Roadside Safety Design and Devices

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Roadside Safety

Introduction

Most of the highway design fundamentals were established by the late 1940s. These components included horizontal alignment, vertical alignment, hydraulic design, and sight distance to name some of the more common highway design elements. These elements have been revised and refined over the years through experience and research. However, the highway design components themselves have remained about the same for several decades.

Roadside safety design, as one component of total highway design, is a relatively recent concept. Roadside safety design did not become a much discussed aspect of highway design until the late 1960s, and it was the decade of the 1970s before this type of design was regularly incorporated into highway projects [1].

In recent years, the Safe Systems approach to road safety, which was initially developed in Sweden, has been adopted by a number of countries as part of their road safety strategies. This approach involves the implementation of a range of targeted measures to manage vehicles, road and roadside infrastructure, as well as vehicle speeds [2].

Figure 1: Safe System Approach

The approach is built on three key concepts:

1. Human Behaviour:

People make mistakes and the road transport system needs to accommodate this.

Figure 2: Roadside Accident

2. Human Frailty (Weakness):

The finite capacity of the human body to withstand physical force before a serious injury or fatality.

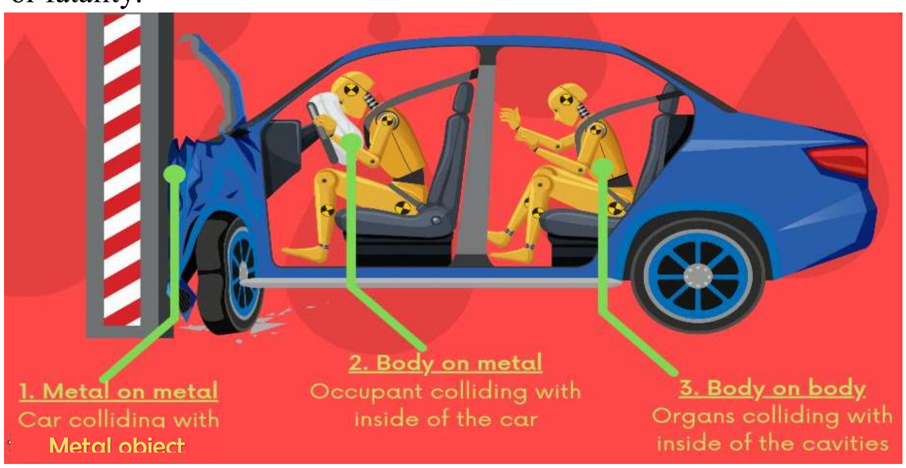


Figure 3: Car accident effect on the human body

3. Forgiving Systems:

Roads that we travel on, vehicles we travel in, speeds we travel at and the attitudes of road users to each other, need to be more forgiving of human error.

Figure 5: Passive safe columns and sign posts

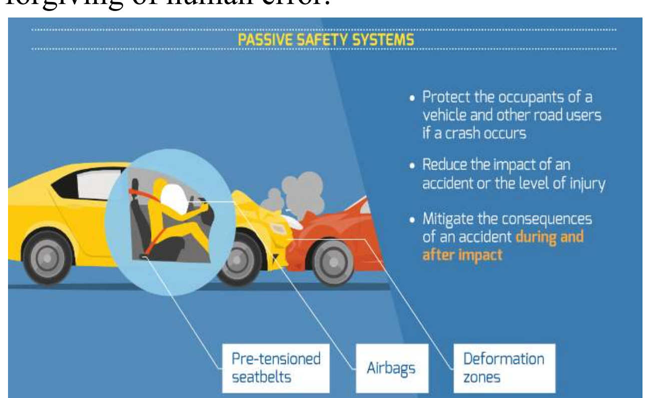


Figure 4: Passive safety System

Under the Safe System approach, addressing severe run-off-road crashes through safer roads and roadsides involves providing roads that [2]:

1. Minimize the risk of vehicles leaving the carriageway.
2. Provide adequate recovery space when vehicles do run off the road.
3. Ensure that any collision that does occur in the roadside will be with objects that limit the impact forces on vehicle occupants to minor levels (no fatal or serious injury outcomes).

The Benefits of Roadside Safety

Roadside design might be defined as the design of the area outside the traveled way. Some have referred to this aspect of highway design as off-pavement design. A question commonly asked revolves around whether spending resources off the pavement is really beneficial given the limited nature of infrastructure funds. Perhaps some statistics can bring the potential of crash reduction and roadside safety into focus [2].

Frequent and serious traffic accidents have become a focal issue because they hinder the sustainable development of society. In China, roadside accidents account for 40% of fatalities resulting from traffic accidents. Roadside safety has become an important issue of traffic management departments worldwide, and performing research on roadside safety contributes to improving the level of road safety and reducing the number of traffic accidents and fatalities [3].

According to Fatality Analysis Reporting System (FARS), 8% of all fatalities on divided highways are due to head-on crashes. When median barriers installed on rural Four-Lane Freeways; 97% reduction occurs in cross-median crashes [4].

Figure 6: Median cable barrier prevents a potential head-on crash

Roadside Hazard Management

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.

A vehicle will leave the roadway and encroach on the roadside for many reasons, including the following:

1. Driver fatigue
2. Driver distractions or inattention
3. Excessive speed
4. Driving under the influence of drugs or alcohol
5. Crash avoidance
6. Adverse roadway conditions, such as ice, snow, or rain
7. Vehicle component failure
8. Poor visibility

The concept of forgiving roads is at the core of the Safe System approach. The forgiving roadside concept allows for errant vehicles leaving the roadway and supports a roadside design in which the serious consequences of such incidents are reduced.

Through decades of experience and research, the application of the forgiving roadside concept has been refined to the point where roadside design is an integral part of the transportation design process. Design options for reducing roadside obstacles, in order of preference, are as follows:

1. Remove the obstacle.
2. Redesign the obstacle so it can be safely traversed.
3. Relocate the obstacle to a point where it is less likely to be struck.
4. Reduce impact severity by using an appropriate breakaway device.
5. Shield the obstacle with a longitudinal traffic barrier designed for redirection or use a crash cushion.
6. Delineate the obstacle if the previous alternatives are not appropriate.

The main types of obstacles that may be found on roadsides and which may represent a risk to vehicle occupants in the event of a driver losing control of the vehicle. Roadside obstacles are categorized under the following three headings [5]:

a.Single Fixed Objects, including:

- Trees.
- Rocks and boulders
- Utility poles and lighting posts
- Safety barrier terminals and transitions
- Headwalls
- Headstones

Figure 7: Utility poles and trees in close proximity to the roadway

b. Continuous Hazards, including:

- Embankments and slopes
- Ditches
- Road restraint systems
- Kerbs
- Permanent water bodies
- Pavement edge

Figure 8: Pavement-Edge Drop-off

c. Dynamic roadside hazards, including:

- Bicycles
- Pedestrians
- Parking
- Temporary advertising signs

Figure 9: Dynamic roadside hazards

According to the Insurance Institute for Highway Safety (IIHS) and Highway Loss Data Institute (HLDI), the proportion of motor vehicle deaths involving collisions with fixed objects has fluctuated between 19 and 23 percent since 1979. Figure **10** shows the percentage distribution of fixed-object fatalities by the object struck in 2008 [5].

