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Roadside infrastructure for safer European roads: D05 Summary of European design - guidelines for roadside infrastructure

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D05: SUMMARY OF EUROPEAN DESIGN GUIDELINES FOR ROADSIDE INFRASTRUCTURE



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GLOSSARY

ADT : Average Daily Traffic

Arrester bed: Deceleration area to contain heavy vehicles, associated with mountainous areas where brake overheating causes runaway vehicles

Backslope: slope associated with a ditch, opposite the road edge beyond the ditch bottom

Crash cushion: Energy absorbing system that protects vehicles from point obstacles

Cut slopes: Earth embankment created when a road is excavated through a hill, slopes up from the roadway

Design speed: Maximum speed at which a safe use of the road should be made possible

Fill slopes: Earth embankment created when extra material is packed to create the road bed, slopes down from the roadway

Foreslope: Associated with a ditch, the slope beside the roadbed before the ditch bottom

Impact attenuators: See Crash Cushion

Overpass: Bridge created over another roadway

Posted speed: Maximum speed which is allowed on the road

Recovery area: Zone beside the travel lanes that allows limited vehicle manoeuvres

Rock cuts: Similar to cut slopes except the material is hard rock

Safety zone: Obstacle free area beside the road

Underpass: Similar to overpass, the roadway passing under another roadway

Verge: Grass border along the road

Abbreviations for National Documents are provided in Appendix A

ABBREVIATIONS FOR THE COUNTRIES REVIEWED

Sweden	SE
Spain	ES
Finland	FI
Germany	DE
Great Britain	GB
Netherlands	NL
Canada	CAN

INTRODUCTION

The purpose of this report is to identify the current state-of-the-art in Europe with regards to roadside design guidelines. The analysis is limited to official national documents and does not include all the policies that are practiced at national and regional levels. All the information presented in this report is derived from the national documents (Appendix A). It should be noted that the use of the word *design* implies the prescribed layout of the roadside environment (placement of light posts, geometry of slopes, installations of road restraint systems. The term *design* does not imply the specification of system components (guardrail metal thickness, bolt sizes on break-away poles, etc.).

The report is divided into six chapters that represent the main issues to be addressed in the analysis and design of roadsides for the purpose of improving safety. The first two chapters describe the concepts of the Safety Zone and the Recovery Zone. These describe the area beside the road travel lanes that are subject to the roadside design process. The third section describes the types of common obstacles / hazards that must be identified in the roadside. The remaining chapters cover the specifications of road restraint systems, as they are reported in the existing guidelines.

Readers unfamiliar to the terminology in roadside safety are referred to the Glossary provided at the end of the report.

I – THE SAFETY ZONE CONCEPT

The seven countries have adopted the “safety zone” concept as a zone adjacent to the road which is free of any obstructions which would be in the path of errant vehicles.

This philosophy of a “forgiving road” is the mere recognition that road users sometimes leave the running carriageway for explainable or unexplainable reasons.

I.1 Definition of the safety zone

Every contracting partner gives an almost common definition for the safety zone. It is a clear, obstacle-free zone designed to reduce the consequences of vehicles leaving the carriageway and entering areas where it would be unsafe to travel (Figure 1).

Table 1: National definitions of the safety zone

Definition of the safety zone	
FI	The safety zone is a clear, obstacle-free zone
FR	The safety zone includes a recovery area + a clear, fixed object-free zone designed to reduce the severity of an accident
DE	The safety zone is a clear, obstacle-free zone
GB	The safety zone is a clear zone which should be obstacle free. However, if obstacles are present within the zone, they should be protected by a safety barrier. The term “safety zone” is not applied specifically and the standard is mandatory for motorways and trunk roads.
NL	The safety zone is a flat zone with a minimal width without obstacles which cannot cause high vehicle deteriorations
ES	The safety zone is an area free of any obstacle, hazards or slope. It includes as a minimum the shoulder or the shoulder and the verge if no safety barrier is needed.
SE	Clear, obstacle-free zone
CAN	The “recovery zone” is the total, unobstructed traversable area available along the edge of the road, measured from the edge of the closest travel lane

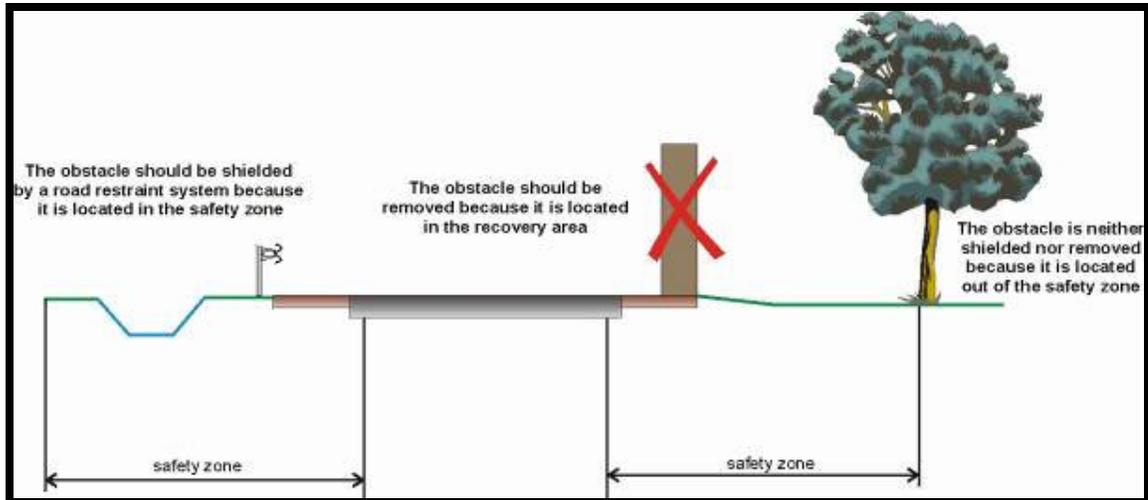


Figure 1: Definition of Safety Zone

I.2 Criteria for the safety zone dimensioning

There are five main criteria important for the dimensioning of the safety zone:

1. All nations reviewed (7/7) agree that **design speed** is important to dimension the safety zone.
2. Depending on their gradients, **side slopes** (6/7) are considered in all countries except Great Britain.
3. **Road type** (5/7) is a main criterion for all countries, except Finland and Sweden. In Great Britain, the road type remains the main criterion although IRRRS states that hazards should be protected which are closer than 4,5m to the running carriageway on roads with a design or imposed speed limit over 50 mph (80 km/h). In Finland, both design speed and real speed may be taken into account.
4. **Traffic flow** (5/7) is important in Finland, France, Germany, Spain and Sweden. In the Netherlands, the philosophy is that the risk prevails, whatever the traffic volume of vehicles.
5. **Horizontal alignment** (4/7): Straight roads or curved roads are key information in Finland, Germany, Spain and the Netherlands. Radius of curves is very important in Spain.

Table 2: National criteria for dimensioning the safety zone

Criteria	FI	FR	DE	UK	NL	ES	SE
Road type	No	Yes	Yes	Yes	Yes	Yes	No
Traffic	Yes	Yes	Yes	No	Yes	Yes	Yes
Speed	Yes						
Side slope	Yes	Yes	Yes	No	Yes	Yes	Yes
Horizontal alignment	Yes	No	Yes	No	Yes	Yes	No
Driving lane width	No	No	No	No	No	No	Yes
Others	Yes	No	Yes	No	Yes	YES	YES

Other criteria are also taken in consideration in the reviewed guidelines:

- Driving lane width (Spain and Sweden).
- The percentage of heavy vehicles (Finland)
- Evaluation of personal and third party risks (Netherlands).

I.3 Different cross-sections for the safety zone

Figure 3 and Table 1 clearly shows that there are important variations in the width of the safety zone provided by the 7 countries reviewed.

In Finland, there are three different safety zone definitions according to embankments, standard cross-sections and earth cuts and values vary from to 2m to 9m, according to proportionally increasing speed and ADT. Values are also provided for median reserves.

In Great Britain, 4.5m is quoted for new and existing roads but sign and structures are often positioned within the verge. Safety zones should be:

- Rural motorways up to 4.8m
- Rural all purpose roads up to 3.5m
- Less at loops, merges, diverges

In France, the safety zone widens in proportion with design speeds under normal conditions. Recommendations are less severe for existing roads when site configurations limit the available space.

In Germany, new roadside guides are under construction.

In the Netherlands, on motorways with a design and posted speed of 120 km/h the obstacle-free zone should be 13 m wide for new constructions and 10 m wide (or greater) on existing motorways or motorways with speeds of 100 km/h. On double or single motorways, design speed 90 km/h, the safety zone should be 10m (normal) to 8m (minimum) ; on single carriageways, design speed 80 km/h: 6m (normal) to 4,5 m (minimum).¹ Values are also provided for the central reserve (at least 25 m for 120 km/h motorways, otherwise safety barrier necessary). The width of the safety zone is measured from the inside of the marking to the nearest obstacle (Figure 2).

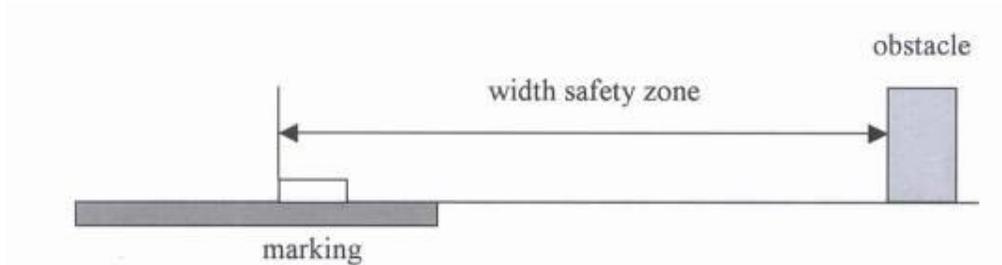


Figure 2: Measurement baseline for safety zone

In Spain the safety zone width depends of the cross slope on shoulder, the radius of the road, AADT, and the accident severity. Values up to 14m are provided for single carriageways and up to 16m on dual carriageways. The Spanish approach considers the consequences of contacting the obstacle using the local road information (see Orden Circular 321/95).

In Sweden, a good standard for the safety zone should be >10m, according to posted speeds

¹ Distances measured from the inside of the marking to the nearest obstacle.

