.

58. The correction only applies to clear zones on the outside of curves. Curves with a radius larger than 1,000 m do not require an adjustment. The curve correction factor is particularly important when crash histories for curves along a highway show that crash potential can be reduced by increasing the clear zone width.

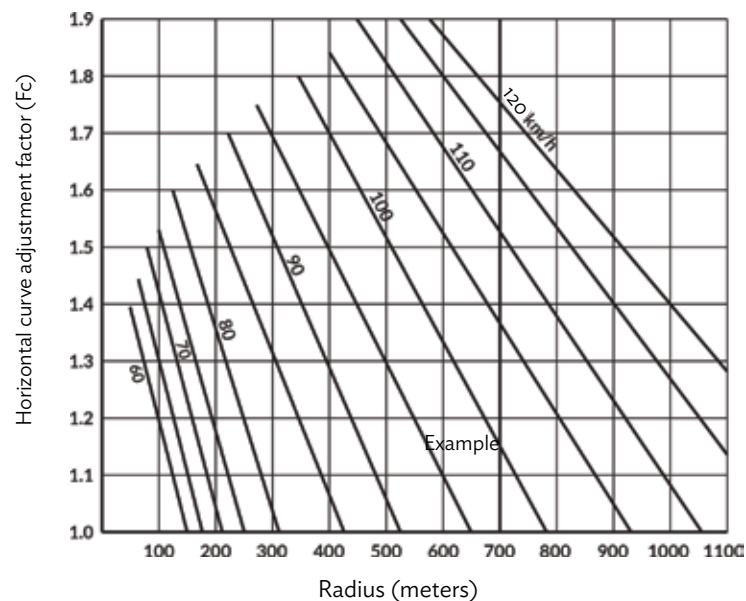
59. Even though the adjustment factor is only applied to the clear zone for the outside of curves, remember that many crashes do involve vehicles running off on the inside of a curve. This is a common form of run-off-road crash. Remember this when looking at blackspots on curves especially if accurate and reliable crash data is not available. Not all run-off-road collisions occur on the outside of curves.

#### 4. Fill slope adjustments for the clear zone

60. Ideally, a safe roadside should be flat, particularly if it is to be traversable for errant vehicles. If a roadside is not flat, an errant vehicle that leaves the roadway may encounter a side slope on a fill embankment, a side slope in a cutting, or a drainage ditch. These geometric features will affect the path of the errant vehicle and the distance it needs to recover.

61. Fill side slopes cause an errant vehicle to travel further from the road before it can be brought under control than do flat side slopes. Fill slopes can be classified as recoverable, nonrecoverable, or critical for errant vehicles. The classification of the slope will affect the clear zone distance required as follows (Figure 2):

Figure 2: Clear Zone Adjustment Factors for Curves



Note: For radii > 1,000 meters use  $F_c = 1.0$

Example:

On a 700 meter radius curve with an operating speed of 100 km/h, the graph suggests an  $F_c$  of 1.15.

$F_c$  = curve correction factor, km/h = kilometer per hour.

Source: AUSTROADS. 2003. *Rural Road Design*. Sydney, Australia.



- Recoverable slopes are traversable and need no adjustment to the clear zone width. Recoverable slopes generally have a slope of 1V:4H or flatter.
- Nonrecoverable fill slopes are slopes steeper than 1V:4H, and flatter than 1V:3H. Most errant vehicles on these slopes will continue to the bottom of the slope, so an errant vehicle recovery area beyond the toe of the nonrecoverable fill slope is required. In these cases, the clear zone distance excludes the width of the nonrecoverable embankment slope. Therefore, the clear zone needs to continue beyond the bottom of the slope.
- Critical fill slopes (which are nonrecoverable slopes) are considered as critical if the slope exceeds 1V:3H. Critical slopes usually cause an errant vehicle to roll over. These slopes need to be flattened or shielded with safety barrier, if the slope is within the clear zone.
- The surface of the fill is also a factor that affects whether a fill slope is traversable or a hazard to errant drivers. The embankment surface must also be relatively smooth, sufficiently compacted, and free of fixed objects. The surface may be relatively even or it may be uneven with low obstacles that can snag a vehicle and cause it to roll over. On sandy roadsides, such as those found along many CAREC highways, the probability of a vehicle overturning is high, even at slopes of less than 1V:3H.
- Slopes can be made more traversable if the top and bottom of the slope are rounded to help an errant vehicle remain in contact with the ground. Many cross-section drawings show a “rounding” of the fill at the road level, but most show nothing at the base of the fill. This location is often close to the edge of the road reserve and is often close to fields. It is easy to forget but rounding the bottom of the slope is a valuable safety treatment.
- The recommended maximum side slope on fill embankments for new road projects in CAREC projects is 1V:6H. Where it is not economically practical to achieve or better this side slope, safety barriers shall be installed on all fill slopes with heights of 2 m or higher.
- In some instances, it may be possible to avoid the need to introduce a safety barrier by constructing a 1V:5H side slope from the edge of the shoulder to the limit of the clear zone, with a steeper

embankment (not exceeding 1V:3H) beyond that point. This option may be preferable and more economical than providing safety barriers.

62. Figure 3 shows the various adjustments to be made to the clear zone when the road is on a fill embankment.

### 5. Applying the clear zone to the site

63. The clear zone concept gives a distance that, experience tells us, will provide an increased level of safety for the occupants of errant vehicles when they do leave the road. If a clear zone is tailor-made for the roads is achieved, injuries and fatalities due to run-off-road crashes will decrease dramatically.

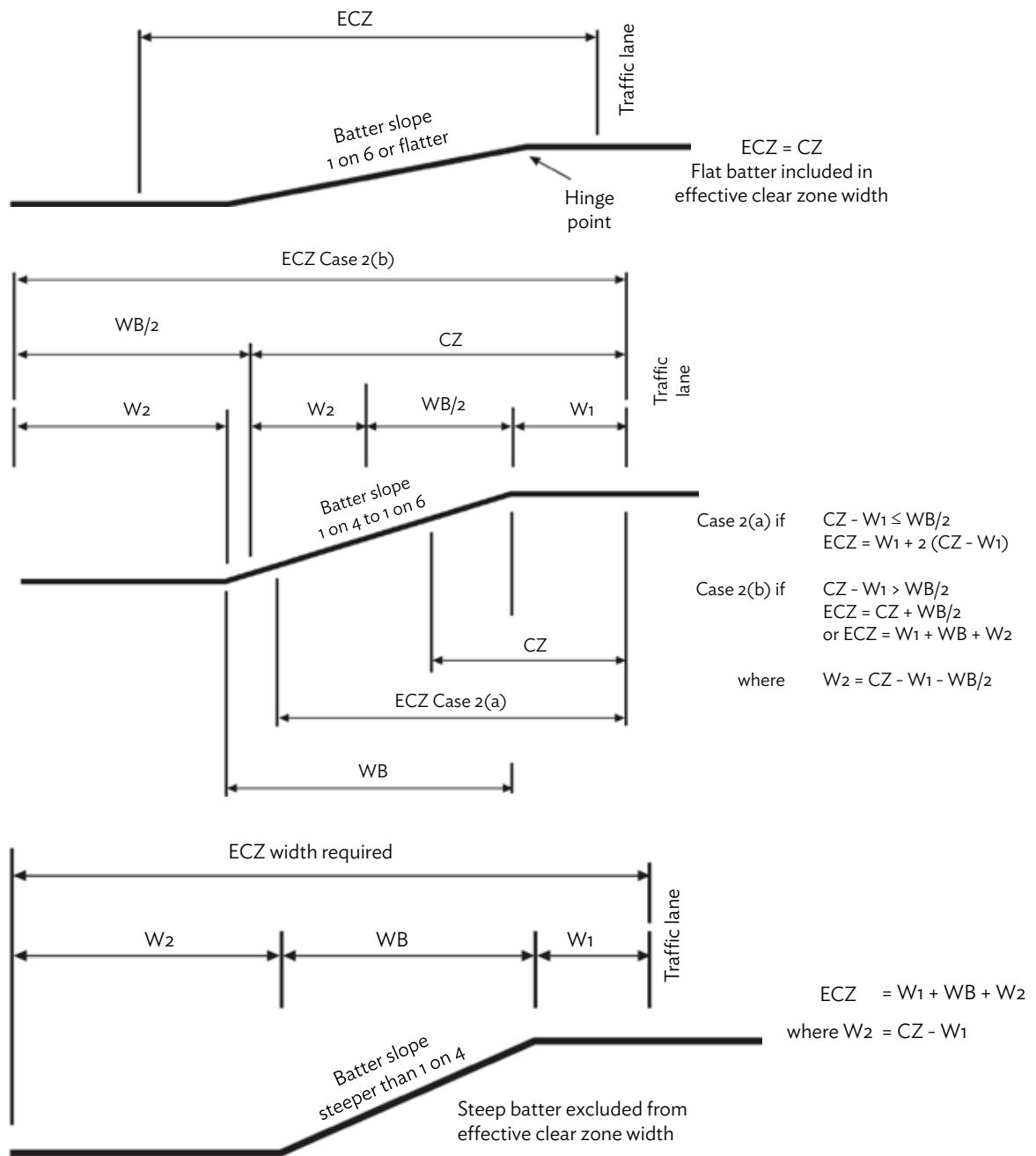
64. How then to apply the clear zone to the site? If the road is (or will be) long, it may have several curves and some steep side slopes along its length. In these cases, work out the required clear zone for each segment of the road.

65. With the set of final clear zone widths, round each one up to the nearest meter for ease of use. This adds a very small safety factor into a system with many variables (such as the mass of the vehicle, its speed, its angle of departure, or the road and soil conditions).

66. Take each clear zone width, and measure it at right angles from the edge line or, if there is no edge line, from the edge of the road pavement. Mark that width in some way that allows standing along the line and visually determining what hazards (fixed hazards, more than 100 mm diameter, or continuous hazards such as concrete lined drains) lie within it.

67. Record those hazards by taking many photographs and/or making digital recordings of observations. Be open to the opportunity to provide wider clear zones wherever possible, particularly for high speed, high-volume roads. There is evidence in research literature that reductions in crashes of all severities can be achieved by extending clear zones to greater distances.

Figure 3: Effects of Side Slopes on Clear Zone Widths



Notes:

1. CZ is the clear zone width determined from Figure 3 adjusted for horizontal curve where necessary.
2. ECZ is the effective clear zone width.
3. W1 is the width from edge of through lane to hinge point.
4. WB is batter width.
5. W2 is width from toe of batter.
6. S is batter slope (m/m).
7. Provide batter rounding to all batter top and toe hinge points.

Source: AUSTRROADS. 2003. *Rural Road Design*. Sydney, Australia.



This side slope is approximately 1V:3H. It is deemed nonrecoverable, and it should not be counted as part of a clear zone. The clear zone here includes the shoulder, the remaining (verge) before the side slope, and some of the flat areas in the field.



An errant vehicle will usually travel further off the road on the outside of a curve such as this. Figure 2 gives adjustment factors for clear zones at curves.

# III. Investigating Roadside Hazards: A Roadside Safety Management Strategy

## A. Investigating roadside hazards

68. Some road authorities have specific programs that address locations with a high number of single-vehicle run-off-road crashes. Using police crash data, these road authorities can accurately determine the locations on their network with run-off-road crashes. In turn they can direct teams to investigate and treat each one.

69. Such programs offer very good returns on the funds spent. Treatments to reduce crash frequency and/or crash severity at these sites are usually low cost (compared with the cost of many other road projects).

70. Two challenges face most CAREC road authorities at present when they begin to address roadside crashes. The first is their difficulty in ascertaining where these run-off-road crashes are occurring. Crash data for some CAREC highways is not accurate enough to identify such locations. Their second difficulty is knowing what is the most appropriate treatment for a location once it has been identified. In most countries, there are not enough engineers with the necessary experience and knowledge in the field of roadside hazard management.

71. As for identifying hazardous locations, that is best addressed by seeking police crash data coupled with local knowledge (from officials or residents) to identify curves and other locations on highways (especially in high-speed rural areas to begin with) that appear to have run-off-road crashes.

72. As for knowing the most appropriate treatment for a run-off-road location, this manual was prepared to assist road authorities and their officers to gain an awareness of the issues involved with roadside hazard management. It offers a clear and practical approach to this topic and is intended to help to build up the technical knowledge needed to make CAREC roadsides safer.

73. Regarding new projects or a road upgrading, generally the earlier in the project cycle a potential hazard is identified, the more likely the hazard can be addressed and the cost considered. In some cases, a change can be made during design, which has no additional cost for the project. Generally, it costs less to change a design drawing than to modify a road feature after it has been constructed. Road safety audit plays an important role in this process.

74. The technical knowledge about how best to treat a roadside hazard can also be applied during road safety audits of the designs of new CAREC highway projects. Road safety audit teams, when trained and experienced, can inject safety into new road designs. They can draw attention to potentially unsafe roadside objects during their audits and can assist design teams to produce safer designs. Applying the clear zone concept to new road designs is taking a positive road safety initiative. Road safety audits can do a lot to prevent unsafe design features from progressing. No one wants to build any more unsafe roadsides.



Being able to identify a roadside hazard, and then knowing what are the best options to treat the hazard, is an important job for highway engineers.



Building up the technical skills to be able to identify, investigate, and treat roadside hazards should be a key responsibility for CAREC road authorities.

## B. Roadside hazard management strategy (a tool to assist decision making)

75. Roadside hazard management is the process that sets out to manage the level of risk on a roadside for the benefit of errant drivers, riders, and passengers. The roadside hazard management strategy aims to address the risks and the consequences of single-vehicle run-off-road crashes. This strategy is a simple step-by-step approach to the most practical treatment for the roadside hazard, depending on costs and practicality.

76. The cost of providing a roadside completely free of hazards is generally prohibitive. In other cases, there may be historic, environmental, or resettlement issues that stand in the way of having a perfectly clear roadside. In some cases, the cost of treating a hazard may be significantly greater than any potential savings from preventing a crash with it.

77. Therefore, we need a strategy to guide us along a consistent and logical path in our decision making. Not all roadside hazards will require the same sort of treatment on every road. Having a clear and logical process followed by all decision makers is a good first step toward investigating and treating the hazards.

78. The five-step roadside hazard management strategy offers five options to treat each identified hazard:

- keep vehicles on the road,
- remove the hazard,
- relocate the hazard,
- modify the hazard, and
- shield the hazard.

Figure 4 shows how this strategy offers a logical step-by-step approach to the treatment of a roadside hazard.

## C. Keeping vehicles on the road

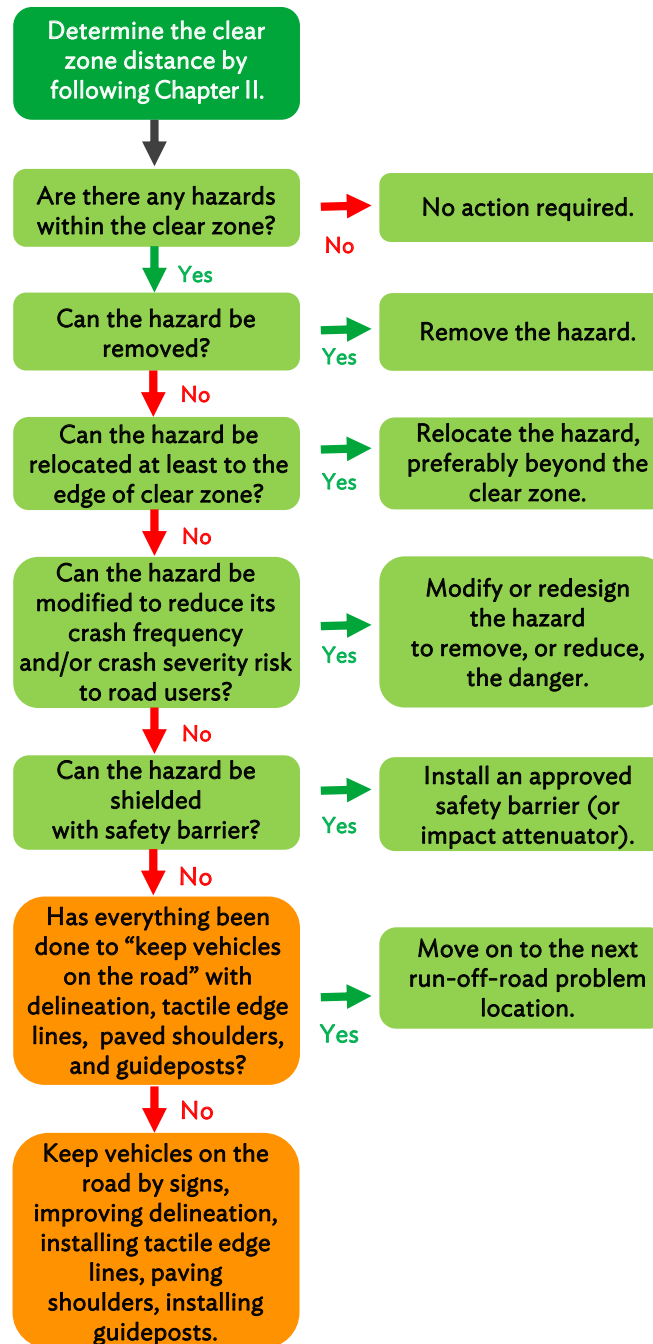
79. The first objective in roadside hazard management is to keep road users safely on the roadway with a reasonable width, a sound road surface, a predictable alignment, and good delineation and signs. The best way to think of this option is to remember that if no vehicle ever leaves the road, there will not be a roadside hazard management problem.

80. This is, essentially, the first and last option in the five-step roadside hazard management strategy. Do all with low-cost options (delineation, chevron alignment markers [CAMs], warning signs, sealed shoulders, tactile edge lines) to keep all vehicles on the road.

81. In some locations, it may be necessary also to ensure that each hazard (particularly trees and poles) is delineated so it can be more easily seen by drivers. Reserve this as the last option; delineating a hazard will likely reduce incidental collisions (sometimes called “innocent hits”), but will be useless to assist the occupants of an errant vehicle that is out of control.

82. Then, after applying the other four steps in the strategy and finding they do not offer a full or appropriate treatment for the hazards, return to this first step as the only viable option that may be open. Recheck to be doubly sure all has been done to keep all the vehicles on the road. Remember that, if all vehicles remain “on the road,” then there will not be a roadside hazard problem.

Figure 4: Flowchart Outlining the Five-Step Roadside Hazard Management Strategy



Source: Roads and Transport Authority of Dubai. 2008. *Roadside Design Guide for Dubai*. Dubai.