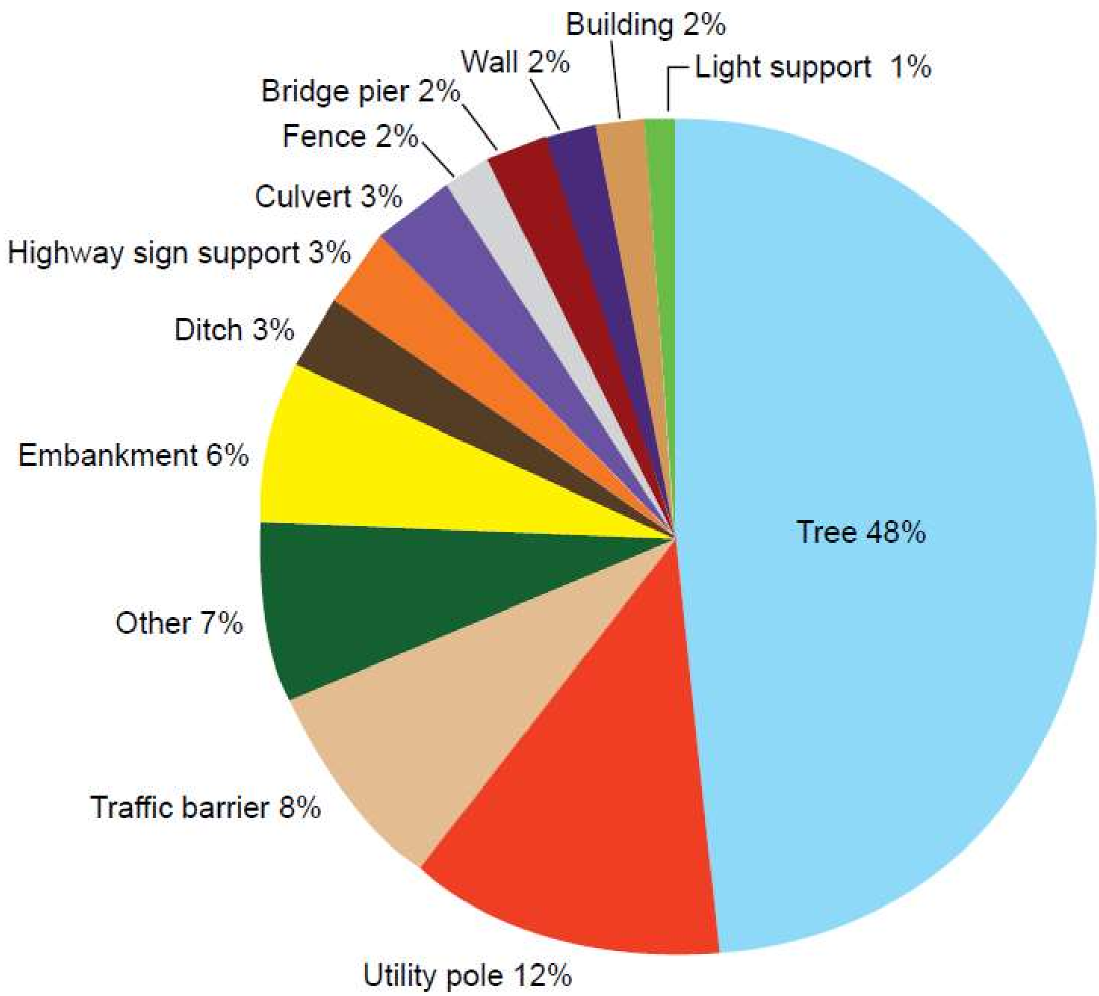


Figure 10: Distribution of Fixed-Object Fatalities, 2008

Roadside Geometry

If a roadside is not flat, a motorist leaving the roadway will encounter a foreslope, a backslope, a transverse slope, or a drainage channel, as shown in Figure 3-1. Each of these features has an effect on a vehicle's lateral encroachment and trajectory as discussed in the following sections:

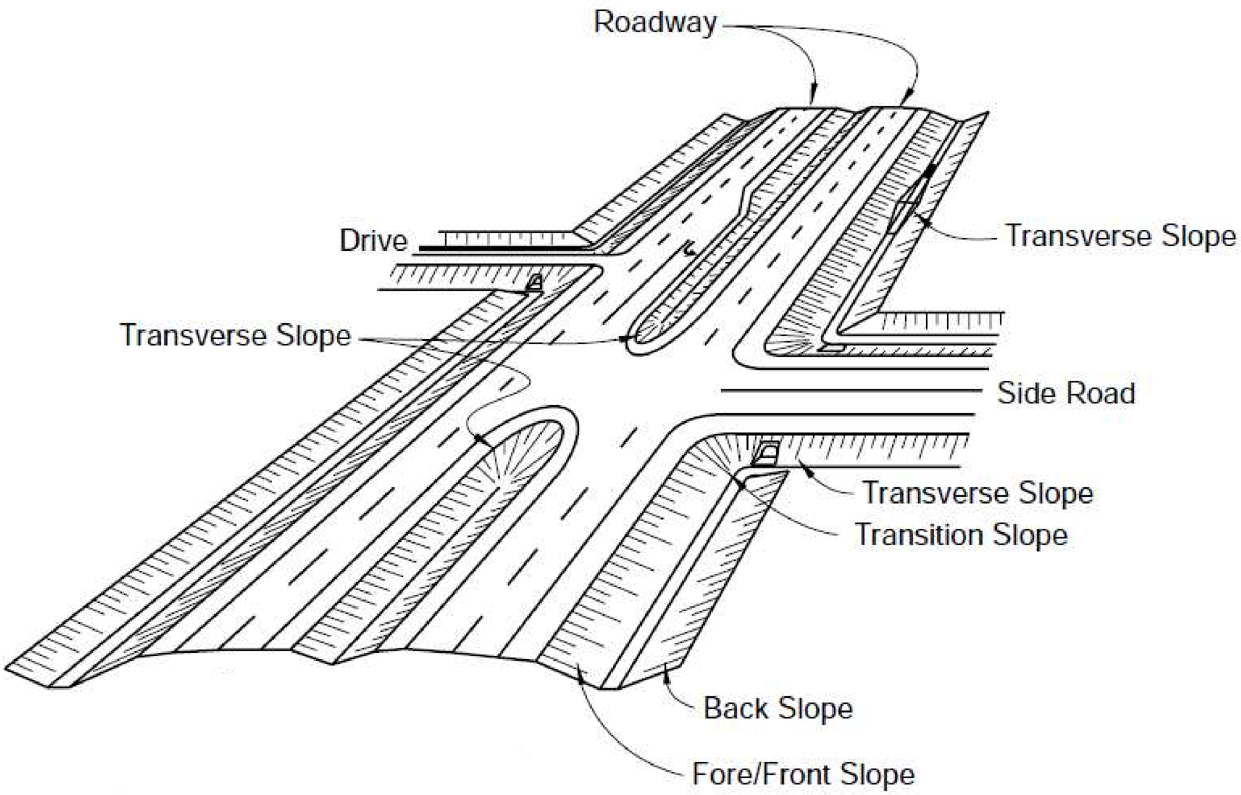


Figure 11: Roadway Geometry Features

1. Foreslopes

Foreslopes parallel to the flow of traffic may be identified as recoverable, non-recoverable, or critical.