Table 3: National dimensions for the Safety Zone

Safety distance on embankments from bottom of foreslope on new and existing roads							
FI	Traffic flow (AADT)			no distinction between existing roads and new projects road class is not a criterion			
	Speed	<1500	1500 - 6000				>6000
	120km/h						6m
	100km/h	4m	4m				6m
	80km/h	2m	4m				4m
	60km/h	2m	2m				4m
	50km/h						2m
Safety distance for new roads on standard cross-section or on cut from the edge of travelled way							
FI	Traffic flow (AADT)			no distinction between existing roads and new projects			
	Speed	<1500	1500 - 6000				>6000
	120km/h						7m
	100km/h	5m	5m				7m
	80km/h	5m	5m				5m
	60km/h	3m	5m				5m
	50km/h		3m				3m
FR							
Existing roads		Road Class		New constructions		No distinction between existing roads and new projects	
130km/h	10m	Motorways		130km/h	10m		
110km/h	8,5m	Motorways		110km/h	8,5m		
130km/h	10m	Motorways		130km/h	10m		
110km/h	8,5m	Motorways		110km/h	8,5m		
90km/h	7m	Motorways		90km/h	7m		
90km/h	4m	Expressways		90km/h	7m		
110km/h	4m	All purpose roads		110km/h	8,5m		
90km/h	4m	All purpose roads		90km/h	7m		
DE							
Existing roads			New constructions				
Table under construction			Table under construction				
GB							
Road Class		Width		Comments		No distinction between existing roads and new projects	
Motorways		4,5m		4,8m for sign and structures			
Dual carriageways		4,5m		4,5m for sign and structures			
Single carriageways		3,5m		less at structures, loops, merges, diverges			
Single carriageways		4,5m*					
* for single or dual carriageway roads with design or imposed speed limit > 50mph (80km/h)							
NL							
Existing roads		Road Class		New constructions		Minimum	
120km/h	10m	Motorways		120km/h	13m		
100km/h		Motorway		100km/h	10m		
100km/h		non-motorway, dual of single carriageway		100km/h	10m	8	
80km/h		Single carriageway		80km/h	6m	4.5	
an obstacle free zone of 10m is desirable				At 100km/h, the dimension of a horizontal safety zone can be reduced by 1,5m per 10km/h in speed difference. The best solution is to maintain a zone of 13m			
ES							
Speed	Lane width	Road Class	Shoulder		Verge		
			Exterior	Interior	Minimum	Maximum	
120km/h	3,5m	Dual Carriageway	2.5	1-1,5*	0.75	1.5	
100km/h	3,5m	Dual Carriageway	2.5	1-1,5	0.75	1.5	
80km/h	3,5m	Dual Carriageway	2.5	1	0.75	1.5	
100km/h	3,5m	Expressway	2.5	2.5	0.75	1.5	
80km/h	3,5m	Expressway	2.5	2.5	0.75	1.5	
100km/h	3,5m	Conventional Road	1,5-2,5	1,5-2,5	0.75	1.5	
80km/h	3,5m	Conventional Road	1.5	1,5***	0.75	1,5**	
60km/h	3,5m	Conventional Road	1-1,5	1-1,5***	0.75	1,5**	
40km/h	3m	Conventional Road	0.5	-	-	-	
* for central reservations with barrier beside shoulder ** for roads in hilly areas with low ADT *** for roads on hilly area with low ADT. It will be possible to justify shoulder width in max value 0,5 m							
SE							
Speed	Standard			no distinction between existing roads and new projects			
	Good	Fair	Low				
110km/h	>10m	>6m	<6m				
90km/h	>9m	>4,5m	<4,5m				
70km/h	>7m	>3m	<3m				

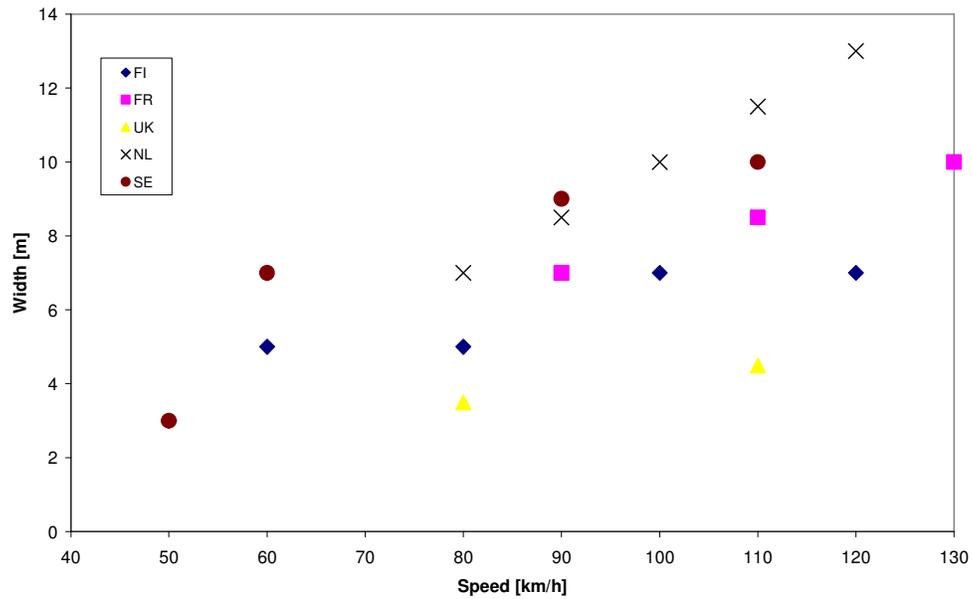


Figure 3: Width of safety zone as a function of speed limit

Note: Data from Spain is not included since the safety zone is not directly related to posted speed

It has to be stressed that there is no difference in the safety zone definitions for existing roads and new construction design in Germany, Sweden, Great Britain, and Spain.

It is difficult to design a unique clear safety zone for Europe. However, there is a consensus that the safety zone must be wider for higher travel speeds.