## 1. Safe road design

83. The appropriate geometric design and the prudent use of road features can help to keep vehicles on the road. The geometric standard should be based on a realistic assessment of the likely operating speed of a road section considering the road function, the terrain through which the road exists, and the road environment. Some of the road design features that assist in keeping vehicles on the road are summarized below.



One of the best safeguards against single vehicle run-off-road crashes is to ensure that your new roads are designed to the best and latest geometric standards.



Good design alone is not a total guarantee against such crashes. Human error, driver fatigue, and a multitude of other events can lead to crashes. Our work also aims to minimize crash consequences.

### a. Lane widths

84. The width of a traffic lane influences the ease with which vehicles can operate in that lane. Higher traffic volumes and higher speeds warrant wider lanes to allow a greater level of safety relative to oncoming vehicles, as well as clearances relative to roadside features. However, lanes that are too wide can create problems if vehicles form two lanes or if drivers or riders try to overtake by squeezing another vehicle (motorcyclists) to the side.

85. The width of a two-way road is also important to provide adequate clearance to oncoming vehicles. Lane widths of 3.5 m are generally accepted as an optimal width.

### b. Road shoulders

86. Road shoulders have important traffic functions, including:

- a recovery area for errant vehicles;
- a relatively safe area for stopped vehicles;
- a route for pedestrians, bicyclists, or other slow-moving vehicles (separate from faster motor traffic);
- a trafficable area for emergency vehicle use; and
- clearance from roadside hazards.



Sealed (paved) shoulders have many benefits. They provide an area that can be used by bicyclists, motorcyclists, farm vehicles, and slow-moving vehicles that are away from traffic lanes.



Sealed shoulders also provide a place where vehicles can stop in emergencies (to check loads, or during medical emergencies).

87. Good shoulders are especially important in roadside hazard management. The shoulder should be well-maintained and kept at the same level as the roadway, without any rutting or drop-off. This permits vehicles moving onto the shoulder, either deliberately or accidentally, to perform the transition safely. Good maintenance of your highway shoulders also improves the ability of the shoulder to fulfill its structural function to provide lateral support to the road pavement, and to drain water from the edge of the pavement.

88. Sealed (paved) shoulders provide many benefits. They offer substantial and proven reductions in road crashes, particularly run-off-road crashes, as they assist errant vehicles to recover. Studies have indicated that sealed shoulders can reduce casualty crashes on a road by 40%. The width of shoulder sealing will depend on traffic speed, traffic volume, and traffic mix. Ideally, the shoulder should be sealed between 1.5 m and 2.0 m wide. A 2-m wide sealed shoulder allows a motor car to stop on the sealed shoulder just clear of the traffic lane. Sealed shoulders 2.5 m wide allow for larger vehicles (trucks and buses) to stop, if necessary. The sealed shoulder width should be increased up to 3.0 m on high-volume roads, such as expressways, to give an increased lateral clearance from the traffic lane.

### **c. Horizontal alignment and localized curve widening**

89. The careful design of horizontal curves is a key consideration in designing a road to minimize the risk of roadside hazards. For a vehicle to travel around a curve at a certain speed, the horizontal friction

between the vehicle and the road pavement must be sufficient to counteract the inertial force that would maintain the vehicle's initial direction. Therefore, providing a curve radius that is appropriate to the speed environment of the road is an important step in providing a safe road. It is also desirable to have a consistent alignment standard along a section of road with well-designed transitions from generous to tighter alignments.

90. Widening of the road pavement may be required at curves in the road, subject to the curve radius, lane width, and the design vehicle for the road. Localized curve widening is often required for the following reasons:

- Vehicles traveling around a curve, particularly trucks and buses, will occupy more of the lane width than the same vehicle traveling on a straight section of the road. This increased width occupied by these vehicles reduces the clearance between vehicles traveling in opposing directions. Extra lane width at curves maintains an acceptable clearance.
- Vehicles typically do not maintain the same lateral position in a curve as they would on a straight section of the road. This is due to a driver needing to steer into and around the curve. Some deviation from the center of the lane must be expected.

91. For most highway engineers who are responsible for existing CAREC highways, there may be few opportunities to redesign and reshape horizontal curves to reduce run-off-road crashes. At best, you may be able to seal the shoulders through these curves, and strengthen their delineation. However, when new highways are being designed, or when an existing highway is to be upgraded, you should ensure that a road safety audit is carried out at the design stage to ensure safe geometric design. Prevention is better than cure. Ensuring the safe geometry of a highway is one of the essential steps toward improved roadside hazard management.

### **d. Vertical alignment**

92. Vertical alignment is an important consideration in road design and keeping vehicles on the road. A poor vertical road alignment may result in increased vehicle speeds through sags in the road, or poor sight distance on the approach to a crest. These situations can result in a driver losing control and, in turn, running off the road.



93. As a rule, grades should be as flat as possible, subject to the nature of the terrain. Steep grades contribute to excessive speeds or differential speeds for different vehicles, which can create a higher risk of rear-end crashes. Differences in vehicle speeds also contribute to bunching on single lane roads, which may lead to frustration and inappropriate overtaking maneuvers. Reasonably flat grades allow all vehicles sharing a road to travel at the same speed.

94. Steep grades are a problem for heavy vehicles. Auxiliary (climbing) lanes or slow vehicle turnout areas (overtaking bays) are desirable features where long steep grades are unavoidable. Auxiliary (climbing) lanes allow light vehicles to safely overtake slower moving heavy vehicles. In this way, they help to provide less frustration and more considered overtaking on a highway. In very hilly terrain with steep and sharp horizontal and vertical geometries, slow vehicle turnouts allow very slow vehicles to pull over and allow smaller faster vehicles to overtake. Slow vehicle turnouts take up less space, and can be useful to keep traffic moving efficiently and safely.

95. In very steep terrain, the installation of safety ramps and arrester beds can safely bring a runaway vehicle to rest. Safety devices like these should be considered where the terrain permits, particularly along highways that carry a high proportion of heavy vehicles.

#### **e. Sight distance**

96. Highway engineers appreciate the need to provide adequate sight distance to allow all road users to see each other, and to make safe decisions about using or crossing the road. Sight distance is related to design speed for the road and can be affected by the road geometry (horizontal and vertical alignments), the terrain (particularly on the inside of horizontal curves), and roadside objects such as trees and signs.

97. It is important that roadsides are well-maintained to ensure that sight distance requirements are not impacted. This includes cutting grass and trimming trees, especially in sensitive locations near intersections, U-turns, and around curves.

98. Roadside features such as embankments, safety barriers, bus shelters, and vegetation that restrict sight distance may need to be removed or modified to ensure sufficient stopping sight distance on curves. On substandard curves, you may decide it is appropriate

to “bench” high batters to improve sight distance. In some situations with poor sight distance, warning signs may be a final option to inform drivers of some hazards ahead. Signs are a low-cost and necessary treatment, but they cannot always be relied upon to compensate for bad geometry or inadequate sight distance.

#### **f. Road surface**

99. Remember to check your road surface when you are investigating run-off-road crashes. A good road surface needs to be maintained to a safe standard to minimize the risk of vehicles losing control. A good road surface is even, and is free of potholes. It must offer adequate skid resistance to vehicle tires to maintain control during braking or cornering maneuvers.

100. Take care to have your highway surfaces inspected on a regular basis. Visual inspections as well as skid resistance testing (measured on a wet surface) are both desirable on older pavements. Visual inspections should involve regular assessments of the extent of rutting and the occurrence of potholes.

101. The temporary presence of gravel or water on a good road surface is another cause of vehicle skidding, increasing the risk of run-off-road crashes. Gravel and sand should be swept away as soon as they are identified on a road. While they are very real skidding threats to motorcyclists, they present risks to all road users (skidding, dust, broken windscreens).

102. Ponding water can often be a tougher challenge to eliminate. Even a thin layer of water lying on a road surface can lead to a vehicle “aquaplaning.” This term refers to the layer of water between the vehicle tire and road surface leading to a loss of vehicle control. Aquaplaning is generally a greater problem where braking or change of vehicle direction occurs, such as on the approach to an intersection or on a curve. When a vehicle is aquaplaning, run-off-road crashes are a common outcome. Ponding of water over a road surface can sometimes be addressed by clearing out the nearby drains. In severe cases, it may involve an asphalt overlay to reshape the run-off area.

103. Drainage of the road surface and surrounding areas is an important factor for a safe road. Drainage of the road pavement with adequate grade, cross fall, and changes in super elevation is important to ensure that surface water does not remain on the road pavement. Inadequate drainage of water away

from the road can lead to pavement damage and the formation of potholes. These potholes may affect safety because road users will usually act to avoid them. In some extreme cases, they may lose control because of this and run off the road.

## 2. Signs and guideposts

104. The visual guidance of drivers along a highway through delineation and signage is an essential safety aspect of preventing vehicles from running off the road. Signing and delineation are used to provide road users with guidance, information, and knowledge about the road ahead, including:

- changes in road alignment, including curves and the severity of those curves;
- visibility or where it is unsafe to overtake;
- need to slow down or stop at intersections;
- changes to the lane configuration or width of the road; and
- temporary changes to the road conditions, including road works.

105. Such information and guidance become particularly important at night. As well as good design and installation of signs and delineation, regular maintenance of devices is also important to ensure that they are performing as needed for the road conditions. The more important delineators and signs that assist in keeping vehicles on the road are summarized below.

### a. Warning signs

106. Warning signs are used to provide advanced warning for drivers and/or riders of a low-standard section of road or an unexpected change in the road geometry. This may include tight curves, narrower traffic lanes, or an undulating surface. Warning signs may also be used to warn of other potential hazards ahead, such as rough surface, intersections, pedestrian crossings, schools, animals, or side roads.

107. Supplementary signing may also be provided with the warning sign to indicate further information to drivers relating to the severity or nature of the hazard. For example, a curve warning sign may include an advisory speed sign.

108. Note, however, that warning signs should not include a regulatory speed restriction sign as a supplementary plate. Regulatory signs should be kept separate from warning signs.



These warning signs are in good condition. But for driver recognition and response, it is better to place signs on individual posts spaced at least 2 seconds of travel time apart. A two-way traffic sign is critical to remind drivers they are no longer on a divided road.



Warning signs are meant to operate as “advance warning signs” and should be at least 100 meters in advance of the hazard. Too many signs in a cluster will also mean drivers cannot take in all the necessary warnings and information.



This warning sign is useful, but it is a long way out from the curve. On this high-speed road approaching a sweeping curve after a long straight, a series of chevron alignment markers around the curve would give stronger delineation where it is needed.



Warning signs should be specific. The sign alerting drivers to the railway crossing is a practical warning sign. The other is a more general warning sign; it offers little useful information to assist drivers.

### **b. Guideposts**

109. Guideposts are used for delineation to mark the edge of the carriageway. Typically, guideposts are located along the outside edge of the shoulder. They assist the road user by indicating the alignment of the road ahead, especially at horizontal and vertical curves. On narrow or lower-volume roads where there is insufficient road width to mark a centerline, guideposts may be the only form of delineation provided.

110. Concrete guideposts are undesirable as they are hazards to errant vehicles. Narrow flexible guideposts made of timber, sheet metal, or plastic present a lower risk to errant vehicles occupants, particularly motorcyclists, if hit. Guideposts should include retroreflective delineators. Because of this, guideposts provide useful guidance for drivers at night.



Lightweight steel guideposts can provide useful delineation. Large areas of reflective material are an important element of useful guideposts.



All guideposts used on CAREC highways should be forgiving. Plastic, lightweight metal, and timber are suitable materials.



Reinforced concrete guideposts are roadside hazards. They should not be used on CAREC roads.



CAREC highways encounter some tough weather conditions. Guideposts are essential to guide drivers, and to assist them to remain on the road in snow.



### 3. Width markers, hazard markers, and chevron alignment markers

111. Width markers alert drivers to sudden narrowing of the road ahead. Typical hazards where these markers are used include narrow bridges, culverts, and isolated hazards such as structures near or on the road. Width markers are usually black on white, but some countries use a different combination of colors. The most important aspect is the contrast between the two colors. Red and white, black and white, or even dark green and white are common combinations. Each pair offers a strong contrast between the colors. Make sure to use the standard color combination of the country, and use width markers consistently across the network.



Width markers are useful to alert drivers to roadside hazards and squeeze points along a highway. They are most effective when used consistently along a route.



This narrow bridge lacks definition; at night, some drivers may not be aware that the road narrows significantly at the bridge. Width markers on all corners of the bridge would alert drivers of this narrowing.

112. Hazard markers are used to delineate roads, and in particular to alert drivers to curves ahead. They are best used at “short” curves at the end of long straights. For longer curves (that is for curves that continue for some distance), it may be better to delineate the road with chevron alignment markers (CAMs). These are an excellent low-cost form of delineation proven to be particularly beneficial on the outsides of unexpected or substandard curves. Remember to use a minimum of three CAMs on a curve and to reserve them for the most severe curves only. Do not overuse them on generous curves as this can lead to driver disregard for them. Retain them for curves where they are essential.

113. Only use them around the outside of the curve, and always show them for both directions of travel (unless dealing with a one-way road). Follow good practice and ensure your CAMs are installed at standard spacings, at a consistent height above the shoulder, and with consistent offsets from the road.



Chevron alignment markers may be black on yellow, red on white, or a similar color combination. Having a good contrast between the two colors is an important safety requirement.



Hazard markers (of whichever pair of colors) are used to highlight curves and other hazards on the road ahead.



Chevron alignment markers have been proven to assist drivers to safely negotiate substandard curves. Their consistent use across the CAREC highway network is encouraged.



This hazard marker is a standard sign, but it is installed in a nonstandard location. The inside of the curve is not the correct place for such markers. They are to be placed on the outside of curves.

#### 4. Pavement markings

114. Pavement markings provide essential guidance for drivers and riders in relation to road alignment and the position where they should drive or ride within the road space. Pavement markings are particularly useful at night when traffic volumes are lower and other road features may be difficult to see.

115. Pavement markings should preferably be made of thermoplastic material and made reflectorized with glass beads. These retroreflective markings provide superior guidance and visibility of the line for a greater distance. They also require less frequent renewal than ordinary road marking paint.

#### 5. Centerlines

116. Centerlines are marked to separate opposing directions of traffic flow on sealed pavements. They are only used on roads 5.5 m wide or more. On pavements that are narrower than this, centerlines are not usually provided; however, they may be used where sight lines for overtaking are deficient. Centerlines may be of the following types:

- **Separation lines.** On two-lane, two-way roads, these are generally broken lines (similar to lane lines). Separation lines may also be continuous lines on multilane undivided roads, on winding two-lane, two-way roads, or where overtaking is undesirable.
- **Barrier lines.** These are either continuous double lines or a single continuous with a parallel broken line. They are used where overtaking is not permitted. Barrier lines should not be used on pavements of insufficient width where it is not practicable for all vehicles to travel on their side of the line.

#### 6. Edge lines

117. Edge lines are used on the edges of the roadway to delineate the outer edge of the traffic lane. Edge lines provide guidance of the vehicle path within the traffic lane, and discourage travel on the road shoulder. Edge lines are particularly beneficial at night, during adverse weather conditions, and to guide drivers and riders around a curve.

#### 7. Tactile edge line markings

118. Tactile line markings make excellent edge lines. The line includes raised, transverse bars of thermoplastic material at close spacings. This type of edge line provides an audio-tactile warning (sound plus vibration) whenever a vehicle drifts across the line marking. While tactile lines are most commonly used as an edge line, they may also be used as a centerline. Some recent trials of these are showing positive results for helping to keep vehicles from crossing to the wrong side of the road.

119. The purpose of tactile marking is to alert drivers that they are drifting out of their lane, either across the road shoulder or into the oncoming lanes of traffic. Tactile edge lines are beneficial in preventing car crashes related to driver fatigue. The sound generated by these line markings can be easily heard by drivers

inside passenger vehicles. The benefits for the drivers of large vehicles, particularly trucks, may not be quite as good. Other noises may sometimes make it difficult for the driver to hear the noise from the tactile edge line, and physical vibration through the tires and/or the truck body may also mask the effects of the tactile markings.



Tactile edge lines have been proven to reduce run-off-road incidents. They are best used in combination with sealed shoulders.



Tactile edge lines alert fatigued or distracted drivers that they are drifting off the highway.

## 8. Lane lines

120. Lane lines are used on a wide roadway to delineate separate traffic lane for use by vehicles. These lines guide drivers and riders and assist in delineating the path for traffic to prevent orderly movement of traffic, as well as prevent side swipe crashes.

## 9. Other markings

121. Other pavement markings that provide guidance and delineation for drivers include:

- chevron markings approaching a traffic island or an expressway exit;
- diagonal markings on the approach to start of a median;
- painted traffic islands; and
- transverse lines indicating a stop line, a pedestrian crossing, or rumble strips.

## 10. Raised reflective pavement markers

122. Raised reflective pavement markers (RRPMs) may be used in conjunction with road markings to improve guidance at night. They may be used in conjunction with lane lines, centerlines, including barrier lines, edge lines, traffic islands, and median markings. RRPMs provide significant advantages on wet roads. They are generally not obscured by water on the road as retroreflective panels sit above the surface and are more prominent than painted markings. They also provide an audible and tactile indication to drivers and riders when crossed by vehicle wheels. International studies have shown that raised reflective pavement markers can reduce nighttime casualty crashes by 8%. RRPMs are available in several colors, and are often used in the following situations:

- White markers are used to augment lane lines, centerlines, markings at traffic islands, and expressway or toll roads ramp gore areas.
- Yellow markers are used on the median side edge lines of one-way carriageways.
- Red markers are used where necessary to augment right-hand edge lines of two-way and one-way carriageways (for driving on the right).



An example of a unidirectional raised reflective pavement marker

## D. Remove the hazard

123. This step in the strategy seeks to remove all existing roadside objects that are fixed and are 100 mm in diameter or larger within the clear zone. Removing the hazards will not prevent a crash, but it will substantially reduce the consequences of a crash. Fixed roadside hazards injure and kill the occupants of errant vehicles. During impact, they impose enormous forces on the occupants; sometimes, these are so strong that the occupants suffer unforgiving internal injuries.

124. If there are several fixed roadside hazards in one location, try to remove all of them. If this is not possible, perhaps half can be removed, determine what else can be done to make the roadside safer. Remove those hazards? It is always good to eliminate hazards. But what if a safety barrier is installed to shield the remaining hazards? Perhaps all the hazards could have been left and shielded with the same barrier?

125. This is one of the many options that require experience and logic. Whatever happens, keep going back to the roadside hazard management strategy and use it as guidance in every location.