Recoverable foreslopes are 1V:4H or flatter. If such slopes are relatively smooth and traversable, the suggested clear-zone distance may be taken directly Table 1.

A non-recoverable foreslope is defined as one that is traversable but from which most vehicles will not be able to stop or return to the roadway easily. Vehicles on such slopes typically can be expected to reach the bottom. Foreslopes between 1V:3H and 1V:4H generally fall into this category.

A critical foreslope is one on which an errant vehicle has a higher propensity to overturn. Foreslopes steeper than 1V:3H generally fall into this category. If a foreslope steeper than 1V:3H begins closer to the edge of the traveled way than the suggested clear-zone distance for that specific roadway, a barrier might be recommended if the slope cannot readily be flattened.

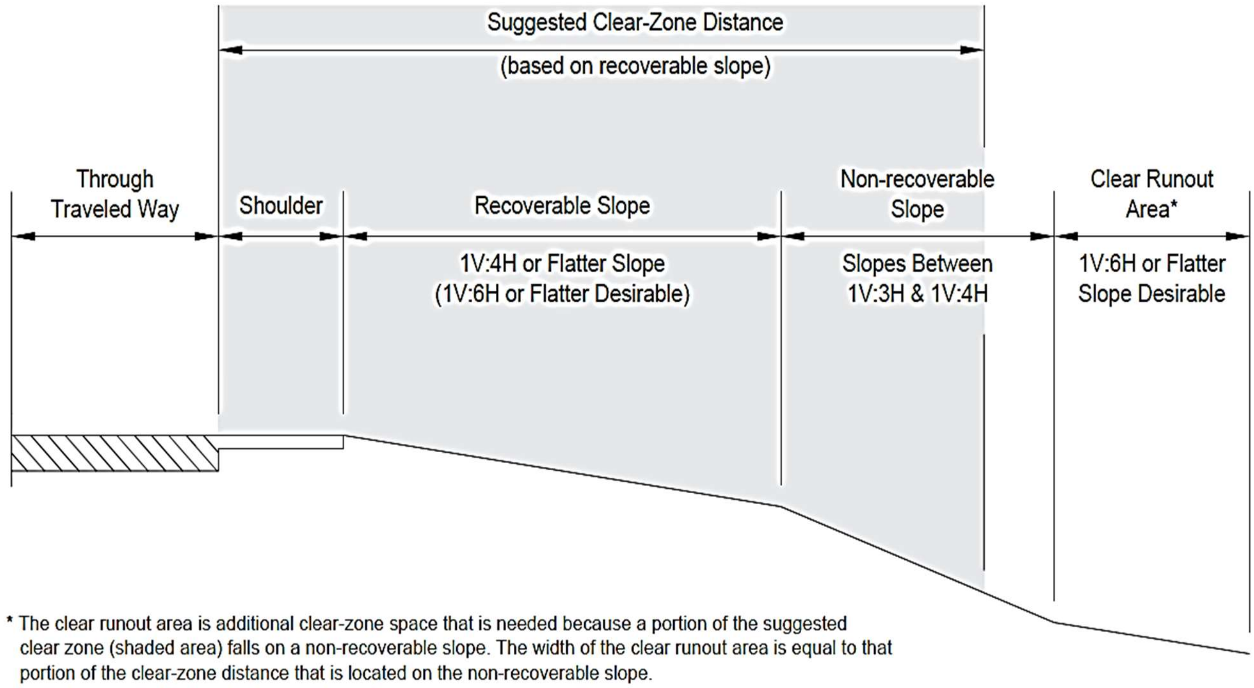


Figure 12: Clear Zone for Non-Recoverable Parallel Foreslope

2. Backslopes

When a highway is located in a cut section, the backslope may be traversable depending on its relative smoothness and the presence of fixed obstacles. If the foreslope between the roadway and the base of the backslope is traversable (1V:3H or flatter) and the backslope is obstacle-free, it may not be a significant obstacle, regardless of its distance from the roadway. On the other hand, a steep, rough sided rock cut normally should begin outside the clear zone or be shielded. A rock cut normally is considered to be rough-sided when the face will cause excessive vehicle snagging rather than provide relatively smooth redirection.

3. Transverse slopes

A common obstacle on roadsides are transverse slopes created by median crossovers, berms, driveways, or intersecting side roads. Although the exposure for transverse slopes is less than that for foreslopes or backslopes, they generally are more critical to errant motorists because run-off-the-road vehicles typically strike them head-on.

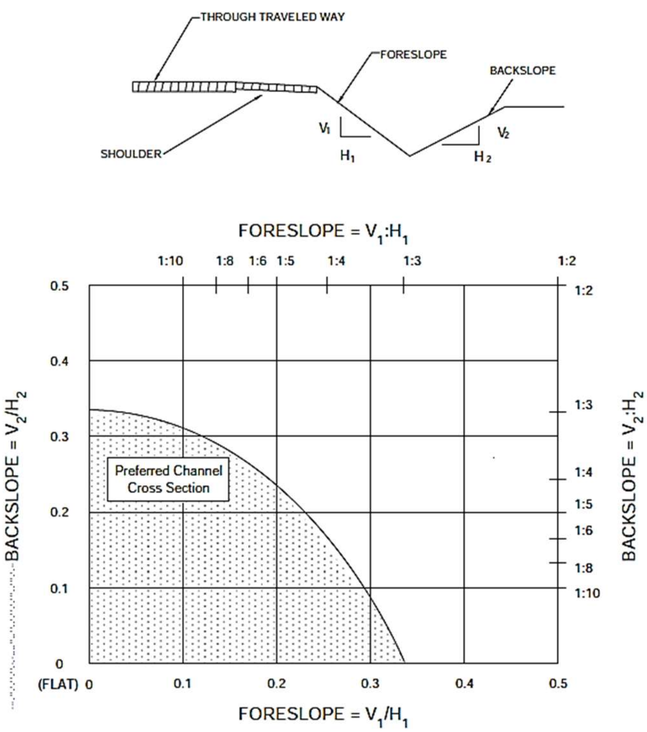
Transverse slopes of 1V:10H are desirable. While transverse slopes of 1V:6H or flatter are suggested for high-speed roadways.