II – THE RECOVERY AREA

Definition of the Recovery Area

The recovery area can be defined in two different ways according to the national policies. The recovery area may be a clearly identified area which is a narrow roadside hard shoulder (Figure 4) allowing for avoidance manoeuvres for traffic and/or a recovery space for errant vehicles which then can steer back to their normal path (France, Germany). Otherwise, the recovery area is included in the total clear, obstacle-free safety zone and not considered as a separate issue (the GB, Finland, the Netherlands, Spain, Sweden).

Table 4: National definitions of the recovery area

Definition of the recovery area	
FI	The concept of recovery area is not specified in Finnra guidelines. Instead, the design of a recovery area is part of design guidelines of cross-sections, which include foreslope, ditch and backslope, with criteria based on traffic flow and maximum speed limit.
FR	The recovery area is a roadside hard strip allowing avoidance and recovery manoeuvres for errant vehicles leaving the roadway, provided that the roadside characteristics allow any movement. This area is also used for the stopping of vehicles and the circulation of vulnerable road users.
DE	The recovery area is a roadside shoulder area that is large enough for emergency rescue services on some roads.
GB	The term hard shoulder (motorway) or hard strip (other roads) is used rather than recovery area. When present, it is included in the safety zone. The recovery area is a roadside hard strip allowing avoidance and recovery manoeuvres for errant vehicles. On motorways it is large enough for emergency rescue services.
NL	In the Dutch regulation, the recovery area is not a separate issue in the roadside design. It is integrated in the total safety zone concept for roadsides. It is a roadside hard strip allowing avoidance and recovery manoeuvres for errant vehicles. Recovery areas are based on practical information and not on research.
ES	The recovery area is an area that allows errant vehicle leaving the carriageway to return on the road and get back to its original path. It includes the area between the carriageway and the restraint system. Recovery area is included in safety zone.
SE	The recovery area is a zone integrated in the safety zone concept (not considered as separate issues in Swedish standards).
CAN	The clear zone falls within the recovery zone. It is the total, fixed object-free area available to the errant vehicle.

The concept of the recovery area is not clearly identified as such among all contributing partners. This zone is used mostly for recovery manoeuvres, but it can provide extra space to avoid vehicles deriving from their normal paths, to avoid left-turning (or right- turning in the GB) vehicles, for emergency stopping of vehicles, for emergency rescue vehicles and also for the circulation of bikes and pedestrians off the driving lanes.

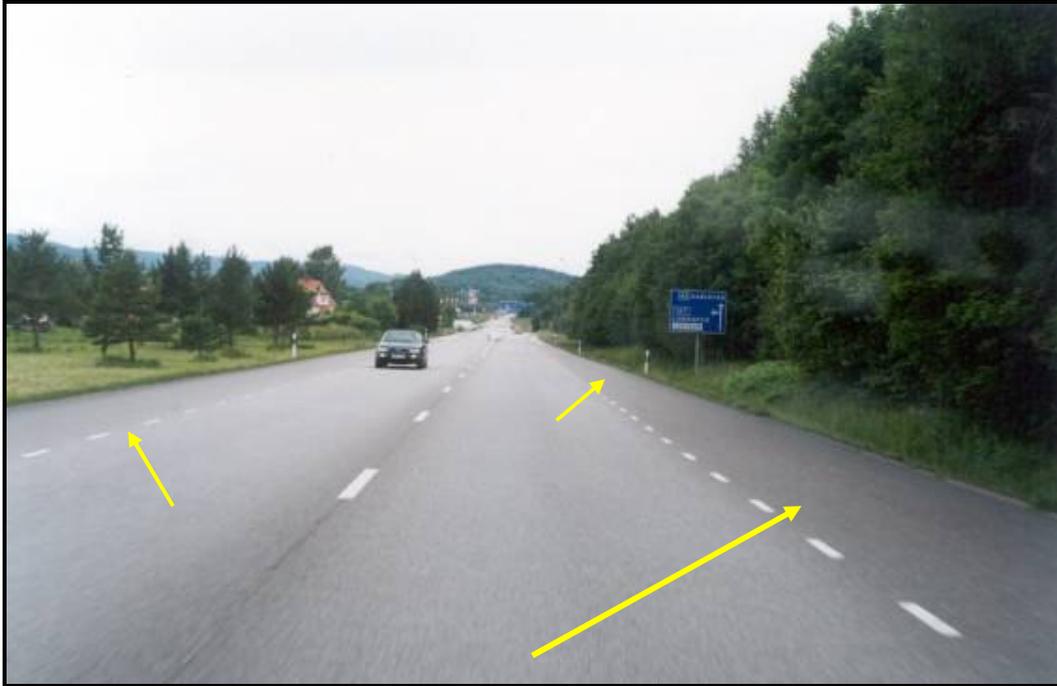


Figure 4: Example of Hard Shoulders

Most European countries design narrow roadside hard shoulders allowing avoidance and recovery for errant vehicles diverting from their normal path. In this picture from Sweden (Figure 4), hard shoulders are paved and delineated by dotted road markings (see arrows).

II.2 Criteria for dimensioning the recovery area

Table 5: National criteria for dimensioning the recovery area

Criteria	FI	FR	GB	DE	NL	ES	SE
Road type	No	Yes	Yes	No	Yes	Yes	No
Traffic	Yes	Yes	No	No	Yes	Yes	No
Speed	Yes	Yes	Yes	No	Yes	Yes	No
Side slope	Yes	No	No	No	Yes	No	No
Horizontal alignment	No	No	No	No	Yes	No	No
Driving lane width	No	Yes	No	No	Yes	Yes	No
Others	No	No	No	Yes	No	Yes	No

Four main criteria are taken into account for the dimensioning of the recovery area:

- 1) **Design speed** (5/7) is an important element in Finland, France, GB, Spain and the Netherlands
- 2) **Road type** (4/7) is used in France, tGB, the Netherlands and Spain
- 3) **Traffic** (4/7) is used in Finland, France, the Netherlands, Spain
- 4) The **driving lane width** (3/7) is of interest for France, the Netherlands and Spain. The French guideline states that in case of a 8-9m cross-section, the lane width can be reduced to 6m in order to design a 1m-1,50m wide hard shoulder. In the Netherlands, when the lane width decreases, the demand for a bigger recovery area becomes more important.