126. To prevent the problem of hazardous objects being created within the clear zone, develop policies that will avoid the placement of new potentially hazardous objects on the roadside. When designing a new road, avoid locating any new hazardous objects within the clear zone.

## E. Relocate the hazard

127. Relocation of hazards to a less vulnerable location will reduce the risk of an errant vehicle hitting them. This may mean relocation to further from the edge of the road or it could mean relocation from the outside of a curve to a location on a straight section of the road.

128. If not possible to totally remove a roadside hazard from the clear zone, the next option is to relocate it beyond the clear zone to minimize the potential for it to be hit by an errant vehicle. Poles,

structures, lighting columns, even drains can be relocated. A relocation of even a few meters will reduce risk, even if it is not possible to place the hazard outside the clear zone.

129. An example of an avoidable new roadside hazard is placing large sign supporting posts in high speed gore areas at expressway exits. Rather than automatically assuming these will be shielded with barrier, look for other locations outside the clear zone so that a hazard is not built in the first place. Relocating the sign gantry at the design stage will be cheaper and safer than having to do this some years later. It will likely save on barrier too.

130. Trees are a hazard that generally cannot be relocated. They are also one of the most common hazards along CAREC highways. As a rule, if a large tree is within the clear zone, there are three choices: remove it (albeit with environmental issues), shield it (with suitable barrier), or do all possible to keep the vehicles on the road at that point. Trees are a hazard that cannot be relocated in any practical way.

## F. Alter the hazard

131. After doing all that can be practically done to keep the vehicles on the road, examining the possible removal of the hazards, and considering options to relocate the hazards, the next step in the strategy is to alter (or redesign) the roadside hazard to reduce its potential for severe injury or death during a crash.

132. This option includes covering drains with drivable covers, replacing rigid posts with frangible (breakaway) posts, flattening side slopes, or installing drivable end walls at driveway crossings. There are many safer roadside devices and furniture now available. Some of these are outlined in Chapter VI of this manual.

133. Altering or modifying a hazard is an option to consider when attempting to improve roadside safety in locations where removal or relocation of a roadside hazard within the clear zone area is not feasible or practicable. Modifying a roadside hazard can reduce the severity of a crash and the potential for serious injury. Common modifications include:



- modifying open longitudinal drains by piping them or covering them with a drivable cover;
- modifying end walls of driveway culverts to make them drivable;
- redesigning rigid sign posts to provide frangible (breakaway) posts;
- designing frangible posts that break away, if struck;
- redesigning rigid street lighting columns to provide frangible columns; and
- flattening a steep fill slope to make it drivable.

134. Longitudinal cut slopes will generally not represent a significant roadside hazard, if kept smooth and free of obstacles. However, they can lead to overturning or “snagging” of a vehicle if the cutting has jagged rocks. In such cases, a cutting may need to be shielded with a suitable barrier.



Covering drains within the clear zone can give a smooth drivable and more forgiving area.



Impact-absorbent poles (such as this one which has been struck) help to minimize injuries to the vehicles' occupants.

## G. Shield the hazard

135. The clear zone should be kept free of fixed roadside hazards. But we know this cannot always be achieved. So, where the earlier steps in the roadside hazard management strategy have been examined without being adopted, we are left with one option: to protect the occupants of errant vehicles from striking the hazards by the installation of safety barriers.

136. Safety barriers are designed to redirect an impacting vehicle and dissipate crash forces in a controlled manner. While it is preferable to remove, relocate, or modify roadside hazards, in some situations, shielding a hazard (with barrier) may be the only practicable option where it is not feasible or economically viable to treat the hazard in other ways.

137. The use of safety barriers requires a good understanding of how barriers work, and what amount of space they need in which to operate correctly, if struck. Barriers cannot be safely fitted to shield all roadside hazards. Chapter V of this manual explains the use of safety barriers, and includes details of such limitations.

138. Safety barriers need to meet appropriate standards to ensure they perform satisfactorily. They must be capable of redirecting errant vehicles and absorbing energy to reduce the severity of a crash to levels that will minimize injury to vehicle occupants. In short, barriers cannot fail when they are needed. The design of safety barriers is based on their ability to perform in a satisfactory manner when impacted by a vehicle.

139. Therefore, care and attention need to be given to selecting the correct barrier and to installing it fully according to the supplier's instructions. A range of factors need to be taken into consideration when selecting and designing safety barriers. These include:

- the need for a barrier (remember that an impact with a safety barrier should be less severe than the impact with the hazard being shielded.);
- the crash performance requirements of the barrier based on the operating speed and the types of vehicles using the road;
- design requirements, including offset from traffic lanes, clearance from the hazard, the slope and condition of the surface in front of the barrier, and any restrictions imposed by vertical or horizontal geometry;



- the length of the barrier required to effectively shield a hazard;
- the type of barrier required;
- terminals for the ends of the barrier so they are not hazardous; and
- maintenance requirements and issues.

140. The three categories of safety barriers are:

- flexible barriers,
- semirigid barriers, and
- rigid barriers.

141. Each has various benefits and constraints that make them suitable for some locations, but unsuitable for others. Engineers need to understand the benefits as well as the limitations of each group of barrier to avoid wasting resources or, worse, installing unsafe barriers.



Flexible barriers (wire rope safety barriers) are a proven and safe type of barrier. They can deflect by 2 meters (or more) when struck.



Semirigid barriers (guardrail) are perhaps the most common type of barrier along CAREC highways. They typically deflect by up to 1 meter when struck.



Rigid barriers (concrete) do not deflect, and are well suited where width is limited and deflections cannot be tolerated.

Note: If used around a curve, a safety barrier should only be installed because it is the sole remaining option for reducing crash severity on that curve. A safety barrier shall not be used solely to delineate a curve. There are better, safer, and cheaper options for delineating curves. Use those.

## 1. Flexible barriers

142. Flexible wire rope safety barrier (WRSB) systems use tensioned cables to restrain and redirect an errant vehicle. WRSBs consist of several tensioned wire ropes (generally three or four), held in place by anchorages at each end and supported at the necessary height by steel posts at spacings of between 2 m and 3.5 m. The wire ropes deflect when struck by an errant vehicle and absorb the energy of the vehicle, causing it to slow down. The wire ropes guide the vehicle along the barrier while the posts progressively collapse when struck. The errant vehicle is redirected back in the direction of travel or slowed to a stop as it travels along the cables. The installation height varies depending on the system, the upper cable typically being between 580 mm and 720 mm above surface level.

143. WRSBs are the most forgiving of the barrier systems. They provide a lower injury risk to vehicles' occupants due to the relatively low deceleration they cause for the impacting vehicle compared with rigid and semirigid barriers. Compared with other barrier types, WRSBs also cause the least damage to vehicles. However, they require more space behind them for deflection when struck. Maximum deflections of

flexible barriers during impacts at 100 km/h may be up to 3 m. Therefore, these barriers need much more space than either semirigid or rigid barriers.



There are several approved wire rope safety barriers in use. They are the most forgiving of the three groups of barriers.



In designing a wire rope safety barrier system, always remember to provide adequate offset between the barrier and the hazard to accommodate the barrier deflection. Flexible barriers can deflect by 2 meters or more.

144. The actual amount of deflection depends on post spacing, the speed and angle of impact, and the mass of the impacting vehicle. Typical post spacings are between 2.5 m and 3.2 m. The closer the posts, the less the barrier will deflect. Reduced post spacing may be used where it is necessary to limit the deflection of the barrier due to the proximity of hazards.

145. As flexible barriers consist of tensioned cables, the horizontal and vertical alignment of the roadside can limit their use. The minimum allowable horizontal

radius for WRSB installations is usually 200 m, or the manufacturer's recommended minimum radius. There are limitations on the use of these barriers on sag curves as the cables may lift between anchors with increased tension. There are no limitations for crest curves.

146. WRSB returns to its original position after most impacts. Damaged posts are easily replaced from their plastic sleeves in the concrete foundations. The open design also prevents accumulation of drifting sand or snow, both of which can be issues in some CAREC countries.

147. WRSB systems are proprietary products and must be installed and maintained in accordance with the manufacturers' detailed drawings, specifications, and maintenance instructions. It is recommended to seek specific details from individual product suppliers. Most, but not all, WRSB products meet National Cooperative Highway Research Program (NCHRP) Report 350 evaluation criteria for TL-3.

## 2. Semirigid barriers

148. Semirigid barriers incorporate a steel rail mounted on galvanized steel channel posts. Other types of posts (such as timber or concrete) should only be considered if crash testing has proven them to perform satisfactorily.



Semirigid barriers have been widely used for decades. They deflect by up to 1 meter when struck. Therefore, they should be at least 1 meter from the hazard they are shielding, and offset by (at least) 4 meters from the road (if the cross-section permits) to allow safe stopping.



What is unsafe with this installation? The rails overlap in the wrong way. If struck here, the closest rail will be pushed away from the road, and the next will be exposed to spear through the impacting vehicle. The concrete posts are also unlikely to offer enough deflection to absorb impact energy. This could cause the occupants of the errant vehicle to be decelerated too rapidly, and they would likely suffer more serious injuries.

### 3. Rigid barriers

149. Rigid safety barriers are essentially reinforced concrete walls constructed to a profile and height are suitable to contain and redirect errant vehicles. Rigid systems offer no or little deflection on impact. Therefore, these barriers are used at locations where there is limited scope for barrier deflection (such as separating expressway carriageways or shielding overpass piers). The vehicle entirely absorbs the impact energy. Therefore, they should be used only where impact angles are likely to be low (ideally less than 15 degrees) to limit the injury severity of any crashes. Concrete barriers must not be located more than 4 m from the edge of the nearest traffic lane as greater distances increase the risk of higher angle impacts with the barrier.

### 4. Roadside devices that are not approved safety barriers

150. There are many devices in use along many CAREC highways that some people may think are safety barriers. Many of these devices have been in place for a long time, maybe decades. However, most are not approved barriers; they are a form of delineation at best, and roadside hazards at worst. Inspect the highways and critically review the devices, posts, and fences along them. Remove the hazardous devices and decide if the highway needs delineation (in which case, use forgiving reflective delineators) or shielding (with an approved barrier). The following

photographs show a sample of such objects. They are unsafe; if struck by an errant vehicle, they will likely cause more damage and more severe injuries.



These cables are not tensioned, and will not redirect an impacting vehicle. The posts are unforgiving and will lead to significant damage if struck.



Despite being a “standard” bridge, the concrete barrier offers an unsafe blunt end to approaching vehicles.



The posts of approved flexible barriers are designed to yield when struck. The posts of this barrier appear too large and rigid to perform in this manner. This barrier does not appear capable of meeting international standards for wire rope safety barrier.





Concrete blocks and concrete barriers like these are roadside hazards. At best, they offer limited delineation only.



Individual concrete barricades like these may be able to prevent illegal turns, but they are hazardous, especially if struck on their exposed ends.



Bridge railings must be strong enough to contain an impacting vehicle. Light gauge rails, such as this, are not strong enough for this task. The low concrete barrier is another hazard.

# IV. Treating (Eliminating or Reducing) Roadside Hazards

151. There are many ways to safely and effectively treat the countless roadside hazards along CAREC roads and highways. Indeed, there are too many options to try to outline all of them in this manual. Instead, the following case studies outline how to treat roadside hazards. They detail the decision-making process that comes from the roadside hazard management strategy, and they offer some common treatments.

## A. Case study 1: treating roadside hazards in hilly terrain

152. A section of rural highway 12 kilometers (km) in length is in hilly terrain with operating speeds around 80 km/h and volumes around 2,000 vehicles per day (vpd) (one way). Figure 2 indicates a clear zone of 5 m is required for straight sections. The highway has many run-off-road crashes. Trees, rocks, and undrivable side slopes exist within the clear zone. Inspect the highway and make practical recommendations to reduce these crashes.



The highway is a two-lane, two-way highway passing through hilly terrain. It has generous geometry but it has numerous roadside hazards along its length.

153. Inspect the highway, day and night, noting the roadside hazards. Note that the line marking is worn out, there is almost no delineation of the horizontal curves, and there is no barrier along the highway.



Operating speeds are around 80 kilometers per hour. Volumes are almost 4,000 vehicles per day (total both directions). The highway lacks delineation. Many of the single-vehicle crashes occurred at night.

154. Using the five-step roadside hazard management strategy, consider:

- **Keep the vehicles on the road.** Decide that the highway needs to have all line marking renewed, and essential delineation installed around the sharpest curves.
- **Hazard removal.** It is obvious this is not an option for this highway as the most significant hazards are the undrivable side slopes and the large rocks. These cannot easily be removed for cost and environmental reasons.
- **Hazard relocation.** As with hazard removal, this is not viable.
- **Modify the roadside hazards.** Consider flattening the side slopes but this will have serious environmental impacts. It will also be expensive. Decide if this option is not viable.
- **Shield the hazard.** In this case, with a limited offset available in which to install barrier, decide whether to install W beam guardrail at the most hazardous locations. Flexible barrier would deflect too much for the available offsets.

### 1. Package of treatments

- Line marking – white thermoplastic centerline and a tactile edge line for the full length of the highway.
- Shoulder sealing (up to 1.5 m) around the inside and outside of those curves with a radius of less than

100 m. Installation of CAMs around the outside of these curves to face traffic from both directions.

- W beam barrier to shield undrivable side slopes (steeper than 1:4) on the outside of these same curves. The barrier is to be offset from the traffic lane by a minimum 2 m, and the shoulder is to be sealed to the underside of the barrier. Minimum lengths of barrier shall be 50 m, plus terminals.

## B. Case study 2: rehabilitation of a rural highway

155. A rural two-lane, two-way highway in flat terrain is to be rehabilitated. Serious damage to the road has led to many crashes, including many run-off-road crashes. The section to be rehabilitated is almost 55 km in length, and includes one large bridge, three short bridges, and more than 20 culverts with headwalls. Give recommendations to the design team on how best to reduce roadside hazard risk along the rehabilitated highway.



This 55-kilometer length of rural highway is to be rehabilitated. It has had many run-off-road crashes.



There are three small bridges (like this), a larger bridge, and 20 culverts in the 55-kilometer length to be rehabilitated.

156. Talk with the design team about the design parameters they are using (cross-sectional width, design speed, standards). There will be 1 m sealed shoulders on each side of the highway, plus two 3.5 m wide lanes. They expect operating speeds on the rehabilitated highway will be around 100 km/h. Traffic volumes will be just under 6,000 vpd (one way). You inspect the existing highway. Noting the existing roadside hazards, calculate the required clear zone for straight sections of the highway (9 m). Then work through the five-step roadside hazard management strategy:

- **Keep the vehicles on the road.** Write a memo to the design team to ensure they will renew all line marking and delineate all sharp curves in their design.
- **Hazard removal.** There are 10 trees (larger than 100 mm diameter) that are within the 9 m clear zone plus an old bus shelter. Recommend these for removal, but the most common hazards along the highway will be the culverts and the bridges. These cannot be removed.
- **Hazard relocation.** This is not viable. Then consider how to modify the roadside hazards. Consider widening the bridges so the bridge parapets are outside the 9 m clear zone, but the expense would be great. Decide to recommend that the 1 m shoulder be continued across each bridge, and W beam barrier be installed to shield all bridge parapets. Make a note to be sure to specify how to safely and securely connect the W beam barrier to the bridge parapets. A reflective width marker is to delineate each parapet of each bridge.
- **Hazard modification.** This may be an option for drivable culvert end walls, or recommend to shield each culvert with barrier. Three culverts will be located close to lengths of the proposed barrier. Recommend these sections of barrier be extended (about 25 m each) to shield the culverts. Recommend the remaining culverts be constructed with drivable end walls.
- **Shield the hazard.** The bridges require barrier to shield the parapets as well as the critical side slopes on each approach.

### 1. Recommendations to the design team

- Line marking – white thermoplastic center line and tactile edge lines over the full length of highway.
- Install CAMs on curves (radius less than 100 m) for both directions.

- Install reflective plastic guideposts at regular spacings along the full length of highway.
- Install W beam barrier to shield all bridge parapets as well as the side slopes leading onto them. A total of 1,400 m of barrier is estimated for the four bridges. Specify clearly that the barrier is to be stiffened as it approaches each bridge to prevent pocketing.
- Install four reflective width markers at each bridge parapet (total 16 markers).
- Extend W beam barrier by approximately 25 m to shield three culverts (total  $25 \times 2 \times 3 = 150$  m).

### C. Case study 3: reducing run-off-road crashes

157. A rural highway in rolling desert terrain has been open to traffic for less than 2 years. It is lightly trafficked but speeds are high (at least 100 km/h), and there has been a recent spate of run-off-road crashes that happened mostly at nighttime. The highway is a four-lane divided road with a 20 m wide median. There are few roadside hazards other than culverts, but the highway is on fill and the grades of some side slopes have been questioned.



The highway has been designed to high geometric standards. The median has been graded for natural drainage in the desert environment.



The pavement encourages high speeds, but there is little to assist, guide, inform, warn, or control drivers.

158. The local police joins on an inspection of this highway. They outline their knowledge of the crashes. Note that the line marking has not been installed even though this road has been open to traffic for 2 years. There is no delineation of horizontal curves. There are a few short lengths of barrier along the highway, generally at the steeper roadsides and some culverts.

159. With the police, conclude the crashes may be mainly due to driver fatigue and inattention. The highway joins two major cities about 450 km apart, and this section is about midway between the two. Driver fatigue is likely. Work through the five-step roadside hazard management strategy:

- **Keep the vehicles on the road.** Decide the highway needs line marking and essential delineation.
- **Hazard removal.** The most significant hazard is the undrivable sandy side slopes. These can be flattened, but this work will take time and will be expensive.
- **Hazard relocation.** This is not an option.
- **Modify the roadside hazards.** As above, determine whether to flatten the side slopes. Keep this option open while considering if other treatments are possible.
- **Shield the hazard.** With a generally wide and open roadside, the use of barrier is a possibility. A flexible WRSB could be an option; there is adequate space for it. But on balance, decide to monitor other improvements before taking this expensive step.



## 1. Package of treatments

- Line marking – white thermoplastic lane line and a tactile edge line on the full length of both carriageways.
- Install plastic guideposts on the outside of the shoulder at standard spacings.
- Shoulder sealing (up to 1.5 m) around the outside of all curves with a reported crash history, or a radius that is less than half of its neighboring curves.
- Install several (minimum three) CAMs around the outside of these curves (for both directions).
- Monitor. If crashes continue, some slope flattening and/or installation of WRSB should be discussed and agreed on.