4. Drainage channels

A drainage channel is an open channel usually paralleling the roadway. The primary function of drainage channels is to collect surface runoff from the roadway and areas that drain to the right-of-way and convey the accumulated runoff to acceptable outlet points.

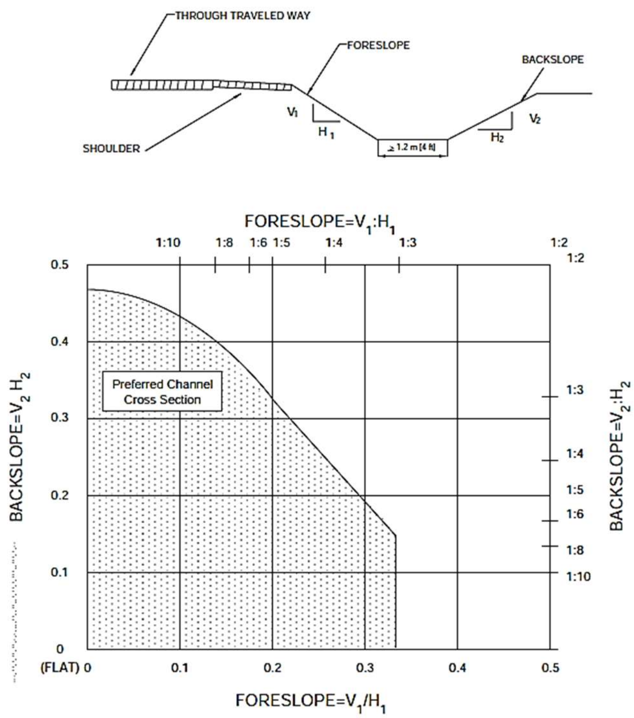
Channels should be designed, built, and maintained with consideration given to their effect on the roadside environment.

Figure 14 and Figure 13 present preferred foreslopes and backslopes for basic ditch configurations.



*This chart is applicable to all Vee ditches, rounded channels with a bottom width less than 2.4 m [8 ft] and trapezoidal channels with bottom widths less than 1.2 m [4 ft].

Figure 14: Preferred Cross Section for Channels with Abrupt Slope Changes



*This chart is applicable to rounded channels with bottom widths of 2.4 m [8 ft] or more and to trapezoidal channels with bottom widths equal to or greater than 1.2 m [4 ft].

Figure 13: Preferred Cross Sections for Channels with Gradual Slope Changes

Cross sections shown in the shaded region of each figure are considered to have traversable cross sections.

Channel sections that fall outside the shaded region are considered less desirable and their use should be limited where high-angle encroachments can be expected, such as the outside of relatively sharp curves.

Channel sections outside the shaded region may be acceptable for projects having one or more of the following characteristics: restrictive right-of-way environmental constraints; rugged terrain; resurfacing, restoration, or rehabilitation (3R) projects; or low-volume or low-speed roads and streets, particularly if the channel bottom and backslopes are free of any fixed objects or located beyond suggested clear-zone distance.

Treatments to make Roadsides Forgiving

The common treatment solutions to make roadsides safer are three categories of works that should be considered [5]:

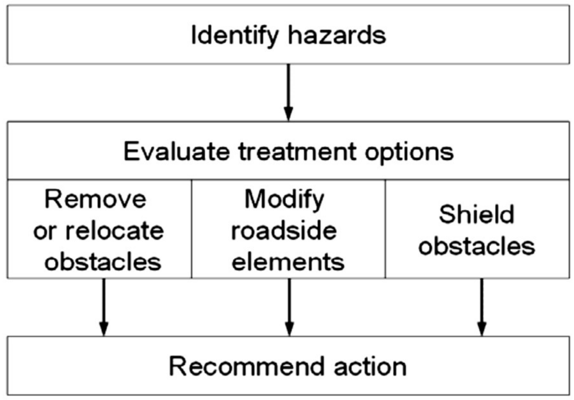


Figure 13 - Procedure for forgiving roadside treatments

1) **Removing and Relocating Obstacles:**

a. **The Clear Zone concept:**

The most effective roadside improvement can be accomplished by providing a Clear Zone. This provides motorists with room and opportunity to regain control of their vehicle in case of a run-off. Objects that cannot be eliminated should be relocated outside the Clear Zone. It may be divided into two areas: the recovery zone (hard shoulders) and the limited severity zone (See Figure 15)

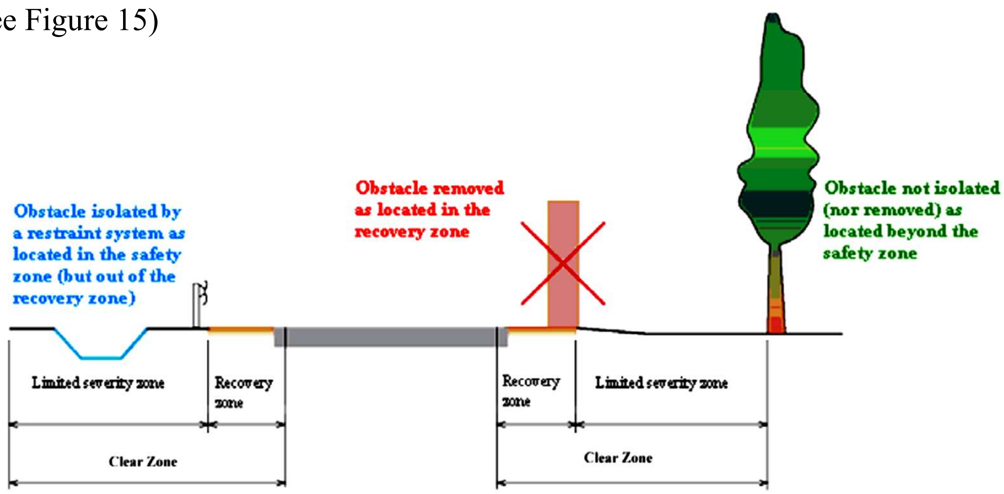


Figure 15: Clear Zone Concept

The width of Clear Zones varies throughout the world, depending on the underlying policy and practicability. Common criteria for determining the dimensions are design speed, side slope gradients, road type, horizontal alignment (straight or curved roads), driving lane width and percentage of heavy-vehicles.

Table **1** used to determine the suggested clear-zone distance for traffic volumes and speeds [2].