Other criteria are considered:

- Road horizontal alignment is of interest in the Netherlands
- Side slopes are considered in Finland and the Netherlands
- Size of the vehicle is considered in Germany
- Distance between vehicles and restraint systems is quoted in Spain
- Risk to third parties in the Netherlands

In Finland, the design of a recovery area is part of design guidelines of cross-sections, which include foreslope, ditch and backslope, with criteria based on traffic flow and maximum speed limit.

In France, apart from the recovery manoeuvre itself and provided that the structure allows the movements, the main functions of the recovery area are:

- Avoidance of multi-vehicle accidents or overtaking cars
- Possibility for vulnerable road users (pedestrians, cyclists) to travel outside the roadway
- Partial or total circulation of slow-moving vehicles (tractors, road operating vehicles, roadside maintenance vehicles)
- Any temporary stop of vehicles (breakdown, etc).

In Great Britain and Germany, the shoulder area must be large enough for emergency rescue services.

The main criteria for the recovery area dimensions are design speed, road type, traffic flow, and driving lane width.

II.3 Width of the recovery area

The width of the recovery area is different for the reviewed countries. As seen in the previous sections, some countries do not specify the recovery area as a separate part of the safety zone. For example, Sweden and Finland use the general roadside geometry to describe the safety risks.

In France, for new constructions, recovery areas should be 2m wide. On existing roads, 1.75m to 2.00m-wide hard strips are highly desirable, but the values can be reduced to 1.00m to 1.50m when widening costs are prohibitive.

In Great Britain, TD 27/96 states the width of recovery area should be 3.3m for rural motorways. This applies to new and existing roads. Also, IRRRS states that safety barriers may be needed at roadside obstructions closer than 4.5m to the edge of the running carriageway.

In the Netherlands, the recovery area is standard 0,6m for design speed of 90km/h and 0,3m for design speed less than 90km/h for new constructions.

In Spain, the recovery zone width is adaptable to the road status with a minimal distance from the hazard to be shielded, according to the circular on road restraint systems.

Table 6: Maximum values for recovery area widths for reviewed countries

Safety zone	FI	FR	DE	GB	NL	ES	SE
New motorways	NC	3m	UC	3.3m*	HS	4m	NC
Existing motorways	NC	NA	UC	3.3m*	HS	4m	NC
New dual carriageways	NC	2.5m	UC	1m*	0.6-0.3m**	4m	NC
Existing dual carriageways	NC	2m	UC	1m*	NA	4m	NC
New single carriageways	NC	2m	UC	1m*	0.6-0.3m**	0.5-4m	NC
Existing single carriageways	NC	1.5m	UC	1m*	NA	0.5-4m	NC

Table legends: UC = under construction - NC = not concerned (Finland, Sweden) since recovery area is not a separate issue) . HS = Hard Shoulder NA = not available

*3.3m = hard shoulder. 1m = hard strip ; **0.60m design speed V =90km/h, 0.30m design speed V<90km/h

As the recovery area is part of the safety zone in most of the guidelines, dimensions are not always provided. For the countries where the recovery area is clearly identified as a separate issue, the recovery area widens according to road type. On single carriageway roads for instance, dimensions vary one country from another (0.5m to 2m).

III – ROADSIDE AND MEDIAN HAZARDS

Roadside hazards are continuous or punctual, natural or artificial, fixed objects or structures likely to deteriorate the consequences for an errant vehicle leaving its normal path (such as high decelerations to the vehicle occupants or rollovers). They can be located either on the verge or in the median reserve of the carriageway.

In the following analysis, hazards are divided in four categories:

1. Distributed hazards
2. Point hazards
3. Road restraint systems
4. Additional factors of risks

III.1 Distributed hazards

Dimensions for continuous obstacles differ slightly one country from another. In the tables, available dimensions are given in meters. Slope gradients (foreslopes and backslopes) are given in height to distance measurements (1:4 means a height of 1 meter against a running distance of 4 meters).

III.1.1 Ditches

Ditches are excavated drainage features that run parallel to the road. They are distinguished by a foreslope (between the ditch bottom and the road) and a backslope (beyond the ditch bottom and extending above the ditch bottom).. All partners (7/7) agree that ditches can become aggressive according to the geometrical shape of the roadsides.

Ditches are dangerous when:

- Depth is > 0.50m (France, Finland)
- Height or depth is greater than 1m and steeper than 1:1 (GB)
- at least one of the two slopes is > 1:4 (France) or 1:3 in Finland, the Netherlands and Sweden, where all foreslopes with gradients 1:3 or steeper and V-shaped ditches together with backslope 1:2 can be considered as hazard for vehicle rollovers. If the foreslope and the backslope (1:2) form a V-shape, it is very possible to crash into the backslope according to Finnra guidelines.
- They are located at the foot of a fill slope (France)
- Steep-sided channels are > 0.20m with a slope > 1:1 (France)
- There is an obstruction inside the ditch (France)

France gives different values to classify very aggressive, moderately aggressive and soft ditches.