## D. Case study 4: upgrade of an urban interchange

160. An urban interchange is to be widened and improved to provide increased traffic capacity. Think and act as part of the design team for this significant road project. Traffic volumes are very high, and the current operating speeds are typically 80 km/h. The existing interchange has several overpass piers, large direction signs on large supporting posts, and rigid light columns. The road project offers an opportunity to reduce these hazards and to build roadside safety into the new layout.



There is a desire to ensure the new interchange offers increased traffic capacity as well as improved roadside hazard management, compared with the present arrangements.



Some hazards in the existing interchange are shielded, but there are others plus some likely new ones that must be addressed. Roadside safety can be improved (at little cost), if hazards are addressed during the design stage.

161. There will be 1 m sealed inner shoulders, 3 m sealed outer shoulders, and three 3.5 m wide lanes for each carriageway. The operating speed will be 100 km/h. The existing and predicted traffic volumes will be more than 35,000 vpd (one way).

162. Calculate the required clear zone for highway to be 13 m. Working through the five-step roadside hazard management strategy, consider:

- **Keep the vehicles on the road.** Check with the design team that they intend to provide all line markings, and they will delineate the sharper curves.
- **Hazard removal.** There are expected to be up to 40 steel lighting columns (larger than 100 mm diameter), overpass piers, and eight sign gantries in the interchange. Recommend that all be placed outside the clear zone. The design team responds that this is not practical, except for four sign gantries that can be relocated behind some proposed W beam barrier sections.
- **Hazard relocation.** Again, this is not viable except for half of the sign gantries.
- **Modify the roadside hazards.** This is not a consideration for the piers, but it may be an option for the lighting columns and the sign gantries. Recommend that the shoulders be continued full width through the interchange, and slip base lighting columns be used. The eight sign gantries are too large to be modified; shielding is the only option for them.



- **Shield the hazard.** Rigid barrier to surround the overpass piers is an option. The end of this will need shielding; crash cushions, while expensive, are the safest system. W beam barrier will be needed to shield the sign gantries.
- Relocate four sign gantries to locations behind existing barrier.
- Install up to 400 m of new W beam safety barrier to shield the other four sign gantries.
- Adopt slip based lighting columns throughout the interchange.

### **1. Recommendations to the design team**

- Use rigid barrier to shield the overpass supporting piers. Pay attention to the working width required at the piers (Chapter V.C.11). Shield the approach ends of each barrier with an approved crash cushion.

# V. Using Safety Barriers Correctly

163. In the designs for some new roads, and when improving some existing roads, fixed hazards (such as bridge parapets, supporting piers, or trees with environmental significance) cannot always be avoided within the clear zone. In these situations, after working through the roadside hazard management strategy (delineate, remove, relocate, and modify), the last option is to shield the hazard.

164. Safety barriers improve roadside safety when hazards in the clear zone cannot be removed, relocated, or modified. Safety barriers are designed to safely redirect errant vehicles with reduced injury to vehicle occupants. When compared with impacting a hazardous fixed object, properly designed safety barriers are proven to greatly reduce trauma in a crash.

165. However, when considering whether to install a safety barrier, it is important to understand that the barrier itself will present a hazard to occupants of errant vehicles, and especially to unprotected road users such as motorcyclists. A safety barrier should only be installed if a crash into the barrier will present less of an injury risk to vehicles' occupants than would result from a crash involving the hazard that is to be shielded. Therefore, the installation of a safety barrier should be the last option in roadside hazard management, not your first.

166. Investment in safety barriers is unusual compared with most other road infrastructure. The life expectancy of a safety barrier can be up to 50 years, and yet it may be in use for only a few seconds during that time. Be sure it works correctly and safely then. And, after that, it needs to be repaired, so a good maintenance regime should be an important concern of the highway agency.

## A. Three groups of safety barriers

167. The three main groups of roadside safety barriers are:

- flexible barriers (commonly these are WRSBs);
- semirigid barriers (common semirigid barrier systems include W beam guardrail, box beam, and thrie beam);

- rigid barriers (made of reinforced concrete; there are several profiles).

### 1. Flexible barriers

168. The best-known type of flexible barrier, WRSBs are (usually) made of four tensioned wire ropes supported by steel posts (see Figure 5). They are described as flexible because they stretch and absorb the force of the impacting vehicle. The barriers use a dual mechanism to slow down and divert excessive force away from the people inside the vehicle. The ropes deflect and absorb the energy, while the posts collapse, slowing down and redirecting the vehicle away from the hazard with little rebound. Flexible barriers are the most forgiving barrier type, usually allowing the occupants to simply walk away from their crash. Current experience is showing flexible barriers are safer than other available safety barriers.

169. Research conducted by the Monash University Accident Research Centre in Melbourne, Australia shows that flexible barriers are superior to rigid (concrete) barriers and semirigid (steel W beam) barriers because of the way they dissipate the energy of the crash away from the occupants of the vehicle, their deflection levels, and the way they contain the vehicle.

170. WRSB is now considered so successful in reducing the consequences of single vehicle run-off-road crashes in several countries (Australia, New Zealand, Sweden, and the United States) that center line WRSBs are now being introduced. These center line WRSBs are specifically used for, and are proven effective, at preventing head-on crashes.

171. Flexible barrier systems are characterized by relatively high deflections upon impact, which dissipates the energy of a crash. This behavior results in lower injury risk to vehicles' occupants in comparison with rigid and semirigid barrier systems. Flexible barriers display good control of vehicle trajectories after impact, which assists in redirecting an errant vehicle to a path along the line of the barrier. This minimizes the likelihood of secondary impacts with other vehicles.



The use of flexible safety barrier along the centerline is becoming a proven method of reducing head-on collisions along two-lane, two-way rural highways, or on wide four-lane highways such as this.



Centerline barrier is designed to prevent head-on collisions. It is proving to be beneficial in reducing the risk of these crashes.

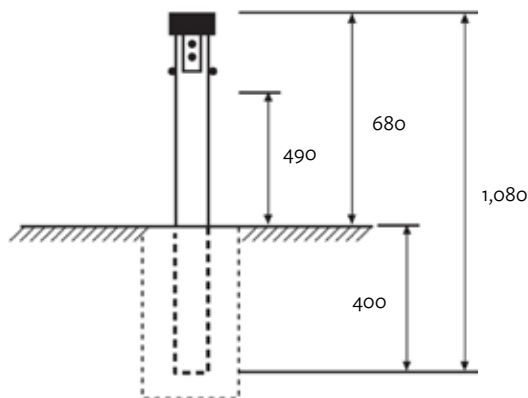


There are several flexible barrier types available. Whichever one chosen, make sure it is an approved type tested by a major standards agency.

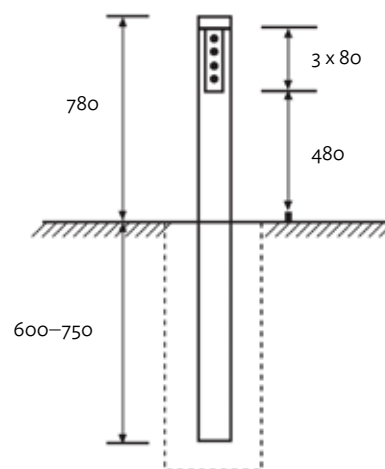


Flexible barriers deflect by a great deal when struck. Locating the barrier off the road, but also offset from the hazard by an approved distance, is an essential design consideration to avoid "pocketing."

**Figure 5: Two Typical Forms of Wire Rope Safety Barrier**



This four-cable system features two intertwined cables and a height of approximately 700 millimeters. Use only approved barriers, and seek the manufacturer's advice about installation standards.



This four-cable system has no intertwining of the cables. It is a little higher than the other system at 780 millimeters.

Source: VicRoads. 2016. Road Safety Engineering Workshop handouts.

172. The offset from the nearest traffic lane should be as generous as can be realistically provided. The ability of a vehicle to stop clear of the traffic lane (for a breakdown, to repair a tire, or for other reasons) is an important factor in the provision of a wide clearance from traffic lane to barrier. It is desirable for the WRSB to be offset from the edge of the nearest traffic lane as follows:

- Desirable minimum offset is 4 m to provide a comfortable width for a vehicle to stop clear of the traffic lane and barrier. This offset also provides a recovery area between the traffic lane and barrier for errant vehicles.
- Minimum offset is 3 m to provide an adequate width for a vehicle to stop clear of the traffic lane and barrier.
- Absolute minimum offset is any offset between 1 m and 3 m. Offsets in this range should be only for short lengths and will usually require highway authority approval.

173. It is desirable to locate flexible safety barriers as far from the edge of the traffic lane as site conditions permit. This will maximize the chance of the driver being able to regain control of the vehicle before impacting the barrier. Nuisance impacts on WRSB systems can be costly for the road authority as their flexible nature allows for greater damage during minor impacts. This can require frequent repair. Remember there is no restriction on the maximum offset of a WRSB from the edge of pavement.

174. The WRSB is to be an approved type, and correctly designed and installed. Due to the higher deflection of the WRSBs relative to other barrier systems, it is important to consider the offset to the hazards to be shielded behind a WRSB (see Table 1).

**Table 1: Approximate Deflection of Wire Rope Safety Barrier**

Post Spacing (m)	Approximate Deflection (m)
1.0	1.5
2.0	2.0
2.5	2.5
3.0	2.7
5.0	3.4

m = meter.

Source: Federal Highway Administration. 1993. *National Cooperative Highway Research Program*. Washington, DC.

- WRSBs may be installed on flat ground or on side slopes up to 1V:10H. The maximum lateral slope also applies to the area immediately behind the barrier over which the barrier will deflect, if impacted by a vehicle.
- Generally, a WRSB is not suitable for installation on curves that have a horizontal radius of less than 200 m, as the required rope tension and height may not be maintained during or after an impact. Radii smaller than 200 m have problems with posts being pulled over when the wire rope is tensioned; 200 m is the minimum radius that has been crash-tested.
- WRSBs should generally not be installed on sag vertical curves where the K value is less than 30. With a vertical curve of this size, the wire rope tension may cause the posts at the bottom of the vertical curve to lift out of their sockets. Other concerns are that the errant vehicle may pass beneath the cables, rather than being captured, or that the errant vehicle may become suspended by the tensioned cables at the bottom of dip.
- WRSBs should not be connected directly to semirigid or rigid barriers, including bridge parapets. This is due to a possible vehicle impact with the more rigid barrier (“pocketing”) as an impacting vehicle runs along the deflecting barrier. However, when transitioning to another barrier type, WRSBs may be installed near other barriers with overlapping of barriers to ensure continuity to the next barrier system.
- The minimum length of a WRSB should generally not be less than 24 m at full height or as specified by the manufacturer. The transition length to the end terminal anchors is additional to this minimum length.

## 2. Semirigid barriers

175. Semirigid safety barriers are (mainly) systems that have a steel beam attached to either wooden or steel posts. Semirigid barriers deform or deflect upon impact but to a lesser extent than flexible systems. When struck by an errant vehicle, the support posts bend and the barrier rail deforms to absorb the force of the impact. The tensile forces developed in the barrier rail assist in redirecting the impacting vehicle.

176. The term “semirigid” was coined because these barriers absorb energy by deflecting during an impact. The maximum amount of deflection is approximately 1 m, about half that of a WRSB. Therefore, they are

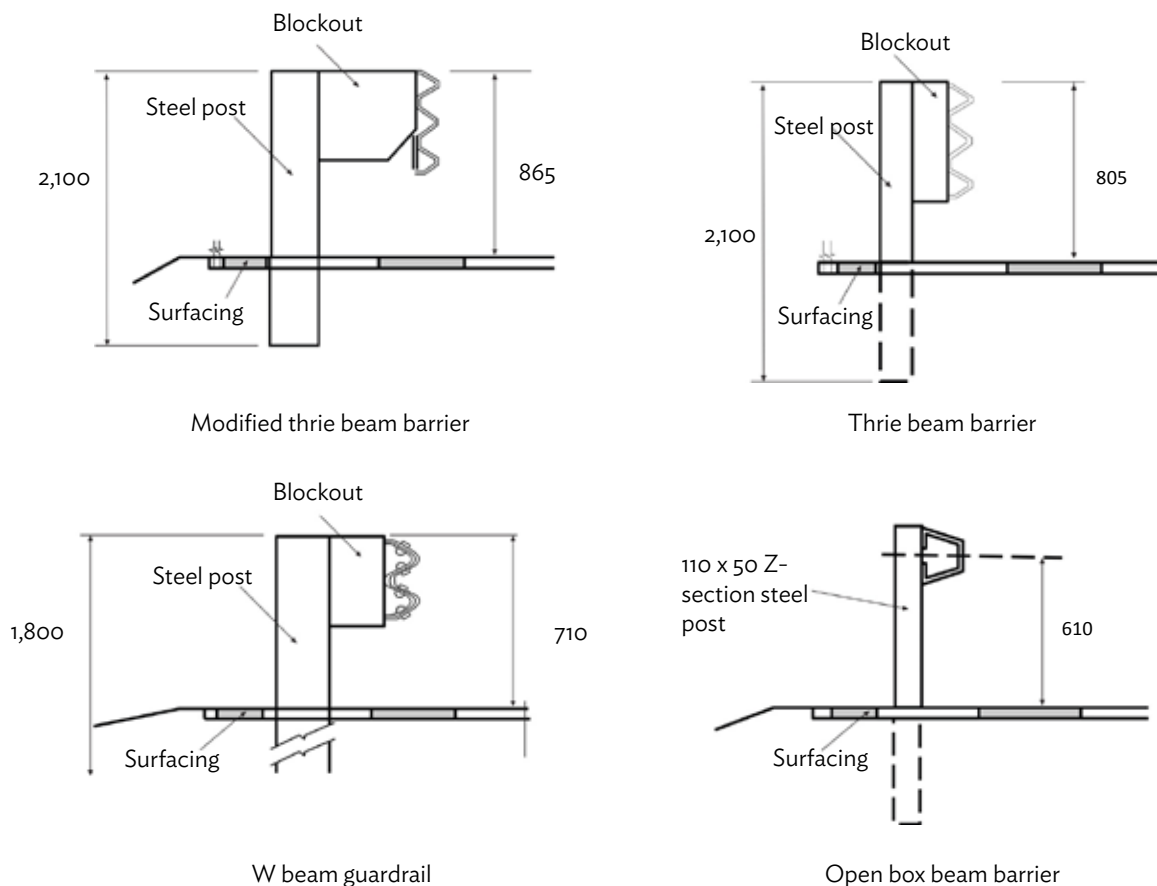
more suited than a WRSB to locations where the hazard to be shielded is close to the roadway, or there is limited space within the roadside (see Figure 6).

177. The most common semirigid barrier is the W beam guardrail. Where a stiffer barrier is required, thrie beam (with two indentations) may be used.

178. When struck, a properly installed W beam barrier will behave as follows:

- The W beam first bends and then flattens out, forming a wide tension band to contain the errant vehicle.
- The posts are initially restrained by passive pressure in the soil, resulting in local failure of the soil at ground level and for a short depth below.
- Wooden posts (if used) rotate. Their point of rotation is some distance below the ground.
- Steel posts (if used) partly rotate, but also bend near the ground line.
- Deflection of the posts and the blockouts cause the line of action of the restraining force acting on the side of the errant vehicle to rise initially, before dropping. This minimizes the risk of the vehicle vaulting or rolling over the barrier.
- The blockouts lessen the risk of vehicle wheels snagging on the posts.
- The posts eventually yield, and the rail tears away from the bolt heads. It restrains the vehicle by tension.
- The deflection of the barrier lessens the rate of change of momentum of the errant vehicle (its deceleration). This reduces the forces on the occupants and, in turn, can significantly reduce vehicle damage and personal injury compared with striking a fixed hazard.

**Figure 6: Profiles of Four Common Types of Semirigid Barriers**



Source: Roads and Transport Authority of Dubai. 2008. *Roadside Design Guide for Dubai*. Dubai.



179. Blockedout W beam guardrail requires the following components to contribute to the successful operation of the guardrail during an impact:

- The W beam steel rail must be strong enough to withstand high tensile stresses, as well as bending stresses, which develop as the kinetic energy of the vehicle is dissipated through the vehicle, the steel rail, and the soil. Individual steel rail sections must also be securely connected to the posts and the adjacent length of rail.
- The posts provide rigidity to the whole system and hold the W beam rail at the correct height, both before and during a collision. The posts need to be spaced correctly. 2-m centers or 2.5-m centers tend to be standard spacing.
- All posts must be secured in holes at least 1.0 m deep below ground level to provide adequate support when impacted.
- The blockouts that connect the rail to the posts prevent the vehicle from snagging on the posts during impact. They help to avoid vehicle rollover by providing restraining forces above the center of gravity of the vehicle.
- The terminals (sometimes called anchorages) are essential for guardrails to develop tensile strength by providing a restraining force at either end.

### 3. Rigid barriers

180. Rigid barrier systems are generally made of reinforced concrete. They are called rigid barriers

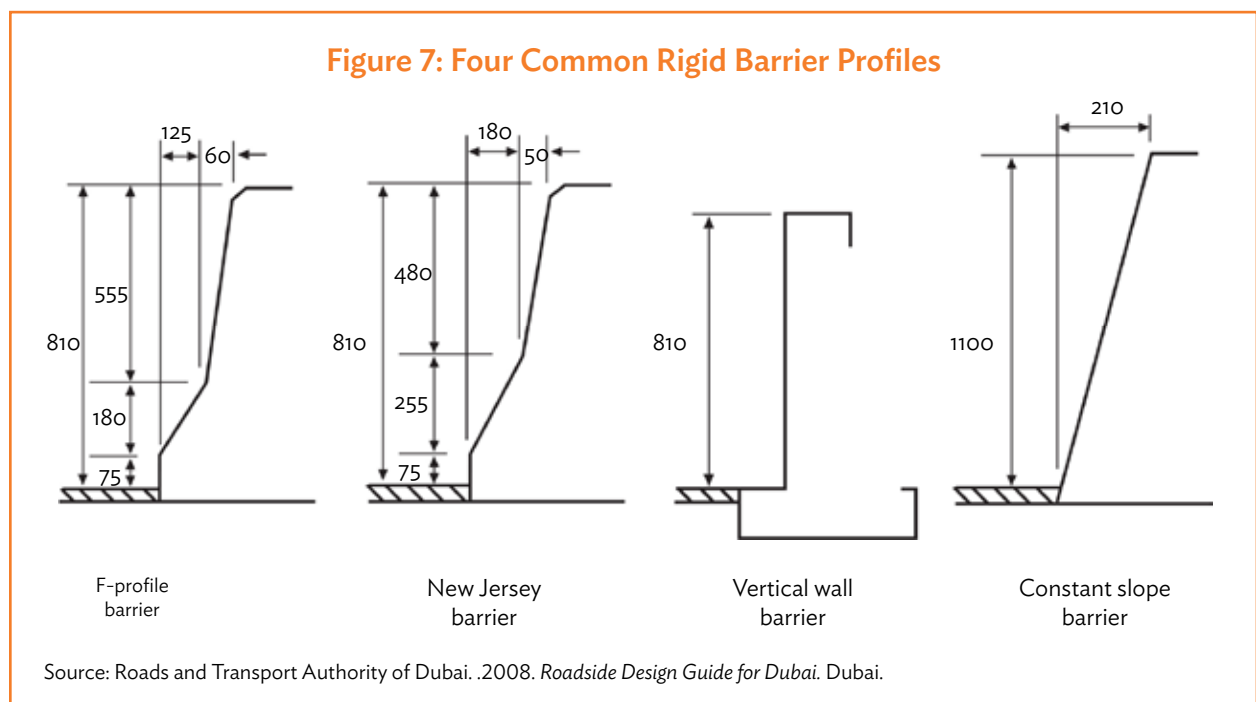
because they do not deflect or deform to any significant extent when impacted (see Figure 7).