Table 1: Suggested Clear-Zone Distance from Edge of Through Travel

Design Speed (km/h)	Design ADT	Foreslopes			Backslopes		
		1V:6H or flatter	1V:5H to 1V:4H	1V:3H	1V:3H	1V:5H to 1V:4H	1V:6H or flatter
≤60	UNDER 750[c]	2.0–3.0	2.0–3.0	[b]	2.0–3.0	2.0–3.0	2.0–3.0
	750–1500	3.0–3.5	3.5–4.5	[b]	3.0–3.5	3.0–3.5	3.0–3.5
	1500–6000	3.5–4.5	4.5–5.0	[b]	3.5–4.5	3.5–4.5	3.5–4.5
	OVER 6000	4.5–5.0	5.0–5.5	[b]	4.5–5.0	4.5–5.0	4.5–5.0
70–80	UNDER 750[c]	3.0–3.5	3.5–4.5	[b]	2.5–3.0	2.5–3.0	3.0–3.5
	750–1500	4.5–5.0	5.0–6.0	[b]	3.0–3.5	3.5–4.5	4.5–5.0
	1500–6000	5.0–5.5	6.0–8.0	[b]	3.5–4.5	4.5–5.0	5.0–5.5
	OVER 6000	6.0–6.5	7.5–8.5	[b]	4.5–5.0	5.5–6.0	6.0–6.5
90	UNDER 750[c]	3.5–4.5	4.5–5.5	[b]	2.5–3.0	3.0–3.5	3.0–3.5
	750–1500	5.0–5.5	6.0–7.5	[b]	3.0–3.5	4.5–5.0	5.0–5.5
	1500–6000	6.0–6.5	7.5–9.0	[b]	4.5–5.0	5.0–5.5	6.0–6.5
	OVER 6000	6.5–7.5	8.0–10.0[a]	[b]	5.0–5.5	6.0–6.5	6.5–7.5
100	UNDER 750[c]	5.0–5.5	6.0–7.5	[b]	3.0–3.5	3.5–4.5	4.5–5.0
	750–1500	6.0–7.5	8.0–10.0[a]	[b]	3.5–4.5	5.0–5.5	6.0–6.5
	1500–6000	8.0–9.0	10.0–12.0[a]	[b]	4.5–5.5	5.5–6.5	7.5–8.0
	OVER 6000	9.0–10.0[a]	11.0–13.5[a]	[b]	6.0–6.5	7.5–8.0	8.0–8.5
110[d]	UNDER 750[c]	5.5–6.0	6.0–8.0	[b]	3.0–3.5	4.5–5.0	4.5–5.0
	750–1500	7.5–8.0	8.5–11.0[a]	[b]	3.5–5.0	5.5–6.0	6.0–6.5
	1500–6000	8.5–10.0[a]	10.5–13.0[a]	[b]	5.0–6.0	6.5–7.5	8.0–8.5
	OVER 6000	9.0–10.51	11.5–14.0[a]	[b]	6.5–7.5	8.0–9.0	8.5–9.0

b. Arrester beds in lane diverge areas:

Arrester beds in lane diverge areas are treatments for vehicles that have lost their braking ability. They reduce the speed of the vehicle and prevent it from going off the road, with no impact against a crash cushion. While they are often used on roads with long downgrades e.g. in mountainous areas, they are also called emergency escape ramps or runaway truck lanes as they are mainly designed to accommodate large trucks to prevent roadside crashes.

Figure 16: Examples of arrester beds

c. Safe plantation:

Controlling roadside vegetation helps to reduce crashes and injuries

d. Roundabouts:

The possibility of a vehicle entering the center of the roundabout is increased due to the 90 degree angle of approach to a roundabout. It is, therefore, advised to keep this area free from any objects.

It is not possible to protect objects in the center of a roundabout with a safety barrier due to the 90 degree angle of approach, as safety barriers are tested at angles of impact of only 30 degrees.

2) Modifying Roadside Elements:

In some cases, it is not possible to remove hazardous obstacles from the Clear Zone. In such circumstances, single and continuous hazards should be modified in order to minimize the risk of personal injury and property damage in the event of a crash. The risks posed by such hazardous obstacles should be reduced by making them breakaway or crashworthy. The following chapters show different treatments to make non-removable obstacles more forgiving [5]:

1. Breakaway devices.
2. Ditch and slope treatments.
3. Route-Based Curve Treatments
4. Crashworthy masonry structures.
5. Shoulder modifications.
6. Modification of retaining walls and rock cuts.
7. Safety barrier terminals.
8. Safety barrier transitions.

Figure 17: Breakaway devices (Passive Safety Pole)

3) Shielding Obstacles:

In many cases, removing or modifying hazardous objects from a roadside is not feasible. To prevent collisions of vehicles with these objects, the third recommended treatment involves shielding hazardous objects through the use of Road Restraint Systems (RRS). The object is fully protected, so that errant vehicles crash into the RRS, which reduce the severity of the impact. While these treatments may appear as hazardous objects themselves, the severity of crashes would be greater in the absence of RRS.

The most important group of RRS is safety barriers. These prevent errant vehicles from leaving the roadway and therefore reduce the risk and severity of collisions with hazardous objects. Safety barriers can be installed either on the roadside or in the median.

Roadside Barriers

A roadside barrier is a longitudinal barrier used to shield motorists from natural or man-made obstacles located along either side of a traveled way. It also may be used to protect bystanders, pedestrians, and cyclists from vehicular traffic under special conditions.

The primary purpose of all roadside barriers is to reduce the probability of an errant vehicle striking a fixed object or terrain feature off the traveled way that is less forgiving than striking the barrier itself.

Figure 18: Roadside Barriers

1. Barriers Recommendation

Typically, barrier recommendations have been based on a subjective analysis of certain roadside elements or conditions. A barrier is considered if the consequences of a vehicle striking a fixed object or running off the road are believed to be more serious than hitting a traffic barrier.

Barrier installation criteria may also be established by using a benefit-cost analysis whereby factors, such as design speed and traffic volume, can be evaluated in relation to barrier need. Costs associated with the barrier, such as installation costs, maintenance costs, and crash costs, are compared to similar costs without barriers.

2. Roadside Geometry and Terrain Features

Embankment height and side slope are the basic factors considered in determining barrier need as shown in Figure 19. These criteria are based on studies of the relative severity of encroachments on embankments versus impacts with roadside barriers.

Figure 20 is a modified barrier consideration chart developed by a state that addresses the decreased probability of encroachments on lower volume roads.

Figure 21 is another example of a modified barrier consideration chart, one which considers the cost-effectiveness of barrier installation for the site-specific conditions noted on the chart. **Figure 20** and Figure 21 are presented as examples only and are not intended for direct application without similar studies conducted for the highway agency's specific needs. Highway agencies can develop similar barrier consideration criteria based upon their own cost-effectiveness evaluations.

Some additional factors to be considered in the evaluation other than the traditional accident and construction costs are environmental impacts, cost for additional right of way and the cost of utility adjustments, to name a few.