Spain gives specifications in the road guideline IC-5.2 on surface drainage from which ditches can be considered hazardous.

In Great Britain, although the term “ditch” is not specifically used, any sort of earth bank which has a height/depth greater than 1m and steeper than 1:1 is considered a hazard (i.e. should be protected by a safety barrier).

III.1.2 Slopes

Slopes can become aggressive according to the geometrical shape of the roadsides in each country. In Great Britain, an “embankment” can be either an upward or a downward slope.

III.1.2.1 Cut slopes



Figure 5: Cut slope

Cut slopes are dangerous when:

- Slope is $> 2:3$ (France) $> 1:3$ (Netherlands, Germany)
- Height is $> 0.50\text{m}$ (France)
- There is a ditch or another type of hazard at foot of slope (GB and France)

To a lesser degree, cut slopes are moderately aggressive when:

- Height of cut slope is between 0.2m and 0.5m (France)
- Slope is between $1:3$ and $2:3$ (France) and between $1:3$ and $1:6$ (Netherlands). In the Netherlands, cut slopes are in lower risks than fill slopes.
- Height $> 6\text{m}$ and steeper than $1:1$, closer than 4.5m to edge of running carriageway
- When a water hazard, road, railway or other feature is at foot of slope (GB)

III.1.2.2 Fill slopes

Fill slopes are dangerous when:

- Height is $> 2\text{m}$ (Finland), 4m (France) or $> 6\text{m}$ (GB)
- Slope is $> 1:1$ (France and GB) and $> 1:3$ (Netherlands, Germany)
- There is a steep-sided or deep ditch at foot of slope

- They are closer than 4.5m to the edge of the running carriageway on roads with speed limits above 80km/h (GB)
- Earth banks are 1:1 or steeper and with a height of 0.75m or greater (GB)



Figure 6: Fill Slope

III.1.3 Rock face cuttings

Rock face cuttings (exposed rock cuts) are dangerous and identified in 6/7 countries reviewed. Rock cuts are created for roads constructed through hard rock outcroppings or hills. Because the road construction is expensive, the amount of safety zone constructed is limited.

Particular problems identified for rock cuts are:

- Steep-sided slope is $> 1:2$ and under 1.5m above carriageway level (GB)
- There is a steep-sided or a deep ditch at foot of slope (Finland)
- Height is < 1.5 m above carriageway level (GB)
- When they are closer than a certain distance to the running carriageway (4.5m is quoted in GB).

In Finland, all rock excavations and exposed rock cuts which are unshielded and can be considered as hazards. The gradient is normally 7:1. On old main roads, the rock cuts are close to the roads (2 to 3m from the edge of the running carriageway) next to the foreslope.

There are no special technical recommendations about rock cuts in France (though they are considered hazards) and this is not an issue in the Netherlands.

III.1.4 Forests and close spaced trees

Forests or several close spaced trees are major concerns in Great Britain, France, Sweden, Finland, and Spain. The problems associated with forests depend on the spacing of the trees and thus influence the type of safety measures required.



Figure 7: Forests or close spaced trees

III.1.5 Retaining walls

There are also some recommendations about retaining walls (GB and France).

Retaining walls are dangerous when:

- Height is < 1.5m above carriageway level and has a non-smooth traffic face (GB)
- When they are too close to the running carriageway (France)

III.2 Point hazards

There are various types of point (or punctual) obstacles described by all partners.

- Some are natural obstructions
- Other are artificial, human-made rigid structures made of concrete, metal, wood, stones, etc

III.2.1 Trees and vegetation

All partners agree that trees (7/7) are the main concern when they are too big and too close to the running carriageway.

Trees are particularly dangerous when:

- Girth is >0,07m Ø (Germany), >0.08m (Netherlands), >0.10m (Finland, Sweden and France) and >0.50m (GB)

- Once trees have been cut off, rough timber is left aside the running carriageway (France)
- Tree stumps are snagging > 0.2m over ground level (France, Finland)

On the other hand, shrubs and hedges are not seen as dangerous in almost all countries (except in the Netherlands).

III.2.2 Masonry structures

III.2.2.1 Buildings and walls



Figure 8: Masonry structure

Buildings and walls are very dangerous obstacles (France, Germany and the Netherlands) when:

- They are too close to the running carriageway
- The exposed angle of the property wall or the wall itself may block the errant vehicle

In Spain, buildings cannot be less than 50 m from highways, dual carriageways, and Expressways and less than 35 m for conventional roads. However permission from the Government allows buildings in the “serfdom zone” but requires a minimum clearance of 25 m to highways, dual carriageways and expressways and 8 m for conventional roads.

There are no buildings within the safety zone in Finland.

III.2.2.2 Bridge piers and abutments, tunnel entrances

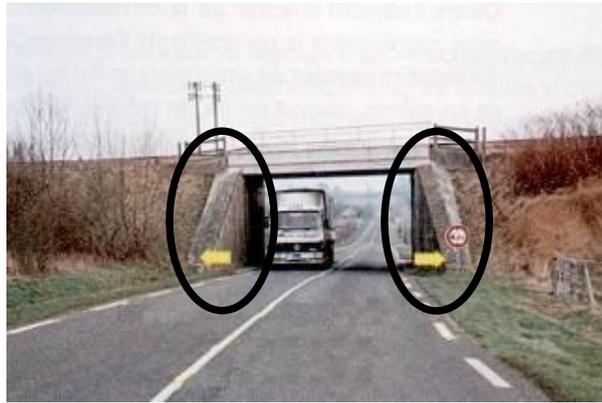


Figure 9: Bridge Pier

Bridge piers and abutments are dangerous (7/7) when:

- They are too close to the running carriageway (GB)
- Piers are unshielded in the median reserve (GB)
- The diameter of the pier is $> 1\text{m}$ (Finland)
- The snagging exposed face does not the vehicle to slide along the structure (France)
- The approach edge is aggressive (France)

Tunnel entrances are structurally similar to bridge piers and are matters of concern in France, Germany and the Netherlands.