181. Rigid barriers are well-suited in locations where space is limited, such as on elevated roadways or in narrow medians. They are also used where there is a need to contain heavy vehicles. Concrete barriers are generally more expensive to install, but less costly to maintain than WRSBs or guardrail. In fact, rigid barriers usually do not require maintenance when struck. This is an added reason for using them on high-volume roadways where maintenance of a barrier could require extensive traffic management. Traffic management can be costly and will often require lane closures while the maintenance is carried out.

182. The most common types of rigid barrier include the F-profile barrier, the New Jersey barrier, the constant slope barrier, and the vertical wall barrier.

#### a. F-profile

183. The F-profile barrier is now the most common profile for new rigid barriers across the world. It has been tested to perform well by redirecting an impacting vehicle back onto its intended path. It has a similar cross-section to the older and perhaps better known New Jersey barrier. The main difference is the lower slope of the F-profile barrier, which helps to reduce the lifting of an impacting vehicle. This results in a reduced risk that the vehicle (especially a small car) may overturn.



### **b. New Jersey**

184. The New Jersey barrier is perhaps the best known rigid barrier profile. Many engineers call all rigid barriers New Jersey barriers, perhaps unaware other profiles are available. It was developed in New Jersey, United States and performs by causing the tires of an impacting vehicle to ride up the lower sloped face. The 75 mm vertical face at the base of this barrier is intended to allow for future pavement overlays.

185. The shape performs by causing the bumper of an impacting vehicle to strike the upper slope and then, as the vehicle becomes parallel to the barrier, the wheel strikes the lower sloping face causing a further rise in the vehicle due to a compression of the front suspension. This lifting reduces the friction between the tires and the road pavement, assisting the banking and redirection of the vehicle back toward its intended path.

186. This profile was withdrawn from national standards following a series of tests that showed it tended to increase the risk of the overturning of small vehicles, relative to the newer F-profile barrier. Although there are great many lengths of New Jersey barrier in use around the world, and no changes are required to these barriers, New Jersey barriers should no longer be installed. The F-profile barrier is to be used instead.

### **c. Constant slope**

187. The constant slope barrier is a traffic barrier made of reinforced concrete and designed with a single slope. Its advantages, compared with more complex shapes, arise because its performance is not as affected by changes in the height of the road during repaving. The constant slope barrier is 1,070 mm high. It gets its name from its constant sloping face that makes an angle of 10.8 degrees with respect to the vertical. The constant slope barrier has performed similarly in crash tests to the F-profile and the New Jersey barriers.

### **d. Vertical wall**

188. The vertical face barrier does not have the capacity to lift an impacting vehicle. Therefore, it does not have the energy management feature of the F-profile barrier (or the older New Jersey barrier).

The vertical wall barrier is an effective alternative to wider concrete barriers, and can be used in narrow spaces such as for narrow medians or in front of bridge piers. Vehicle damage due to impacts with vertical wall barriers tends to be greater than with F-profile barriers, but injuries are comparable. In an impact with a vertical wall barrier, all four wheels tend to remain on the ground, thus minimizing the rollover risk. However, the trajectory of a vehicle after impact with the vertical wall barrier is uncertain because wheel damage may occur during the impact.



Rigid barriers allow high containment levels to be attained within narrow cross-sections, while (in this photo) still providing sufficient space for a wide inner shoulder.



Concrete barriers can be cast in place, or precast and then installed. In complex highway structures, including major interchanges, it is common to cast the concrete barrier as an integral part of the structure.

189. Because rigid barriers do not deflect or deform to any significant extent when impacted, exercise care in where these are used. Some barrier deflection (such as with flexible or semirigid barriers) is “good” because it allows the occupants of the impacting vehicle to decelerate over a small distance (usually 1 m–3 m), rather than be stopped in zero distance with a rigid barrier. The human body cannot withstand deceleration forces more than 20 times the force of gravity. Deflection of a safety barrier provides an opportunity for the body to be decelerated over a short distance, which in turn reduces impact forces on the body.

190. Therefore, it is easy to imagine how rigid barriers can cause serious injuries, if struck at a high-impact angle. Some vehicles rotate as they leave the road, increasing their angle of impact the further they travel. To minimize the risk that such vehicles will impact a concrete barrier at a high angle, ensure that all rigid barriers are installed within 4 m of the edge of the nearest traffic lane. Unlike flexible and semirigid barriers, which are installed as far from the traffic lane as practical (to minimize “innocent” strikes for instance), rigid barriers must be kept close to the traffic lanes to try to encourage low-angle impacts.

## B. Selection of barriers

191. The barrier selection process is not straightforward and is complicated by the number of choices of barrier available, the range of real-world situations, and several site-specific variables. When selecting a type of barrier that will best suit needs, a variety of factors should be considered (see Table 2). These include:

- performance capability and level of containment requirements;
- available clearance to the hazard, coupled with the dynamic deflection characteristics of the proposed barrier;
- site conditions, such as vertical and horizontal alignments and cross-slopes;
- end terminals;
- sight distance;
- compatibility with adjacent barriers;
- installation and maintenance costs;
- aesthetics and environmental impact; and
- maintenance capacity of organization (because barriers will sometimes need repair).

**Table 2: Guidance on the Selection and Design of Safety Barriers**

	Barrier Type		
	Flexible	Semirigid	Rigid
Typical examples	WRSB	W beam steel guardrail	F-profile and New Jersey concrete barriers
Typical crash performance standards	TL-3 (basic level)	TL-3 (basic level)	TL-4
Ability of barrier to meet higher performance standards	No	TL-4	TL-5 and TL-6
Relative severity of crashes with barrier	Low	Low–medium	Medium–high
Typical maximum deflection of barrier at 100 km/h impact	3.0 m	1.0 m	0.1 m
Potential to reduce maximum deflection	Yes, by reducing post spacing or distance between anchors	Yes, by reducing post spacing or stiffening the steel beam	No
Minimum length, excluding terminals	25 m	25 m	None, but must be structurally stable
Required length (length of need)	Varies	Varies	Varies

*continued on next page*

Table 2 continued

	Barrier Type		
	Flexible	Semirigid	Rigid
Provision for traffic to stop	Where clearance between a barrier and the nearest traffic lane is less than 2.5 m and the length of the barrier > 500 m, provision shall be made for vehicles to stop clear of traffic at intervals not exceeding 500 m. This requirement does not apply to roads with curbs, or the median edge of divided carriageways.		
Slope in front of barrier	1V:10H or flatter	1V:10H or flatter or maximum 1V:5H if last 2 m are 1V:10H or flatter	1V:10H or flatter
Surface in front of barrier	Paved when close to traffic lane, otherwise a compacted surface	Paved when close to traffic lane, otherwise a compacted surface	Paved
Restrictions due to horizontal alignment	Minimum radius of 200 m (or as specified by the manufacturer)	Some restrictions on the inside of curves	Care needs to be exercised where it is likely that impact angles will exceed 15 degrees
Restrictions due to vertical alignment	Care needs to be taken on some sag curves	None	None
End treatments	Integral part of system for WRSB	Various	Various

km/h = kilometer per hour, m = meter, WRSB = wire rope safety barrier.

Source: Roads and Transport Authority of Dubai. 2008. *Roadside Design Guide for Dubai*. Dubai.

### 1. Use tested and approved barriers only

192. Many kilometers of safety barriers may be installed, but much of them may never be put to their intended use. It is hoped that no errant vehicles will ever impact any of the barriers that exists along CAREC highways. But, in the real world, drivers will make mistakes, incidents will occur, and errant vehicles will invariably strike some of the barriers. In those instances, be certain the barrier installed is an accepted and internationally tested type, and that it has been correctly installed. In addition, be sure it is well-maintained.

193. Barriers can only be expected to perform satisfactorily if they meet applicable standards. Therefore, barriers should only be installed if manufacturers have subjected their products to crash-testing to confirm they perform satisfactorily. Installation should follow the applicable standards on which the crash-testing was carried out.

194. There are several major-testing and standard-setting organizations for roadside furniture (including barriers) around the world. These organizations test barriers and other roadside furniture against accepted

minimum standards. They approve the use of those devices that meet these minimum standards. The Manual for Assessing Safety Hardware (MASH) from the United States, and the Comite European de Normalisation from Europe are perhaps the best known standard-setting agencies. A table of the MASH testing matrix is in Table 3.

195. The highway authority will likely have its own standards or references for safety barriers. These may come from state standards (GOST)-construction rules and regulations (SNIIP), the AASHTO MASH, or the earlier NCHRP standards.

196. It is valuable if those responsible monitor closely these international standards and decide which offers the country the safest barrier systems. Use these. Keep standards up-to-date. Standards are gradually improving and any agency that fails to monitor such improvements will fail to offer its road users the best safety options available. A national standards committee (comprising public and private sector representatives, and representatives of academia and research) is a responsible way to manage changes and updates to standards.

**Table 3: Manual for Assessing Safety Hardware (MASH)  
Test Levels for Barrier Systems**

Test Level	Test Vehicle Designation and Type	Test Conditions		
		Vehicle Weight (kg)	Speed (km/h)	Angle Degree
1	1100C (passenger car)	1,100	50	25
	2270P (pickup truck)	2,270	50	25
2	1100C (passenger car)	1,100	70	25
	2270P (pickup truck)	2,270	70	25
3	1100C (passenger car)	1,100	100	25
	2270P (pickup truck)	2,270	100	25
4	1100C (passenger car)	1,100	100	25
	2270P (pickup truck)	2,270	100	25
	10000S (single unit truck)	10,000	90	15
5	1100C (passenger car)	1,100	100	25
	2270P (pickup truck)	2,270	100	25
	36000V (tractor or van trailer)	36,000	80	15
6	1100C (passenger car)	1,100	100	25
	2270P (pickup truck)	2,270	100	25
	36000T (tractor or tanker trailer)	36,000	80	15

kg = kilogram, km/h = kilometer per hour.

Source: American Association of State Highway Transportation Officials. 2015. *Roadside Design Guide*. 4th ed. Washington, DC.

197. Table 3 can be used to assist with test levels and, in turn, for evaluating safety barrier performance:

- The acceptance of a safety barrier is based on an evaluation of its performance in an idealized crash test for a specific weight and type of vehicle at designated speeds and impact angles. The minimum test level for general application for longitudinal barriers and terminals on arterial roads is test level TL 3. This relates to cars and four-wheel drive and utility trucks impacting the barrier at 100 km/h. The approach surface is 1V:10H or flatter, paved, and free from obstructions such as a curb.
- Lower performance levels are only applicable for car parks or low-speed roads. Higher test levels are applicable to barriers that can restrain heavy trucks, and which may be required for barriers that shield a severe hazard (such as a deep drop into a river), or where a significant hazard needs to be shielded from impact by trucks (such as an overpass pier in a vulnerable location).

198. Ensure all the safety barriers, barrier terminals, and crash cushions installed on CAREC roads and highways conform to the test requirements of either the Comite Europeen de Normalisation or the MASH testing regimes. Approved barriers have been tested for:

- **Structural adequacy:**
  - Barrier shall contain and redirect vehicles
  - Vehicle will not penetrate, under-ride or over-ride the barrier
  - Provide controlled lateral deflection
- **Predictability of behavior:**
  - No breaking away
  - No fracturing or yielding
- **Redirection of vehicles:**
  - Controlled penetration
  - Controlled stopping



- **Minimal occupant risk**
  - Damaged parts of barrier must not penetrate the inside of the vehicle;
  - Nonhazardous to pedestrians or road workers
  - Vehicle to remain upright during and after impact
- **Post-impact vehicular trajectory**
  - Controlled exit angle to prevent vehicle intrusion into adjacent traffic lanes
  - Deceleration not to exceed a maximum specified value

199. Make sure approved barriers are used on CAREC roads and highways. The task is also to ensure all the barriers used are installed correctly and maintained well, so they perform satisfactorily in the event of being impacted by an errant vehicle. The best way to ensure correct installation is to use quality-assured contractors who have developed a sound reputation for good work installing barriers.



The best way to ensure correct installation is to use only quality-assured contractors with sound reputations for installing barriers correctly.

### C. Design and installation considerations

200. The performance of safety barriers depends on several design and installation factors. These factors relate to impact dynamics and driver behavior when traveling close to a barrier. Once decided on the type of barrier to be used, the following details require attention during the design stage:

- length,
- height,
- offset from the road,
- deflection clearance from the hazard,
- proximity to curbs, and
- terminals.

201. When located on horizontal curves, safety barriers may need to be offset further from the edge of the traffic lane so they do not impede horizontal sight distance. Sight distance is a factor that also needs to be considered near intersections, median breaks, pedestrian crossings, and driveways.

#### 1. Length of barriers, including the length of need

202. The length of barrier required to effectively shield a hazard from errant vehicle impacts is termed the barrier length of need. The length of need includes the length of effective barrier required in advance of the hazard to intercept errant vehicles plus the length of barrier adjacent to the hazard. It does not include the end terminals.

203. The length of a barrier depends on its location with respect to the traffic lanes. When located closer to the hazard, and with maximum offset from the road, a barrier will have its shortest possible length. This requires a suitable slope from the road to the barrier, and is often referred to as “Line A” in standard drawings for barrier designs.

204. Alternatively, the barrier will be at its maximum length when it is located closer to the road. This arrangement may be necessary when the slope between the hazard and the road is not drivable. This design is often referred to as “Line B” in standard drawings.

205. To work out the length of need, follow the procedures contained in a reputable barrier design guide. Do not be surprised to find the length of need for a new installation is much longer than expected. It is essential to fully shield a hazard, and some vehicles leave the road at shallow angles. Lengths of need can become quite substantial. The total barrier length is the length of need, plus the length of the terminal at each end.

### **a. Minimum lengths for barriers**

206. Many barriers along CAREC highways are too short to perform correctly. In some cases, they simply do not fully shield the hazard; they could allow an errant vehicle to pass behind to strike the hazard. In others, the barrier is too short to have sufficient structural integrity to withstand an impact.

207. Flexible and semirigid barriers rely on a degree of tensile strength to restrain an impacting vehicle and to spread the impact over several posts along its length. The minimum length of WRSB required is 60 m where the WRSB system adopted is not specified in the design. When a system type of barrier is specified, the approved minimum length may be sought from the product supplier.

208. Subject to the “length of need” requirements at a site, the minimum length for a W beam guardrail is generally 30 m plus appropriate end terminals.

209. There is no minimum length requirement for rigid barriers. The length of a rigid barrier is subject to the “length of need” requirements at the site, plus the necessary end terminals.

## **2. Barrier height**

210. A barrier must be installed at the height recommended by its manufacturer. A barrier that is too low can lead to an impacting vehicle vaulting over it. A barrier that is too high can cause “submarining” by an errant vehicle. In extreme cases, a vehicle could pass beneath the railing, and this can have tragic consequences. Therefore, barrier height is important for safety.

## **3. Offset from the road**

211. It is preferable to locate flexible and semirigid barriers as far from the road as practical. This will maximize the chance of a driver being able to regain control of a vehicle and it will also minimize the length of barrier required. However, a greater offset from the edge of the traffic lane can result in higher impact angles, more severe impacts, and an increased probability of the barrier being penetrated. For this reason, rigid barriers must not be located more than 4 m from the edge of the nearest traffic lane.

212. Irrespective of the type of barrier being used, it is preferable that the slope in front of the barrier is

essentially flat. Safety barriers perform best when they are impacted by vehicles with their center of gravity at or near the normal position. The slope in front of the barrier should be 1V:10H or flatter. For semirigid barriers, a maximum slope of 1V:5H is acceptable, providing the slope for the 2 m immediately in front of the barrier does not exceed 1V:10H. The full width between the road and a rigid barrier should be suitably paved to ensure optimum barrier performance.

213. Consideration should also be given to sealing the shoulder for other barriers when minimum or small offsets are used.

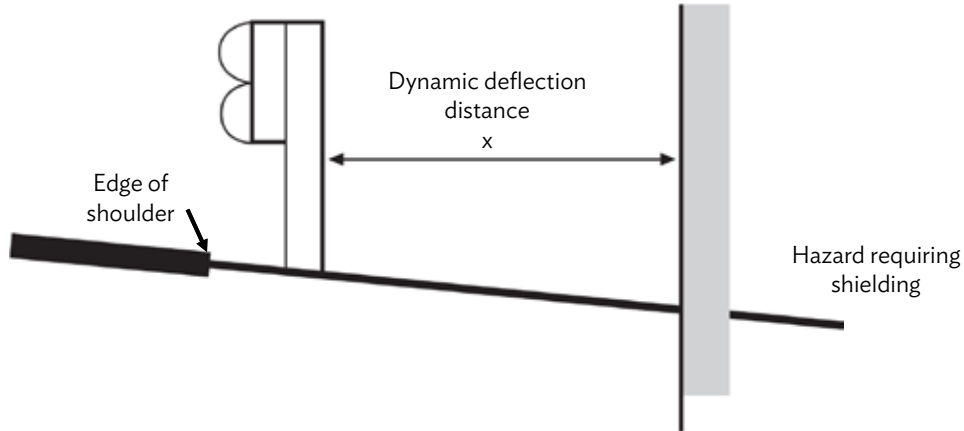
## **4. Deflection clearance from the hazard**

214. Once the restraint requirement has been determined, the available space to allow for deflection may dictate the type of barrier to be used. Flexible systems are generally considered the barrier of choice where site conditions are compatible with their use, and the level of containment required is within their performance capability. This has been demonstrated by controlled crash-testing and actual field performance that has shown that cable systems have significantly lower occupant injury risk than semirigid barriers, which in turn have lower occupant injury risk than rigid systems. But, if the barrier must be located immediately adjacent to the hazard, a rigid barrier may be the only viable option.