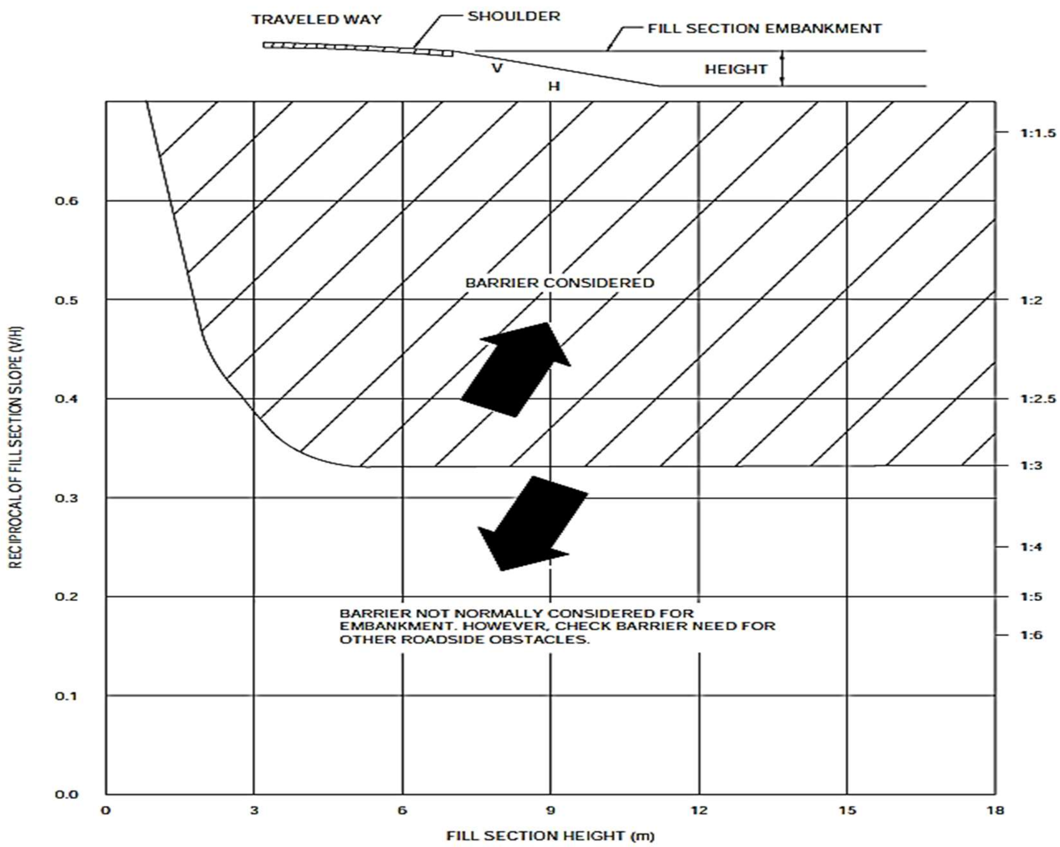


Figure 19: Comparative Barrier Consideration for Embankments

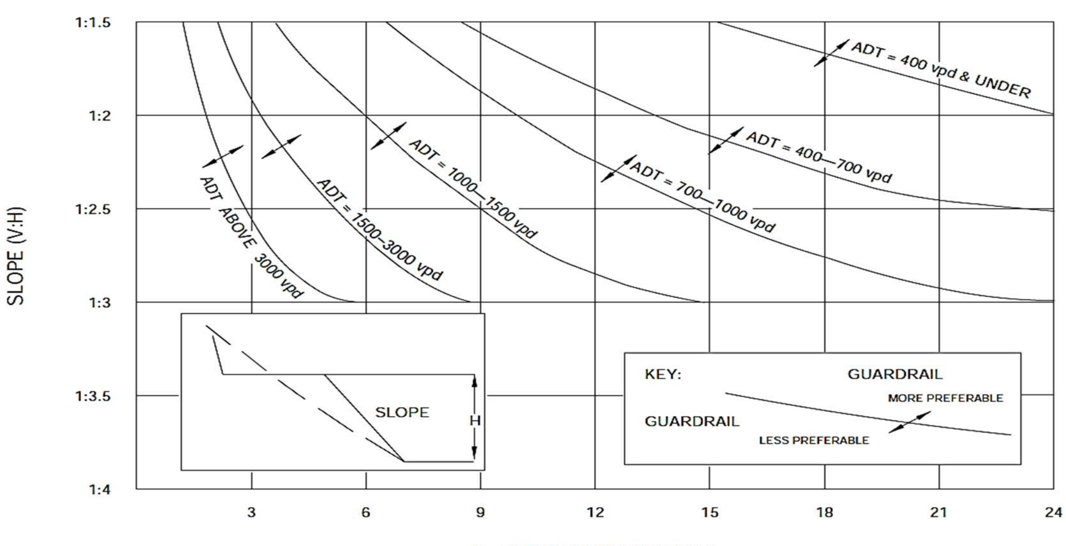


Figure 20: Example Design Chart for Embankment Barriers Consideration Based on Height, Slope and Traffic Volume

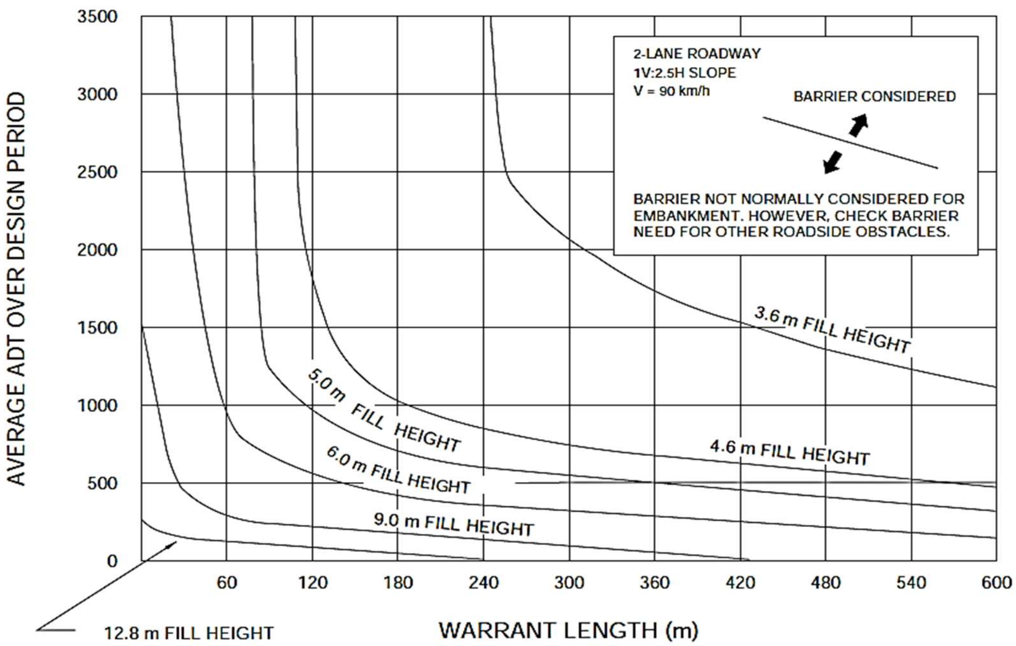


Figure 21: Example Design Chart for Cost effective Barrier for Embankments Based on Traffic Speed and Volume , Slope Geometry and Length of Slope

3. Structural and Safety Characteristics of Roadside Barriers

Figure 22 graphically depicts each of these elements for typical installations. Information on the structural and safety characteristics of each system is presented in narrative format.