III.2.2.3 Bridge parapets



a) Metal



b) Concrete

Figure 10: Bridge Piers

Steel or concrete bridge parapets are dangerous when:

- Height is $< 1.1\text{m}$ (steel) or < 0.80 (concrete) (Finland), $< 0.30\text{m}$ (France)
- The upper railing is not designed for absorption of car crashes (Finland)
- Parapet terminations are aggressive and not bevelled (France, Finland)
- In Great Britain, the IRRRS (chapter 5) states that the height of vehicle parapets should not be less than 1m (1.25m for bridges carrying motorways over railways). The Containment Performance Class should not be less than N1 (normal), or N2 for bridges over railways.

III.2.2.4 Other masonry structures

Other masonry structures which may be considered as hazards, such as:

- Anchorage structures when snagging $> 0.20\text{m}$ above carriageway level (France)
- Kerbs $> 0.20\text{m}$ above carriageway level (France)



Figure 11: Kerbs

- Road reference points when they are made of concrete or granite (France).

In Finland, they are not in use anymore.



Figure 12: Masonry roadside marker

- Property fences (France, Netherlands)

III.2.3 Drainage features

III.2.3.1 Drainage culvert headwalls and agricultural underpasses



Figure 13: Culvert headwall

Agricultural underpasses and drainage culvert headwall are dangerous (Finland, GB and France) when:

- They are too close to the running carriageway and useless.
- The terminals are not bevelled (Finland, France).

In Great Britain, when agricultural underpasses and drainage culvert headwalls are present within 4.5m of the running carriageway, they should be protected by safety barriers.

III.2.3.2 Drainage pipes/culvert ends

Culverts are dangerous almost everywhere when:

- Size is $> 10\text{cm } \varnothing$ (Finland)
- They are mounted into the ditch longitudinally to the running carriageway (Finland, France)
- When culvert ends are not bevelled (Finland, France)

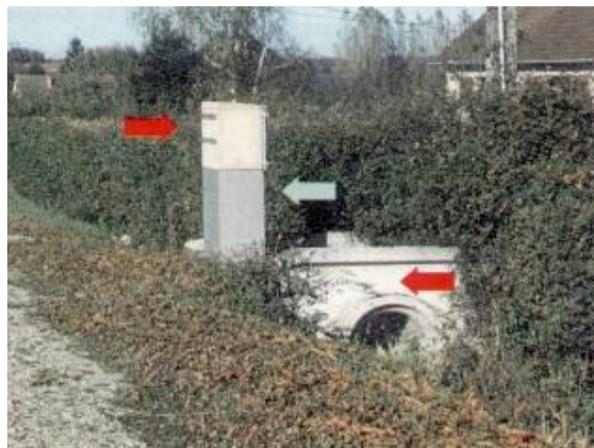


Figure 14: Culvert end and drainage pipes

III.2.4 Road equipment

In almost all contributing countries, most of the road equipment rely on breakaway or energy-absorbing structures ensuring a good passive safety for errant vehicles (however, a few rigid poles remain). As a consequence, these breakable or frangible road equipment can be installed in the safety zone without shielding.

To the contrary, in France and Spain, all the masts, poles, sign and luminaire supports which are too close to the running carriageway are dangerous because their rigid structure is not designed to absorb the vehicle's energy when hit. In Finland, some breakaway devices may not work as expected and should be replaced by energy-absorbing posts or should be protected.

Among road equipment considered as potential hazards, all contributing partners quote :

- Utility poles (poles carrying power and telegraph or telephone overhead cables) and high-voltage electricity columns
- Sign supports broadly speaking, including vertical sign supports, sign gantry legs, posts of large signs and overhead sign supports, traffic sign supports
- Steel and high-mast lighting columns, lighting poles and luminaire supports
- Any non-yielding pole

III.2.4.1 Utility poles

Utility poles are dangerous:

- They are made of wood, metal or concrete or any rigid and aggressive composition
- They are within the safety zone (all countries). 4.5m is quoted in Great Britain.
- They are not designed to breakaway or to absorb energy when hit (all countries and particularly in France and Spain)



Figure 15: Rigid utility pole

III.2.4.2 Sign supports

In almost all countries, vertical sign supports, traffic signs, posts of large signs, sign gantry legs are dangerous when:

- The structure is not yielding when hit (Finland, France, GB, Netherlands, Spain)
- The diameter is > 0.15 m (the GB) and > 0.11 m (Finland). The Great Britain guidelines reduce this to less than 0.1 m stating that it is not acceptable to reduce size of posts by increasing the number of posts unless frangible.
- Posts of large signs < 1.5 m high (GB)
- Traffic signs of 11.4 cm are a hazard in Finland

III.2.4.3 Lighting poles and luminaire supports



Figure 16: Rigid lighting pole

Lighting poles are dangerous when:

- They are within the safety zone (all countries)
- The structure is not yielding when hit (Finland, France, GB, Netherlands)
- High mast lighting columns < 10 m from carriageway edge (GB), unless they are protected by a safety barrier with a Performance Class of "Higher Containment Level" (H1).
- Unshielded lighting columns on central reserves (GB)

III.2.4.4 Other hazards

Electricity transformers (4/7), CCTV masts, control cabinets and pillars (GB) and traffic counting stations (France) are also quoted in the guidelines.