215. An essential aspect of barrier design is to provide sufficient clearance from the hazard so the expected deflection of the barrier will not allow the impacting vehicle to contact the hazard (see Figure 8). Barrier deflection depends on the type and installation arrangement of the barrier used as well as the mass, speed, and impact angle of the vehicle. As a rule of thumb, the deflection of a semirigid barrier may be up to 1 m, and the deflection of a flexible barrier may be up to 3 m (see Table 4). The dynamic deflection of rigid concrete barriers is minimal (0.1m or less).

216. Note that most semirigid systems can be strengthened by reducing post spacings or by reinforcing the rail with a double beam (termed “double nesting”). This will reduce the barrier deflection in a crash. However, stiffening of the barrier will increase the potential for vehicle occupant injuries. The deflection of WRSB can also be reduced by reducing the post spacing.

**Figure 8: Deflection Clearance Required between Barrier and Hazard**



Source: Asian Development Bank.

**Table 4: Indicative Maximum Deflection of Barriers**

Barrier Type	Deflection
Wire rope safety barrier	1.3 m–3.0 m
W beam guardrail	0.5 m–1.0 m
Concrete barrier	0.1 m

m = meter.

Source: Roads and Transport Authority. 2008. *Roadside Design Guide for Dubai*. Dubai.



W beam barrier can deflect by up to 1 meter when struck. If the barrier is a part of a back-to-back barrier system in the center of a highway, it could present a risk to traffic in the other carriageway.

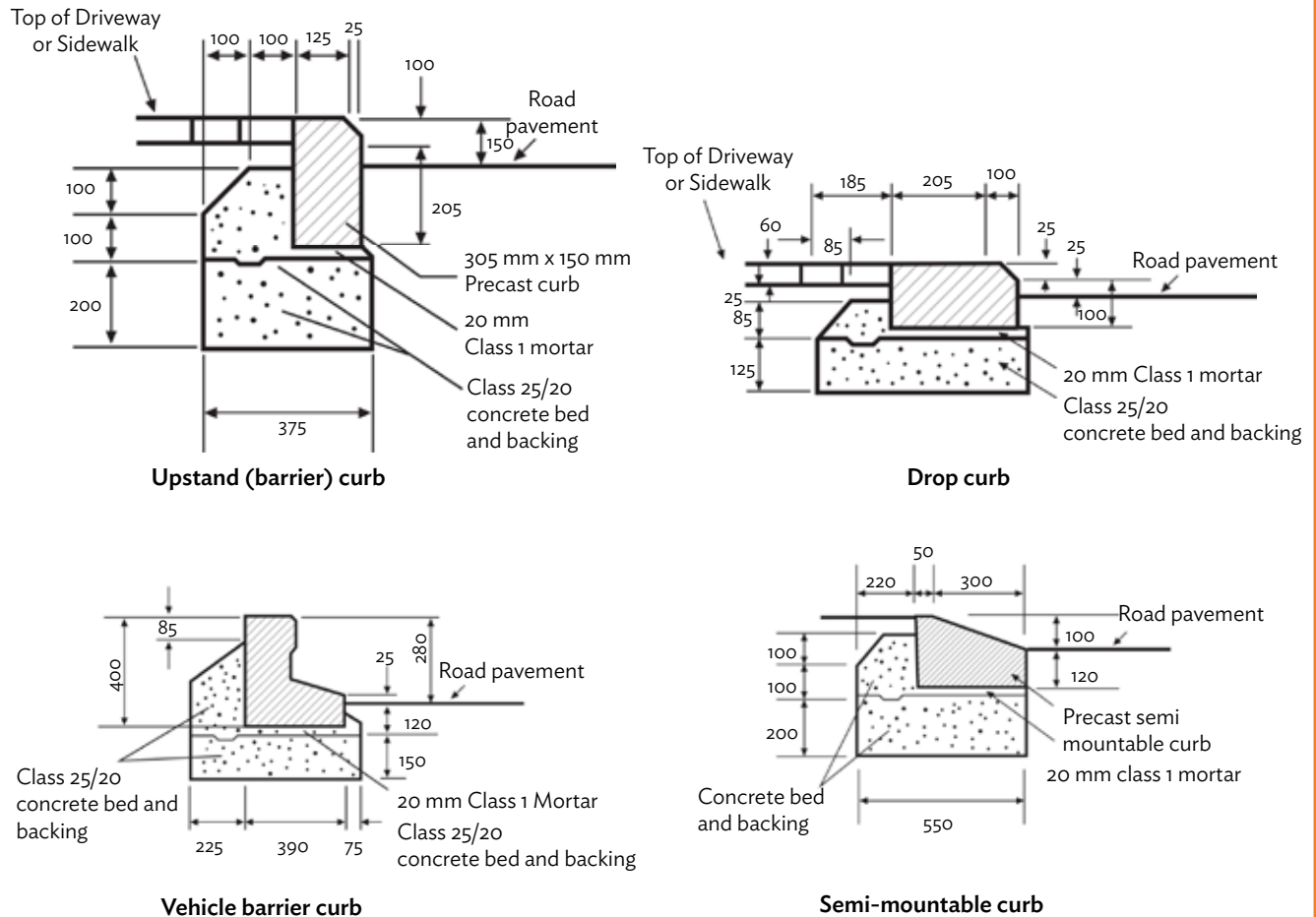
## 5. Proximity to curbs

217. Several basic curb types are commonly used on CAREC roads. Figure 9 shows four of these. Some countries have other profiles, but these are in common use. Curbs are used for drainage purposes and/or to delineate the roadway and traffic islands.



Fast, efficient maintenance is necessary after a W beam barrier is struck. It will not likely serve its intended purpose if it is struck again in the same vicinity before repairs are made.

Figure 9: Curb Profiles



mm = millimeter.

Source: Roads and Transport Authority. 2008. *Roadside Design Guide for Dubai*. Dubai.

218. Incorrect use of curbs can have a significant effect on roadside safety, particularly on high-speed roads. On high-speed roads, curbs should be used only where absolutely necessary, and then, only low profile curbs are acceptable.

219. It is preferable to avoid the use of curbing near safety barriers. But, if a curb is necessary for drainage, the location of safety barriers relative to the curb needs to be considered carefully as it may affect the

barrier performance when impacted. A curb in front of and close to a barrier can cause an errant vehicle hitting the curb at high speed to jump and either vault over the barrier, or hit the barrier at a greater height than provided for in the design and testing. Injuries are more severe in such crashes.

220. Where the curb is used near a barrier on a high-speed road, the curb should generally be located so that the barrier is struck first (that is, before the

curb). Alternatively, the barrier must be located at a sufficient distance behind the curb to ensure the impacting vehicle does not vault over the barrier.

221. When an errant vehicle strikes a curb, its trajectory will depend upon several variables, including the size of the vehicle, its suspension characteristics, its impact speed and angle, and the height and shape of the curb itself.

222. When a vehicle crosses a curb, vehicle roll and pitch are developed. This is especially so at speeds above 70 km/h. This can have a profound effect on the way a vehicle strikes a barrier located behind a curb.

223. Figure 10 illustrates the effect a curb would have on the trajectory of a vehicle bumper as the vehicle mounts the curb. The offset of the safety barrier from the curb is critical to the performance of the barrier. If it is located where the bumper cannot make contact with the barrier at an appropriate height, the performance of the barrier cannot be predicted and the vehicle will either under-ride the barrier or be at risk of vaulting it.

#### a. Curbs and flexible barriers

224. Where practicable, WRSBs should not be installed behind curbs.

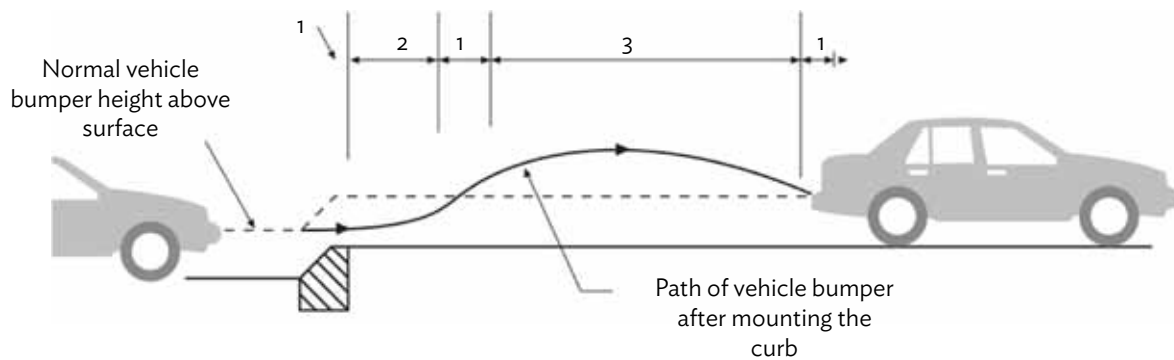
#### b. Curbs and semirigid barriers

225. Where possible, guardrail should not be installed behind curbs. But there are recommended guidelines for use of curb and guardrail combinations where curbs are required for drainage or other reasons. Upstand curb may be used in combination with guardrail only on roads with speed limits of 60 km/h or less. Semi-mountable curb may be used on roads with speed limits of 100 km/h or less. Curbs, other than drop curb, must not be used in combination with semirigid barriers on roads with speed limits greater than 100 km/h.

#### c. Curbs and rigid barriers

226. Curbs must not be located in the vicinity of rigid safety barriers. In the event of a concrete barrier being impacted, energy is dissipated by the lifting and lowering the vehicle, compression of the vehicle suspension, and deformation of the body of the vehicle. The height of the point of impact is critical to the performance of the barrier. If a curb is located in front of the barrier, there is a high risk that an errant vehicle will either vault the barrier or overturn as it will strike the barrier at a point higher than would otherwise be the case as a consequence of mounting the curb.

**Figure 10: Effect of Curb on the Trajectory of an Impacting Vehicle**



1. Acceptable barrier locations, vehicle would strike a barrier at an acceptable height.
2. Vehicle would strike a barrier too low, not acceptable.
3. Vehicle would strike a barrier too high, not acceptable.

Source: Roads and Transport Authority, 2008. *Roadside Design Guide for Dubai*. Dubai.



227. Where the installation of curb is essential, the use of upstand curb in combination with flexible barriers should be confined to roads with a speed limit of 60 km/h or less. Semi-mountable curbs may be used on roads with speed limits of 100 km/h or less.

228. Permitted offsets between curbs and barriers are detailed in Table 5.

## 6. Terminals

229. The end of a safety barrier can be a particularly hazardous object when impacted by an errant vehicle. In some crashes, and unless a correctly installed safe terminal is used, the end of a semirigid barrier (guardrail) can spear through an impacting vehicle into the passenger compartment.

**Table 5: Use of Curbs in Combination with Safety Barriers**

Barrier Type	Curb Type	Offset between Curb and Barrier	Conditions and Comments
Flexible	None	Not applicable	This is the preferred option for high-speed roads.
	Drop	No restrictions	May be used without restrictions.
	Semi-mountable Speed limit 60 km/h	X = 0 or X = 1.0 m–2.0 m or X ≥ 2.5 m (desirable)	If curb is required, this is the preferred type. It should preferably not be used on high speed roads (above 80 km/h); if it is, it should comply with the offsets below.
	Speed limit 80 km/h	X = 0 or X = 1.2 m–1.8 m or X ≥ 4.0 m (desirable)	
	Speed limit 100 km/h	X = 0 or X = 1.2 m–1.8 m or X ≥ 4.5 m (desirable)	
	Upstand	X = 0 or ≥ 2.5 m (60 km/h roads only)	This type of curb should not be used on high speed roads (above 80 km/h). Its use near barriers should be limited to low-speed roads (below 60 km/h) only.
	Vehicle barrier	Not applicable	Not to be used in combination with flexible barriers.
Semirigid	None	Not applicable	This is the preferred option for high speed roads.
	Drop	No restrictions	May be used without restrictions.
	Semi-mountable Speed limit 60 km/h	X = 0 or ≥ 2.5 m	If curb is required, this is the preferred type. It should preferably not be used on high-speed roads (above 80 km/h); if it is, it should comply with the offsets below.
	Speed limit 80 km/h	X = 0 or ≥ 4.0 m	
	Speed limit 100 km/h	X = 0	
	Upstand	X = 0 or ≥ 2.5 m (60 km/h roads only)	This type of curb should not be used on high-speed roads (above 80 km/h). Its use near barriers should be limited to low-speed roads (below 60 km/h) only.
	Vehicle barrier	Not applicable	Not to be used in combination with semirigid barriers.
Rigid	All	Not applicable	Curbs should not be used in combination with concrete or other rigid barriers.

km/h = kilometer per hour, m = meter.

Source: Roads and Transport Authority, 2008. *Roadside Design Guide for Dubai*. Dubai.

230. The ends of concrete barriers are also hazardous. Rigid barriers simply do not move when struck. Crash tests show that an impacting vehicle will come to a sudden stop if it strikes the end of the barrier. The barrier may also penetrate the vehicle, sometimes as far as the passenger compartment. The rigid nature of the barrier, and the absence of any ability to absorb energy and to decelerate in a safe manner mean the ends of these barriers must be shielded with safe terminals. Ensure appropriate end treatments are provided to minimize the potential for serious injuries to vehicles' occupants.



"Fish tail" terminals present a spearing risk and should not be used on CAREC highways.

231. The terminals shield the end of the barrier and provide a system that minimizes the possibility of the guardrail spearing into a vehicle. The terminals may be flared or straight and either "gating" terminals (designed to allow a vehicle to pass through the barrier and stop in a run-out area beyond the terminal), or

"nongating" terminals (designed to absorb the impact or redirect it along its length).

232. The type of terminal used will depend on the type of barrier and its location. Ask questions such as: Is there space for flaring the barrier approach? Is there space behind the terminal for a run-out area? Does a crash cushion offer the best option?

233. Well-designed terminals provide controlled deceleration of errant vehicles below recommended values causing injury to vehicles' occupants. They also ensure the vehicle is not speared, vaulted, snagged, or rolled on impact. Preferably, the terminal should be flared away from approaching traffic and terminated beyond the limits of the clear zone. However, terminals are available that do not require a flared layout.

234. Various types of terminals are commercially available. Follow the manufacturer's specifications for installation to ensure they meet appropriate performance standards. While the cost of a properly designed terminal will add to the cost of the barrier treatment, the benefits will significantly outweigh the costs if the end of the barrier prevents serious injury or death to vehicles' occupants.

235. Remember too that a terminal of known impact performance needs to be installed on the departure end of a barrier, if that end is within the clear zone for oncoming traffic on a two-way carriageway.

#### **a. Terminals for flexible barriers**

236. WRSB terminals need to be considered as an integral part of the barrier system to keep the cables tensioned. WRSB terminals are provided in accordance with the WRSB manufacturer's specifications.

237. The end anchors are required to be frangible, and to detach from the anchor block when hit by an errant vehicle. Short safety cables are provided to ensure uncoupled wire ropes are not hazardous to traffic. An errant vehicle that runs into the end of a WRSB will generally straddle the cables and be restrained as the vehicle progressively flattens the posts supporting the wire rope. The terminated wire ropes will release vertically, if the system is impacted in a reverse direction by oncoming traffic on a two-way road.

### b. Terminals for semirigid barrier

238. There are various types of terminals designed to behave differently in relation to an impacting vehicle:

- **Gating terminals.** These terminals are designed to allow an impacting vehicle to strike and pass through them and to stop in a run-out area beyond the terminal. This run-out-area is to be a drivable area free of hazards. Based on crash-testing for 100 km/h operating speeds, this drivable area should be a minimum of 20 m long parallel to the rail and 6 m wide behind the rail with a maximum slope of 10:1.
- **Nongating terminals.** These terminals do not allow the impacting vehicle to pass through the terminal, and are designed to absorb the impact and stop an errant vehicle, or redirect it along its length. This type of terminal is appropriate if a hazard exists behind the terminal, where vehicle penetration is not acceptable or where it is not possible to extend the barrier to provide a gating terminal.
- **Redirective terminals.** These terminals alter the path of a vehicle in a controlled manner following impact. They are designed to redirect the errant vehicle back toward its intended path.
- **Nonredirective terminals.** These terminals absorb the energy of an impacting vehicle and perform effectively when hit end-on. They are typically crash cushions, including those made from containers filled with sand. When the impact is to the side of the crash cushion, or the sand barrels, the vehicle will either be stopped or slowed down without any appreciable redirection of its path.

239. Terminals may be either flared or nonflared (parallel to the roadway) on the approach. A flared terminal is desirable where the barrier is close to the roadway or to provide a gradual transition to a major hazard close to the roadway. Typical examples of this include a bridge parapet, or a concrete pillar on a median strip. Motorists are less likely to perceive a roadside barrier to be a hazard, if it is introduced gradually using a flared section. However, a flared terminal occupies more space and may not be feasible with a narrow road formation.

240. Common terminals typically used for steel guardrail include the modified eccentric loader terminal and similar. The modified eccentric loader

terminal is designed to provide a soft gating impact to prevent the railing from spearing the impacting vehicle. There are many varieties available from a variety of international manufacturers. Make sure to use only those terminals that are tested and approved for use by an internationally recognized agency. Information about the correct way to install them should be obtained from representatives of the manufacturer.

### c. Terminals for rigid barriers

241. Because of their rigidity, and their generous cross-section compared with the other barrier groups, rigid barriers have a special need for safe terminals. The most common terminal for a rigid barrier is the crash cushion (impact attenuator). Crash cushions are designed to absorb the energy of an impacting vehicle, and gradually decelerate it to a controlled stop. They are suited for use in situations in which they are likely to be struck head-on by an errant vehicle in locations where the fixed object cannot be treated with other types of terminals or transitions to other barrier types.

242. Crash cushions should be installed in accordance with the manufacturer's specifications. A crash cushion of appropriate test performance should be chosen and expert advice obtained due to their specialized use. Typical locations include the end of a concrete median barrier, bridge piers, hazards in the gore areas of expressways, and toll plazas.



Impact attenuators come in various sizes to accommodate different cross-sections, as well as different speed environments.



Some impact attenuators have crushable cells inside the steel structure to absorb much of the impacting energy. Lower-cost models have alternative systems.



There are several impact attenuators approved for use in advance of temporary rigid barriers at work sites.



Some impact attenuators are designed to be used in narrow areas at road work sites.

#### ***d. Only use approved terminals***

243. Take care when selecting and using terminals. All barriers need terminals to reduce the risk of injury should an errant vehicle impact the end of a length of barrier. Installing barrier without adding a suitable terminal is an unsafe practice and should not be done. However, some older-style terminals are now considered unsafe; they should not be used.