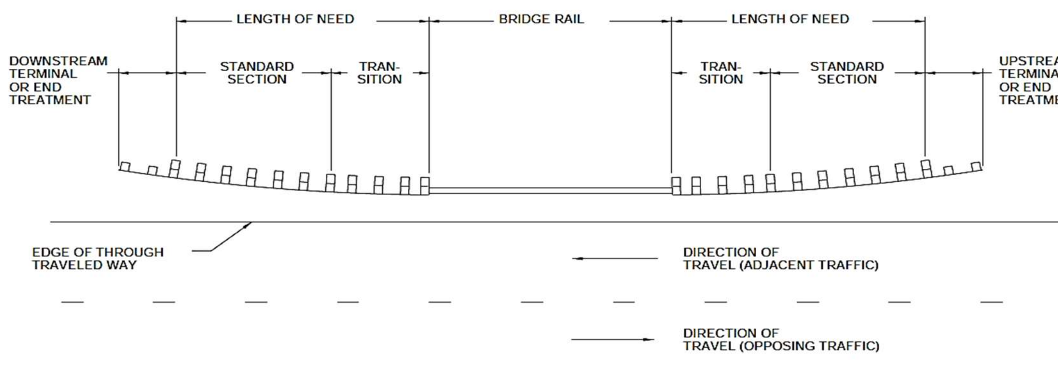


Figure 22: Definition of Roadside Barriers

4. Standard Sections of Roadside Barriers

Safety barriers are categorized in the following three groups, depending on their deflection characteristics resulting from an impact:

1. Rigid barriers.
2. Semi-rigid barriers.
3. Flexible barriers.

Table 2: Roadside Barriers

System	Test Level	FHWA Acceptance Letter
FLEXIBLE SYSTEMS		
W-Beam (Weak Post)	2	B-64
Three-Strand Cable (Weak Post)	3	B-64
High-Tension Cable Barriers	3 and 4	Various
Modified W-Beam (Weak Post)	3	B-64
Ironwood Aesthetic Barrier	3	B-56, 56-A, and 56-B
SEMI-RIGID SYSTEMS		
Steel Post with Steel Blockout	2	B-64
Box Beam (Weak Post)	3	B-64
Steel or Wood Post with Wood or Plastic Blockout	3	B-64
NU-GUARD by Nucor Marion	3	B-162
Trinity T-31 and Trinity Guardrail System	3	B-140
Gregory (GMS)	3	B-150
Midwest Guardrail System (MGS)	3	B-133
Blocked-out Thrie-Beam (Strong Post)	3	B-64
Merritt Parkway Aesthetic Guardrail	3	B-38
Steel-Backed Timber Guardrail	2 and 3	B-64-D
Modified Thrie-Beam (Strong Post)	4	B-64
Trinity T-39 Non-Blocked-Out Thrie Beam	4	B-148
RIGID SYSTEMS (Concrete and Masonry)		
Stone Masonry Wall/Precast Masonry Wall	3	B-64-D
New Jersey Safety-Shape Barrier		
• 810 mm [32 in.] tall	4	B-64
• 1070 mm [42 in.] tall	5	B-64
F–Shape Barrier		
• 810 mm [32 in.]	4	B-64
• 1070 mm [42 in.]	5	B-64
Vertical Concrete Barrier		
• 810 mm [32 in.]	4	B-64
• 1070 mm [42 in.]	5	B-64
Single Slope Barrier		
• 810 mm [32 in.]	4	B-17, B-45
• 1070 mm [42 in.]	5	Note 1
Ontario Tall Wall Median Barrier	5	B-19

5. Median Barriers

Median barriers are longitudinal barriers most commonly used to separate opposing traffic on a divided highway. They also may be used along heavily traveled roadways to separate through traffic from local traffic or to separate high occupancy vehicle lanes from general-purpose lanes. Most median barriers are similar to the roadside barrier designs

The increased use of median barriers has some disadvantages. The initial costs of installing a barrier can be significant. In addition, the installation of a barrier will generally increase the number of reported crashes as it reduces the recovery area available. Another concern associated with the installation of a median barrier is that it will limit the options of maintenance and emergency service vehicles to cross the median. In snowy climates, a median barrier also may affect the ability to store snow in the median [2].

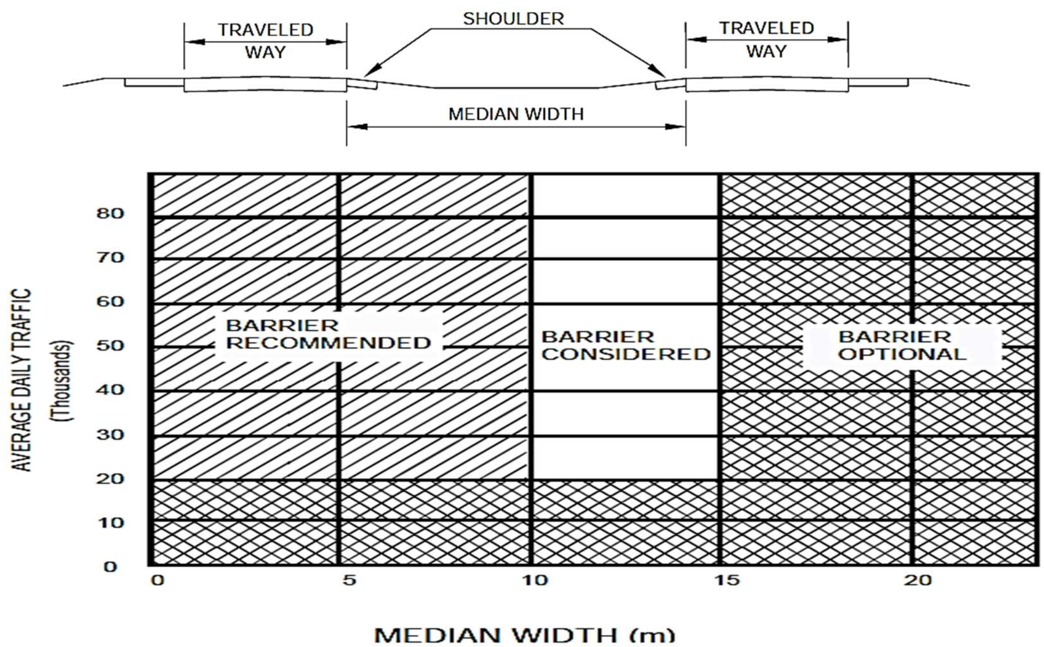


Figure 23: Guidelines for Median Barriers on High-Speed, Fully Controlled-Access Roadways

6. Test Level Selection Factors

Many barriers have been developed to accommodate both small cars and pickup trucks in accordance with National Cooperative Highway Research Program (NCHRP) Report 350, Manual for Assessing Safety Hardware (MASH) and European Normative (EN 1317) testing criteria. Properly designed and installed barrier systems have proven to be very effective in reducing the amount of damage and lessening the severity of personal injuries. Although objective warrants for the use of higher performance traffic barriers do not presently exist, subjective factors most often considered for new construction or safety upgrading include:

1. High percentage of heavy vehicles in the traffic stream or a high concentration of trucks at an interchange
2. Hazardous materials routes

3. Adverse geometrics, such as sharp curvature, which are often combined with limited sight distance, or long downhill grades combined with horizontal curvature
4. Severe consequences associated with penetration of a barrier by a large vehicle, such as multi-level interchange ramps, highly sensitive environmental areas, or critical highway components (nationally significant bridges or tunnels).