244. Fishtail terminals are an old style of end terminal used on the W beam guardrail. If struck end-on, it can spear the vehicle and cause critical injuries to occupants. They should no longer be used on approach ends of semirigid barriers, especially in high-speed environments.

245. The turned down (or ramped) terminal was a concept introduced many years ago for use with semirigid as well as rigid barriers. Ramping down the ends of W beam barrier helped to eliminate spearing of the passenger compartment of the impacting vehicle that often occurred with fishtail ends. Using a ramped down section of concrete on the end of a rigid barrier helped to diffuse impact energy by raising the impacting vehicle, and allowing it to decelerate along the ramp rather than impact the blunt barrier end.

246. While these turned down terminals were improvements over fishtail terminals or no terminal, field experience and crash-testing have shown that vehicle rollover or launching is likely with them under high-speed impact conditions. Based on observed crash test performance and reported field experience, it is now recommended that CAREC road authorities do not use turned down (ramped) terminals on the approach end of concrete barriers or steel guardrails on roads with operating speeds of more than 80 km/h.

247. For new installations at these locations, road authorities should only specify “state of the art,” crashworthy terminals that have met appropriate testing criteria such as NCHRP 350, MASH, or EN 1317 (or their updates).

248. Turned down terminals and fishtail terminals remain appropriate for trailing (downstream) ends of traffic barriers on divided highways and in other locations where end-on, high-speed impacts are unlikely to occur.





Turned down (or ramped) terminals should not be used on the approach end of barriers in high-speed environments as they tend to launch an impacting vehicle.



Failing to install a terminal is an unsafe practice. Barrier should not be installed or retained like this as the horizontal rail can easily spear an errant vehicle.



Old tires and similar untested and nonapproved devices must not be used to shield the ends of rigid or semirigid barriers.



Ramped terminals, such as this, are not to be used on high-speed sections of CAREC highways, except on the trailing end of barrier on one-way carriageways.

## 7. Barriers on medians

249. The installation of barriers along medians can be a challenge. In some cases, the barrier will cut off the natural path of pedestrians who may be using the median as a refuge to cross the road. In other cases, the median may be quite narrow and the space available for a barrier may be limited (see Figure 11). The barrier along a median may have to be designed and installed to accommodate impacts from either side. Rigid barriers are often chosen for use in these situations. However, a back-to-back semirigid barrier or even flexible barrier may be used if there is sufficient deflection space behind the barrier so the deflection on impact will not create an unacceptable risk for opposing traffic.

250. A further consideration for median barriers is the special need for end terminals. Gating terminals will create issues and, therefore, there is a need to take care in using nongating redirective terminals only.

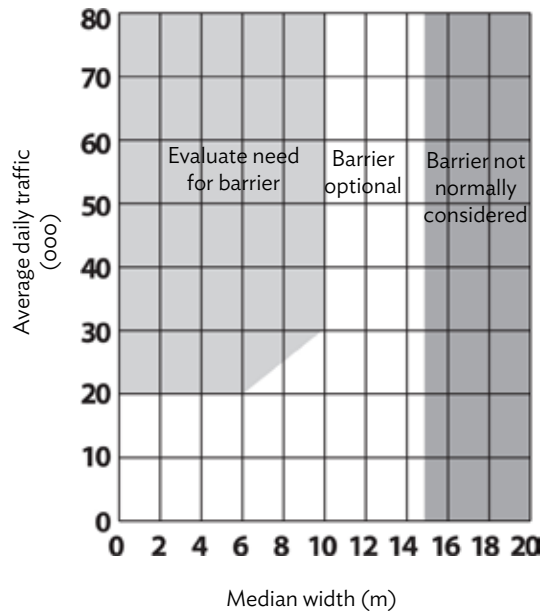
## 8. Barriers on fill slopes

251. A fill slope is a side slope beside a road built up above the surrounding land. Fill slopes are common along CAREC roads and highways, as they allow the road to stay dry above surrounding water and damp soils. They range in height and slope. When they are steep and when they are high, these side slopes are roadside hazards. Why?

252. Because an errant vehicle leaving a road and traveling onto a fill slope is at risk of overturning (with serious consequences) or at least passing to the



**Figure 11: General Guide for the Use of Barriers along Medians**



m = meter.

Source: American Association of State Highway Transportation Officials. 2015. *Roadside Design Guide*. Washington, DC.

base of the fill before recovering. The slope of a fill slope and its height are critical for the safety of the occupants of that vehicle.

253. A nonrecoverable fill slope is one on which a typical errant vehicle cannot recover; it will travel to the base of the slope before being able to recover. Slopes steeper than 1V:4H are deemed nonrecoverable. Also, take into account the surface condition of the embankment. Smooth firm slopes offer a better chance of recovery than do soft, uneven slopes.

254. A critical slope is steeper, and particularly hazardous for errant vehicles as it is likely to cause an errant vehicle to overturn. Critical fill slopes are those steeper than 1V:3H. The risk they present increases with the height of the fill. Many countries have standards that require a barrier to be installed to shield these critical slopes only when their height exceeds 3 m. But standards are sometimes dictated as much by cost considerations as by practical road safety performance. Who wants to be in a vehicle that

is out of control and heading quickly toward a 3m high critical side slope?



As the roadside changes from a reasonably flat to a high fill, there is a need to introduce suitable barrier to shield undrivable side slopes greater than 2 meters in height. Alternatively, flatten the side slopes to make them drivable (<1V:4H).



When side slopes (>1V: 3H) exceed 2 meters in height, suitable barrier is required along CAREC highways. The culvert in this photograph requires attention, regardless of the fill height.

255. Standards are the best place to begin a design. If the national standards call for barrier to be installed only when a critical slope exceeds 3 m height, then follow that standard. But always look to provide safety enhancements that may take road safety further.

256. For CAREC highways, the maximum height of an unshielded critical fill slope shall be 2 m. This may be less than the current country standard, but is recommended for added safety. This guide is based on the relative severity of a crash involving the slope compared with a crash involving a barrier. Remember

also to ensure adequate ground support for the barrier posts on fill. If post restraint is a concern, deeper post embedment, closer post spacing, or use of soil plates may be necessary.

### 9. Joining barriers to bridges

257. A bridge parapet is often a blunt concrete object that would result in a severe crash if impacted by an errant vehicle. Therefore, guardrail approach barriers are generally provided to shield bridge parapets. Such guardrail approach barriers must be designed and installed with three main safety considerations:

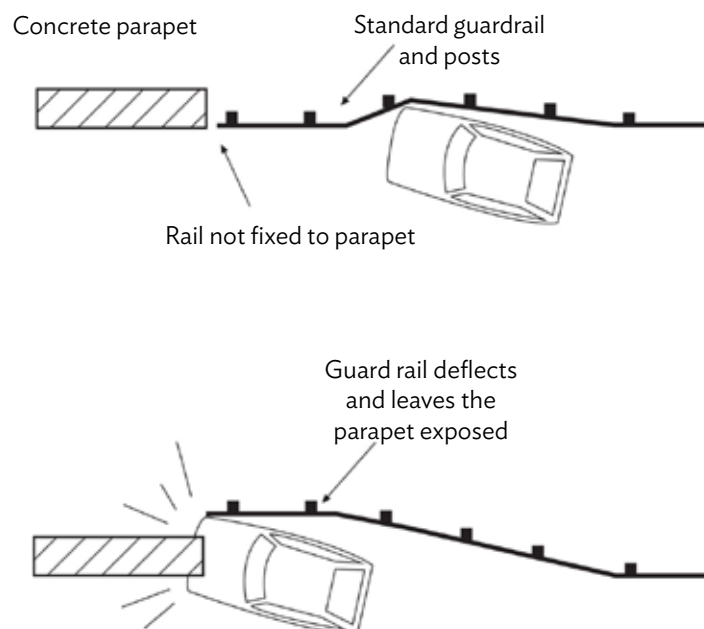
- The transition from the approach barrier to the bridge parapet should provide a continuous face along which an errant vehicle can be controlled

without snagging. Exposed rail ends, posts, and sharp changes in the geometry of the barrier components or curbs should be avoided.

- The strength and stiffness of the approach barrier needs to provide a smooth transition from the semirigid barrier to the rigid barrier to prevent “pocketing” of the vehicle into the parapet. This is assisted by reducing post spacing over the final 10 m approaching the parapet.
- To further prevent pocketing, and to assist with tensile continuity, the guardrail should be firmly affixed to the parapet.

258. A sketch of inadequate barrier transition arrangements leading to the pocketing of an errant vehicle is in Figure 12.

**Figure 12: Examples of Inadequate Barrier Transition**



Source: Asian Development Bank.



Reduced post spacings and a strong connection of the W beam barrier to the rigid barrier strengthen the semirigid barrier and reduce pocketing risk. The width marker aids conspicuity of the hazard.

## 10. Temporary barriers

259. There are times when barriers for temporary or short-term occasions are needed. Such occasions may be due to road works, or because of a need to close a road or a part of a road for an emergency. The first objective when using a temporary barrier is to ensure it is safe. It must not present a hazard to road users.

260. The most commonly used temporary barriers across the CAREC region are concrete barriers. It seems these are used because they are robust, relatively inexpensive (compared with other options), and they can be lifted into place quickly and efficiently with a small crane.

261. However, many of these temporary barriers are as much a hazard as they are an assistance on roads. Too many of them are placed without any strong and regular connection between adjoining sections. Mostly, they have blunt ends. They are basically hazardous blocks of concrete that could damage an errant vehicle, and could lead to serious injuries for occupants.



Whether temporary barriers are used at road works or along a highway, they must be securely joined together and must not leave exposed blunt ends within the clear zone.



There are too many hazardous concrete barricades along CAREC highways. Road agencies should replace such barricades with suitably approved safety barrier systems.

262. The weakest point of a temporary barrier system is the joint between adjacent segments. It is vital that the method of connecting the barriers is robust and able to resist the forces that occur in an impact without excessive rotation of the barrier units. It is important that connections are installed

in accordance with the system that has been tested, and are adequately maintained. Several connections have been successfully tested and are operational (see Figure 13). Refer to technical guides like the AASHTO Roadside Design Guide for details of connections such as:

- pin and loop joint,
- channel split joint,
- vertical I-beam joint,
- lapped joint, and
- J-hook joint connectors.

263. It is suggested to review all the temporary concrete barriers in use on CAREC highways and ensure they meet at least two important criteria:

- All adjacent sections are securely connected.
- Suitable end terminals are used on the ends of all temporary barriers. (If there are no terminals, try to flare the barrier away from approaching traffic and end it outside the clear zone.)

264. There are also some portable temporary steel barriers available. They offer an excellent alternative to concrete barriers for temporary use, especially at road work locations. They can be towed into place, securely pinned together, and anchored onto a smooth surface. Several proprietary types of temporary steel barrier have been tested to international standards.

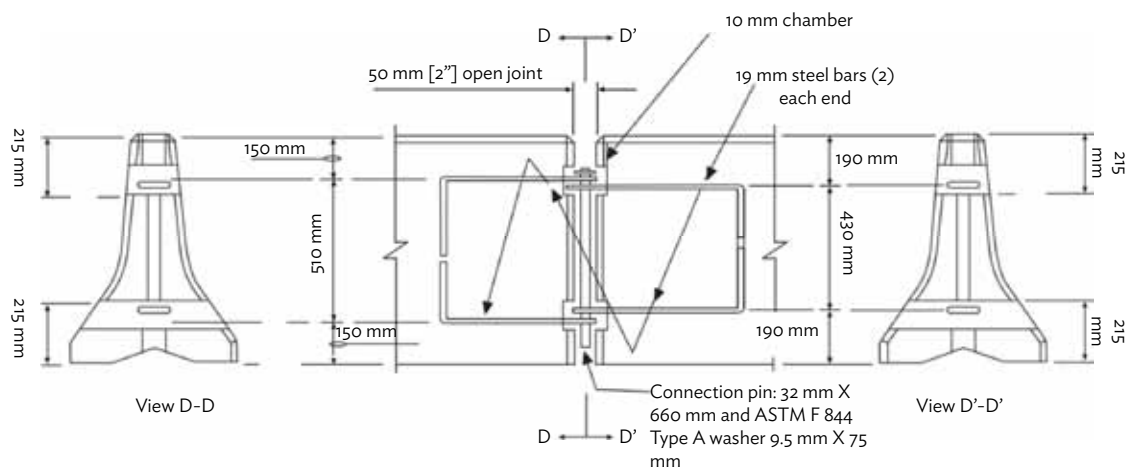
265. In addition, a small number of plastic water-filled barriers are approved for use as temporary barriers. But beware, as some of these are only suitable as delineators. Some do not meet crash test standards, while most have been tested only to TL-2 or less. This means they have been tested with light vehicles at impact speeds of up to 75 km/h only. Even then they experience considerable deflection, meaning any workers behind such barriers may still be at risk.

266. Therefore, be careful what to select. Only if a plastic barrier has been crash-tested (to TL-2 or higher) should it be considered as an option to use on a CAREC highway. Even then, make sure it is in a suitable speed environment according to its test level.



There are portable semirigid barriers that have been approved for use at road work zones. They are recommended for use in work zones.

**Figure 13: Pin and Loop Joint Connection for Rigid Barriers**



mm = millimeter.

Source: Roads and Transport Authority of Dubai. 2008. *Roadside Design Guide for Dubai*. Dubai.





Plastic water-filled barriers, if used, must be filled with the correct volume of water. The barriers must be secured together, and they must only be used in a speed environment for which they are tested.



There are several safe terminals for use on temporary barriers. While the initial cost for these may be considered high, they can be reused often, and moved to new work sites easily and freely.



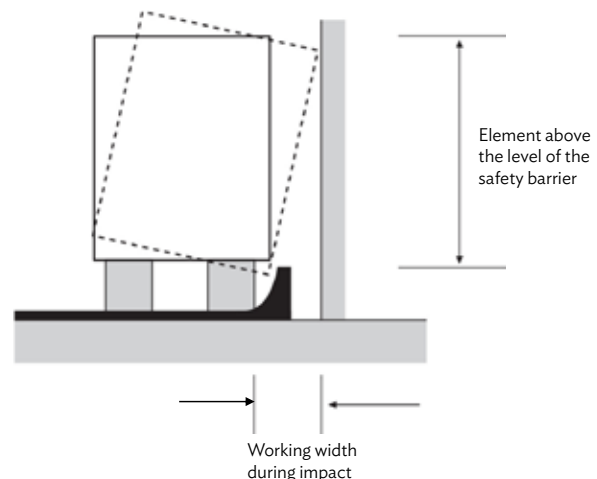
At major long-term road work sites on busy and high-speed CAREC highways, crash cushions are recommended to shield the end of lengths of temporary concrete barriers.

## 11. Working width

267. Many rigid barriers are used along expressways. When the expressway passes under a structure (a railway bridge, an overpass), take care with the placement of the barrier at supporting piers. When considering deflection requirements, provide allowance for the roll effect of vehicles having a high center of gravity. Rotation of the upper part of the vehicle may cause impact with the object being shielded. In some collisions involving a high-loaded truck, the truck will roll; the higher the load the greater distance the load or container will roll. In some circumstances, the load will snag on the vertical pier. This seriously increases the impact and often causes a catastrophic crash. A rigid barrier should, therefore, provide sufficient space between it and the pier to reduce this “snagging” risk. They must be installed with what is known as an adequate “working width.”

268. The working width is the width that includes the barrier deflection (zero for rigid barriers), plus the roll distance of an impacting high vehicle (see Figure 14). It is a necessary consideration when designing barriers to shield hazards, such as bridge-supporting piers, on expressways from impacts by large trucks. For rigid barriers, this is also known as the zone of intrusion. The working width is measured from the face of the barrier to the face of the fixed object.

**Figure 14: Working Width for Concrete Barriers**



Source: Asian Development Bank.



269. Thus, it is desirable to ensure the distance between a rigid (or a semirigid) barrier and a hazardous object is sufficient to prevent a high vehicle from snagging on the hazard should it impact the barrier and pivot about its roll axis. This becomes particularly important when the hazards are structural components such as bridge piers or gantry columns. In these situations, secondary effects (such as if a structure collapses and falls onto the roadway) can

be tragic. A desirable working width measured from the face of the barrier to the face of the fixed object is necessary.

270. Some values for working widths for a 4.3 m rigid van or an articulated truck are given in Table 6. The working width is dependent on the cross fall of the carriageway and the likely impact speed. Values can be interpolated as necessary.

**Table 6: Typical Working Width Requirements for High-Speed Roads**

Situation	Dynamic Direction	Roll Allowance	Working Width
W beam protecting slopes (can be penetrated by trucks)	1.7	1.1	2.8 (light vehicles)
Concrete barrier protecting sign gantry or pedestrian bridge	0.0	3.0	3.0 (trucks)
Concrete barrier protecting road bridge	0.0	2.1	2.1 (trucks)

Source: American Association of State Highway Transportation Officials. 2015. *Roadside Design Guide*. Washington, DC.

# VI. Other Roadside Safety Furniture

## A. Frangible lighting columns

271. Lighting columns are frequently-struck roadside objects. They tend to be close to roads and highways to provide sufficient illumination of the road, and until now, tend to be made from rigid concrete and/or steel. If struck by an errant vehicle, such columns can cause serious injuries, even fatalities to occupants of the errant vehicle. To reduce this risk, many road authorities place these rigid light columns behind semirigid barriers. This leads to a higher cost, added maintenance issues, and sometimes a less-attractive roadside environment.

272. Safer lighting column options are now available. The two most common are the slip base lighting column and the impact-absorbing lighting column (see Figure 15).



Slip base lighting columns are suitable for use in high-speed areas (80 kilometers per hour and above) where there are few pedestrians and little parking.



Impact-absorbing lighting columns are suitable for low-speed areas (less than 80 kilometers per hour) where there may be more pedestrians and more parking nearby.

### 1. Slip base lighting columns

273. A slip base lighting column is designed to break away at the base when struck by a vehicle. This type of column can often be reused after a collision, with only minimal repairs. The electrical connections also break away and are easily reconnected. Slip base columns are mostly suitable for locations where vehicle speeds are greater than 80 km/h. They are not recommended for areas where there is high pedestrian activity, or lots of parked vehicles.

### 2. Impact-absorbing lighting columns

274. Impact-absorbing columns do not break away but yield progressively when impacted, controlling deceleration and absorbing the energy of the vehicle. Impact-absorbing columns have slots within their welds that weaken them to reduce their rigidity. Impact-absorbing columns are suited to locations where it is undesirable for them to fall to the ground, such as in high pedestrian use areas or where the median or traffic island in which the pole is located is narrow and traffic volumes are high.

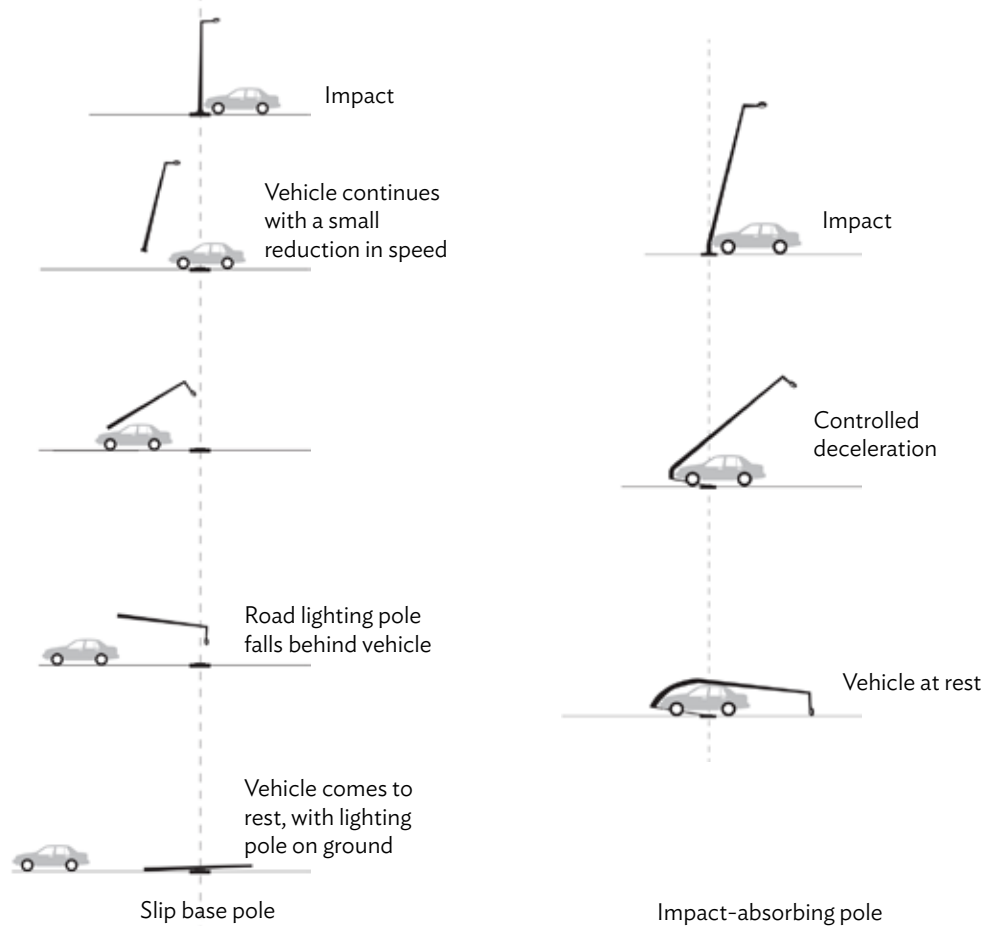
## B. Drivable end walls

275. Culvert end walls within the clear zone of a road are roadside hazards, and should be treated to reduce their risk. They can be treated by:

- delineation with guideposts and width markers, or
- extending the culvert to a point outside the clear zone, or
- shielding with suitably designed and installed safety barrier, or
- drivable end walls

276. Improving delineation to keep vehicles on the road at the culvert is an acceptable activity, but may not be sufficient to reduce the risk satisfactorily. Extending the culverts is a preferred option, but this may not always be possible in constrained road reservations. The use of safety barriers to shield the culvert may be suitable, but will require suitable barrier terminals and ongoing maintenance. Therefore, it is recommended to use other

**Figure 15: Operation of Frangible Lighting Columns**



Source: Asian Development Bank.

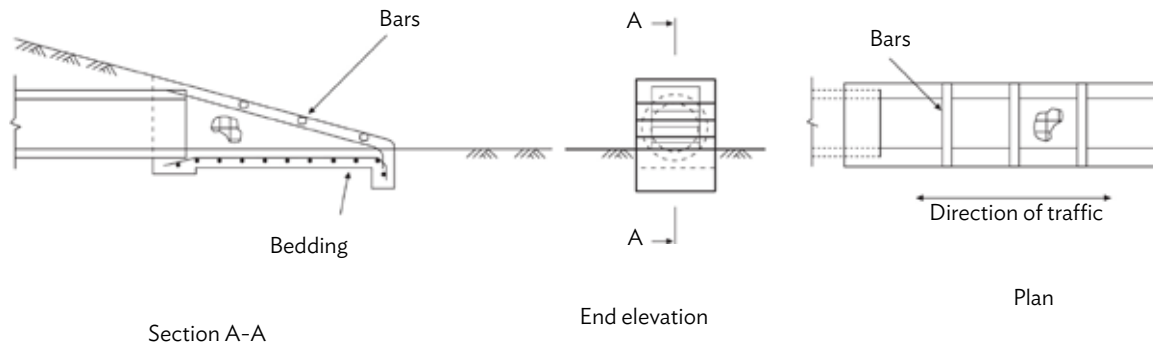
options before resorting to barriers to shield these short point hazards.

277. Drivable culvert end wall type 1 is for use when the direction of vehicular travel is parallel with the culvert direction (see Figure 16). Culvert end wall type 2 is for use when the culvert is oriented perpendicular to the direction of travel.



A type 1 drivable end wall is suitable for shielding the ends of pipes parallel to the road.

**Figure 16: Type One Drivable End Wall**



Source: Roads and Transport Authority of Dubai. 2008. *Roadside Design Guide for Dubai*. Dubai. .



A type 2 drivable end wall is suited for safeguarding the ends of cross culverts.

### C. Impact attenuators (crash cushions)

278. Crash cushions, also known as impact attenuators, are protective devices that significantly reduce the severity of impacts with fixed objects. They gradually decelerate a vehicle to a safe stop for head-on impacts and by redirecting a vehicle away from the fixed object for side impacts. Crash cushions are ideally suited for use at locations where fixed objects cannot be removed, relocated, or made to break away, and where they cannot be adequately shielded by a longitudinal barrier.

279. Commonly, crash cushions are applied at an exit ramp gore on an elevated or depressed structure in which a bridge rail end or a pier requires shielding. Frequently, crash cushions also are used to shield the ends of rigid barriers, especially those located along medians.

280. Another special use for crash cushions is the protection of construction and maintenance personnel as well as motorists in work zones. Portable and temporary crash cushions have been developed for use in such situations.

281. Crash cushions have proven to be effective and safe devices for shielding particular roadside hazards that cannot be shielded by other methods. Their use has saved many lives by reducing the severity of crashes. Their relatively low cost and potentially high safety payoff make them ideally suited for use at selected locations. Like other safety hardware, crash cushions lessen the severity of crashes rather than prevent them from occurring.

282. Most crash cushions are patented, and were carefully designed and tested by their manufacturers. It is suggested to seek acceptable units directly from the manufacturer's design charts, thus eliminating the need for case-by-case design in most instances.



Impact attenuators are well-suited for shielding rigid barrier ends in confined and heavily trafficked locations.



There is a variety of types of impact attenuators. Use only approved types.

#### D. Emergency crossings in medians

283. On expressways, continuous median barriers generally limit the opportunity for movements between carriageways. However, provision for access between carriageways may be required for emergencies. The need for, and locations of, emergency median openings must be established as part of a route-specific emergency and incident management plan.

284. It is important that such openings only be provided as a last resort. The preferred option is to have sufficient overpasses, underpasses, or interchanges so emergency vehicles can access either carriageway in minimum time. However, if there must be an “at grade” median crossing, it needs careful design. It should also be restricted to emergency vehicles only. It is very unsafe if other vehicles use such openings as U-turn facilities.

285. In a median with sufficient width, and where WRSBs are installed, it is possible to provide emergency access between carriageways by having a terminal of the barrier on one side of the median shielded by the overlapping barrier on the other side. This minimizes the probability an errant vehicle will cross onto the wrong carriageway, while allowing access for emergency vehicles.

286. The overlapping of flexible or semirigid barriers to provide an emergency vehicle crossing is only possible if the median is wide enough to allow a minimum width of 4 m between the barriers. Otherwise, the passage of vehicles will be restricted.

287. In a median where a rigid barrier has been installed, a crossing between carriageways can be

provided by the use of a reinforced steel barrier section which replaces part of the concrete barrier. Typically, the steel section slides along the barrier to create an opening in the event of an emergency. Emergency median crossing facilities for concrete barriers are proprietary products, and must be designed and installed in accordance with manufacturer’s specifications.



There are several products that close median openings, provide good containment levels, and still permit ready access by authorities during an emergency.



These products can be winched open by an authorized person, and traffic can pass safely from one carriageway to the other during an emergency. It should remain firmly closed at all other times.

288. Median openings created by providing a gap in a concrete barrier are not recommended. They should only be used if approved barrier terminals or crash cushions are installed to shield the ends of the barrier, and if the risk of an errant vehicle crossing between carriageways through the gap is low. In addition, frangible bollards should be installed in the opening to discourage nonemergency vehicles from using the crossing. Maintenance vehicles must not use these crossings, unless they are involved in emergency activities.



# Glossary of Terms



**Advance warning sign.** A sign placed in advance of the road works to provide advance warning to approaching traffic.

**Anchorage.** Another term for a barrier terminal (see below).

**Barrier terminal.** A device installed at the end of a safety barrier, designed to shield vehicles from collisions with an exposed barrier end.

**CAREC highway.** One of the designated national and/or international highways under the CAREC program.

**Clearance.** The lateral distance between a safety barrier and a roadside hazard.

**Clear zone.** The width of an area beside a road (measured at right angles from the edge line or the edge of the nearest lane) to be kept free of fixed roadside hazards and steep side slopes so errant vehicles can recover or stop before striking a hazard.

**Client.** The road authority responsible for the road and/or highway.

**Consultant.** The client's representative for the project.

**Contractor.** The company contracted to undertake the work for the client.

**Crash.** A rare random multifactorial event in which one or more road users fail to cope with their environment. It includes a motor vehicle colliding with a fixed roadside object resulting in property damage, injury, or death.

**Crash cushion.** A device that prevents an errant vehicle from impacting fixed objects by gradually decelerating the vehicle to a stop, or by redirecting the vehicle away from the fixed object. It is also known as an impact attenuator.

**Critical slope.** A side slope on which most errant vehicles are likely to overturn (roll over).

**Deflection.** The transverse displacement of a safety barrier during an impact by an errant vehicle.

**Delineation.** A general term for the signs and devices used to provide clear definition of the designated traffic path through a road work site.

**Errant vehicle.** A vehicle out of control (for any reason) and traveling (usually at speed) off the road.

**Flare.** The increasing (or decreasing) variable offset of a barrier from the traffic lane.

**Flexible barrier.** A barrier made from wire rope and supported by frangible posts. These barriers deflect more than other barrier types; they are, therefore, often the best option for minimizing injuries to vehicles' occupants.

**Frangible.** The ability of a device, including structure supports, posts, and poles, to break away or be deformed upon impact by an errant vehicle without causing significant risk of serious injury to vehicles' occupants.

**Gating terminal.** A barrier terminal designed to break away or yield to allow a vehicle to pass through and beyond the terminal when impacted at an angle.

**High-speed road.** A road where vehicle speeds are typically greater than 60 kilometers per hour.

**Impact attenuator.** A device, designed to absorb an errant vehicle's kinetic energy, intended to reduce the damage to structures, vehicles, and road users resulting from a motor vehicle collision.

**Length of need.** The length of safety barrier system needed to prevent errant vehicles from colliding with a roadside hazard.

**Longitudinal barrier.** A safety barrier running generally parallel with the roadway. It is designed to prevent penetration and to safely redirect an errant vehicle away from a roadside hazard.

**Low-speed road.** A road where vehicle speeds are typically 60 kilometers per hour or less.

**Median barrier.** A longitudinal barrier located in a median of a divided road. It is designed to prevent an

errant vehicle crossing from one carriageway to the other, or to shield roadside hazards within the median.

**Multilane.** Two or more traffic lanes in one direction.

**Nongating terminal.** Terminals designed to redirect and absorb some of the energy of an impacting vehicle at any point along the terminal, without allowing the vehicle to pass behind the barrier system.

**Nonrecoverable slope.** A roadside slope that is traversable but on which an errant vehicle will not be able to recover and return to the roadway. The vehicle will continue to the bottom of the slope without significant risk of overturning.

**Offset.** Lateral distance from the traffic lane to a roadside hazard, including safety barriers.

**Performance level.** The degree to which a longitudinal barrier, including bridge barrier, is designed for containment and redirection of different types of vehicles.

**Pocketing.** An errant vehicle striking a barrier but directed by that barrier into a fixed object.

**Posted speed limit.** The maximum legal speed limit for a road indicated on a sign.

**Proprietary system.** A safety barrier system that is the subject of a patent (or other intellectual property rights), thus preventing the use of its design without authorization or purchase from the manufacturer.

**Public domain system.** A safety barrier system that is not the subject of a patent (or other intellectual property rights), hence, its design may be used without restriction.

**Recoverable slope.** A side slope on which a driver can generally retain (or regain) control of an errant vehicle.

**Rigid barrier.** A barrier made of concrete designed not to deflect. They are used where there is no room for the deflections associated with semirigid or flexible barrier systems. Depending on their height and other details, these provide the highest level of containment of heavy vehicles.

**Roadside.** The area between the boundary of the road reservation and the edge of the shoulder, or traffic lane in the absence of a shoulder. The median

between carriageways of a divided road is also a part of the roadside.

**Roadside hazard.** Any feature located in the clear zone (along the roadside or within the median) that could cause significant injury to vehicles' occupants in an errant vehicle.

**Road user.** Any driver, rider, passenger, or pedestrian using the road.

**Roadway.** That portion of the road for the use of vehicles, including the shoulders and auxiliary lanes.

**Road work.** Any work on a road or a roadside that has potential to disturb traffic flow and/or safety.

**Road worker.** Any person engaged in work on a road or roadside.

**Safety barrier.** A physical barrier separating a hazard from the traveled way, designed to resist penetration by an out-of-control vehicle and, as far as practicable, to redirect the colliding vehicle back into the traveled path.

**Safety barrier system.** A device generally constructed of steel, concrete, or steel cables designed to contain and redirect errant vehicles by providing a physical restriction to penetration in a way that reduces the risk of injury to occupants of the errant vehicle and other traffic. A safety barrier system consists of end terminals and longitudinal safety barriers.

**Semirigid barrier.** A barrier usually made from steel beams or rails. Commonly called "guardrail," it deflects less than a flexible barrier and so can be located closer to a hazard when space is limited.

**Shielding.** The introduction of a barrier or crash cushion between the road and a roadside hazard to prevent or reduce the risk of a crash involving the hazard.

**Side track.** A short road constructed to take traffic away from the work zone. It may be a one-way or a two-way road, and is like a diversion.

**Slope.** The relative steepness of the terrain expressed as a ratio or percentage. Slopes may be fill slopes or cut slopes, and parallel or cross slopes in relation to the direction of traffic.

**Test level.** A set of conditions, defined in terms of vehicle type and mass, vehicle impact speed, and impact angle, which quantifies the impact severity of a matrix of crash tests as specified by National Cooperative Highway Research Program Report 350 (an update with American Association of State Highway and Transportation Officials' Manual for Assessing Safety Hardware).

**Traffic.** All vehicles (including cars, trucks, buses, bicycles, motorcycles, and animal-drawn vehicles), persons, and animals traveling on the road.

**Traffic control devices.** The signs, cones, barriers, and other devices placed on or near the road to regulate, warn, or guide road users.

**Traffic lane.** A portion of a road used for the movement of traffic (excluding shoulders).

**Transition.** A section between two different barrier types which allows a gradual change in the properties of the barrier so there is no discontinuity that would be hazardous in the event of an impact (such as pocketing of a vehicle).

**Traversable slope.** A roadside slope which is relatively smooth, sufficiently compacted, and free of fixed objects, and which allows a driver to retain or regain control of a vehicle or stop safely.

**Two-way roadway.** A roadway with lanes allotted for use by traffic in opposing directions without physical separation between them.

**Vaulting.** The term used when an errant vehicle rises into the air (usually due to striking a curb or some other object) and passes over the safety barrier. Vaulting often increases injury levels for vehicles' occupants as the vehicle often rolls over.

**Vulnerable road user.** A road user group considered most vulnerable, due to their relative frailty, in the event of a collision with a motor vehicle. The most common groups of vulnerable road users on CAREC highways are pedestrians, bicyclists, motorcyclists, and animal-drawn vehicles and/or carts.

**Working width.** The width that includes the barrier deflection plus the roll distance of an impacting high vehicle. It is a necessary consideration when designing barriers to shield hazards, such as bridge supporting piers on expressways from impacts by large trucks. For rigid barriers, this is also known as the zone of intrusion.

# Reading List



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## **CAREC Road Safety Engineering Manual 3**

### *Roadside Hazard Management*

Single vehicle “run-of-road” crashes are a significant problem on CAREC roads. They are particularly severe and can occur anywhere and at any time. Identifying, investigating, and treating roadside hazards are significant road safety challenges along CAREC highways. This third manual in the series provides practical information about roadside hazard management for CAREC countries. It uses a roadside hazard management strategy and the clear zone concept to explain how CAREC road authorities can: (i) identify roadside hazards, (ii) investigate how best to treat those roadside hazards, and (iii) implement effective safety improvements. The manual explains the three groups of safety barriers and offers options for safer roadside furniture.

### **About the Central Asia Regional Economic Cooperation Program**

The Central Asia Regional Economic Cooperation (CAREC) Program is a partnership of 11 member countries and development partners working together to promote development through cooperation, leading to accelerated economic growth and poverty reduction. It is guided by the overarching vision of “Good Neighbors, Good Partners, and Good Prospects.” CAREC countries include: Afghanistan, Azerbaijan, the People’s Republic of China, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Pakistan, Tajikistan, Turkmenistan, and Uzbekistan. ADB serves as the CAREC Secretariat.

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ADB’s vision is an Asia and Pacific region free of poverty. Its mission is to help its developing member countries reduce poverty and improve the quality of life of their people. Despite the region’s many successes, it remains home to a large share of the world’s poor. ADB is committed to reducing poverty through inclusive economic growth, environmentally sustainable growth, and regional integration.

Based in Manila, ADB is owned by 67 members, including 48 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.



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