7. Barrier Standards Comparatives

The supporting parts of European Normative (EN) 1317 and AASHTO's Manual for Assessing Safety Hardware (MASH) are equivalent documents produced in Europe and the United States for assessing the safety performance of roadside hardware. While it is understood that there are some differences there are also many similarities.

Many people are confused regarding the status of NCHRP 350 and MASH. Much of this confusion is due to the implementation procedure for MASH compared to the implementation process used for NCHRP 350.

The purpose of MASH, like NCHRP 350, is to provide criteria and standards for evaluating new safety hardware devices. Neither MASH nor NCHRP 350 provides guidelines for the design of roadside safety hardware. This information is contained within the AASHTO Roadside Design Guide.

MASH and NCHRP 350 represent uniform guidelines used to conduct full-scale crash tests for permanent and temporary highway safety features along with recommended evaluation criteria to access the test results.

The major differences between NCHRP 350 and MASH can be summarized as follows [6]:

1. Test vehicles are updated to reflect the 85th percentile of the United States' passenger vehicle fleet.
2. Impact condition criteria were modified to correct inconsistencies and to identify needed conditions.
3. Evaluation criteria were modified to correct subjective criteria and to better define other criteria.

In March 2011, the International Road Federation endorsed the resolution by a global group of road safety experts who met at the TRB's Roadside Safety Design Subcommittee on International Research Activities on January 14, 2008.

This resolution recommends **"that road authorities in all countries should only specify roadside safety hardware, i.e., longitudinal safety barriers, crash cushions, terminals and transitions that has met either NCHRP 350 or EN 1317 criteria (or their updates)."** [6].

European Road Restraint Systems EN 1317

The parameters that determine the qualities of a vehicle restraint system and classify it within the standard EN 1317 are: the containment level, the working width, the dynamic deflection and the impact severity [7].

1. **Containment Level:**

It indicates the capacity of a containment system to withstand the impact load of a vehicle. To guarantee that the system contains the vehicle (no intrusion, no rollover)

Table 3: Containment Classes for road restraint systems

Containment Class	Normal		High			Very High	
EN-1317 Containment Level	**N1**	**N2**	**H1**	**H1**	**H3**	**H4a**	**H4b**

Table 4: Containment Levels for Road Restraint Systems

EN-1317 Containment Level	EN-1317 Test Designation	Vehicle Type	Test Conditions: Vehicle Mass (kg)	Speed (km/h)	Angle of Impact ()
N1	TB31	Light	1,500	80	20
N2	TB32	Light	1,500	110	20
	TB11	Light	900	100	20
H1	TB42	Heavy, non-articulated	10,000	70	15
	TB11	Light	900	100	20
L1	TB32	Light	1,500	110	20
H2	TB51	Bus	13,000	70	20
	TB11	Light	900	100	20
L2	TB32	Light	1,500	110	20
H3	TB61	Heavy, non-articulated	16,000	80	20
	TB11	Light	900	100	20
L3	TB32	Light	1,500	110	20
H4a	TB71	Heavy, non-articulated	30,000	65	20
	TB11	Light	900	100	20
L4a	TB32	Light	1,500	110	20
H4b	TB81	Heavy, articulated	38,000	65	20
	TB11	Light	900	100	20
L4b	TB32	Light	1,500	110	20

2. **Working Width (W):**

It is the distance between the traffic face of the restraint system before the impact, and the furthest lateral position reached by any essential part of the restraint system and the vehicle. To guarantee low decelerations.

Table 5: Working width classes for vehicle restraint systems according to UNE EN-1317

Normalized Working Width Classes	Normalized Working Width Value (W), in meter
Wn1	Wn1 ≤ 0.6
Wn2	0.6 < Wn2 ≤ 0.8
Wn3	0.8 < Wn3 ≤ 1.0
Wn4	1.0 < Wn4 ≤ 1.3
Wn5	1.3 < Wn5 ≤ 1.7
Wn6	1.7 < Wn6 ≤ 2.1
Wn7	2.1 < Wn7 ≤ 2.5
Wn8	2.5 < Wn8 ≤ 3.5

3. **Dynamic Deflection (D):**

This is the maximum lateral displacement of the traffic face of the restraint system during the impact.

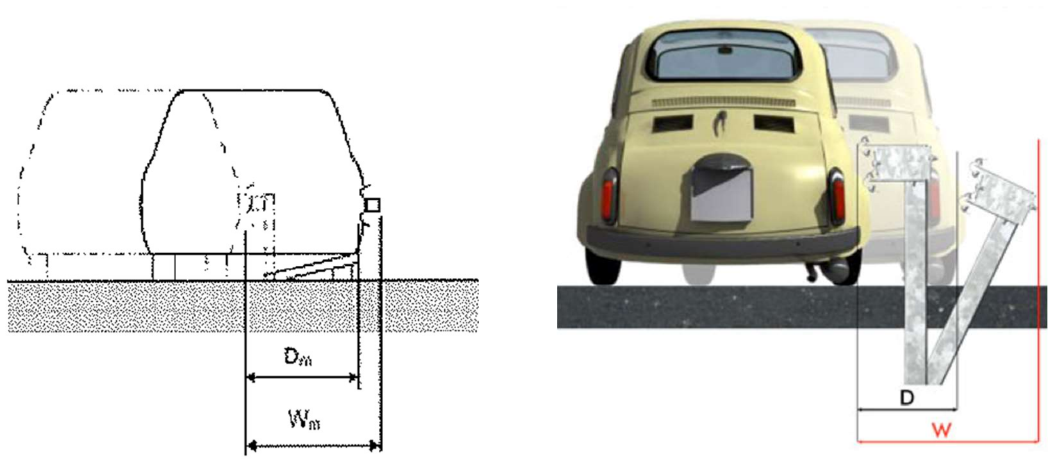


Figure 24: Drawing of working width (W) and dynamic deflection (D)

4. **Impact severity:**

It is an index that assesses the damage suffered inside the vehicle in an impact against a restraint system.

Table 6: Impact Severity Level

Level or class	Maximum permissible values	
A	ASI ≤ 1.0	THIV ≤ 33 km/h
B	1.0 ≤ ASI ≤ 1.4	THIV ≤ 33 km/h
C	1.4 ≤ ASI ≤ 1.9	THIV ≤ 33 km/h

ASI: Acceleration Severity Index THIV: Theoretical Head Impact Velocity

References

Uncategorized References

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