III.3 Roadside and median restraint systems considered as hazards

III.3.1 The safety barriers

Road restraint systems are composed of safety barriers and crash cushions. They may be seen as obstacles, although less aggressive than natural or artificial roadside objects. The discrimination of older safety barriers as higher risks of safety is not easily determined and few countries have formalised this process. For example in Great Britain, there are no guidelines as such.

However, if any roadside and median restraint systems are considered hazards or have been damaged, the procedure would be to replace or repair the system in accordance with BS 7669-3:1994 - Vehicle restraint systems, Part 3: Guide to the installation, inspection and repair of safety fences and the Trunk Road Maintenance Manual (TRMM), which contains the standards and policies for Highways Agency trunk road maintenance.

There are various factors of risks where the vehicle crashes against old roadside or median barriers, due to barrier components, improper dimensions of restraint systems, bad positioning or untreated terminations of safety barriers or fences.

III.3.1.1 Construction and Condition

Safety barriers may be dangerous in the following situations:

- There are steel W-beam strong-post guardrails (Finland)
- There are W-beam guardrails with concrete or steel I-shaped posts (Finland, France)
- Wooden guardrails are not appropriate when speed is high (> 90km/h) (France)
- There are still strong rigid U-160 posts which cause severe damages when struck
- Joints are not stiff because bolts are weakening as time goes on (Finland)
- Guardrails that are not stiff (Netherlands)
- Expansion joints are not present on guardrails for bridges (France)
- Bolts are too strong and the guardrail does not break away as expected (France)
- No motorcycle screen on safety barriers in curves (France)

In Finland, almost all barriers on main roads are W-beam steel guardrails. The new weak-posted guardrails is used since 1995 and fulfils with EN 1317-2.

In the Netherlands, the old guardrails (single rails) are not stiff enough. It is recommended in the Dutch regulation that it should be replaced with the highest priority.

III.3.1.2 Positioning

The purpose of safety barriers is to provide a shield between hazardous roadside areas and vehicle traffic. The location of the barrier should be such that vehicles cannot move behind the system, the vehicle cannot directly come into contact with the hazard, or an impact with the safety barrier will allow the vehicle to deform the barrier and contact the hazardous features.

The longitudinal or lateral positioning of the barrier:

- The distance from the obstruction (object or slope) is too short
- The distance from the carriageway edge is too short

III.3.1.3 Dimensions

The dimensions of the safety barriers are not appropriate to roadside safety when:

- The height of the guardrail is too small
- The length of need of guardrail is under dimensioned
- The length of anchorage is too short
- There is a short gap between two barriers



Figure 17: Gaps in guardrail

III.3.1.4 Barrier terminations

Safety barrier terminals which do not fulfil the standards can be dangerous in the following situations:

- The terminations of the barrier is not properly anchored
- The termination is not ramped down in the ground
- The termination is not anchored in the backslope
- The termination does not flare away from the running carriageway
- The distance between the obstruction and the barrier terminal is too short

The transition between deformable safety barriers and rigid barriers may cause high decelerations (France)



Figure 18: Guardrail termination

III.3.2 Crash Cushions / Impact attenuators

In most countries, there are only a few of the newer crash cushion / impact attenuators in use.

In Great Britain, crash cushions are described with the same technical characteristics (i.e. Performance Class requirements) as safety barriers. Crash cushions may be considered hazards if they do not meet these Performance Class requirements. Arrester beds may be considered hazards if the length is not appropriate (i.e. too short) for the vehicle entry speed. IRRRS now gives advice and guidelines on crash cushions (Chapter 9) and arrester beds (Chapter 11).

III.4 Additional factors of risks

Some other roadside features should be recognized as contributing to the safety risks of vehicles leaving the roadways. The following items have been identified in the national guidelines:

- Watercourses and water canals (Finland, Great Britain, Netherlands, Sweden)
- Vicinity of railway tracks (Finland, Great Britain, Netherlands, Sweden)
- Other roads and ways requiring underpasses or overpasses bigger roads (Finland, Sweden)
- Presence of vulnerable road users (pedestrians and cyclists)
- Central reserves of dual carriageways
- Curves less than 850m radius, depending on embankment steepness (Great Britain)
- Chemical/fuel storage tanks (Great Britain)
- Roundabouts and four-legged junctions (France)
- Boulders

Additional factors of risks are not treated in the French guidelines, except as a concern for vulnerable road users.

III.4.1 Watercourses, rivers and water canals

Watercourses are dangerous when they are deeper than 1m (Finland, Netherlands, Sweden) and are in the vicinity of the road. The distance to water is a concern and varies according to traffic flows and speeds (Sweden).

In Great Britain, the IRRRS states that safety barriers shall be provided on embankments where there is a road, railway, water hazard (permanent or expected) or other feature at or near the foot of a slope. Water hazards include rivers, reservoirs, stilling ponds, lakes at the same level or below the highway.

In the Netherlands perpendicular water channels are the most dangerous obstructions due to the high deceleration they can create.

III.4.2 Railway tracks

In Great Britain, a railway track at the foot of an embankment should also be protected, according to IRRRS.

In Sweden, the safety zone should be modified when the road passes near a railway track. In general the edge of a motorway should be more than 25m to the centreline of a railway track.

III.4.3 Other roads and ways

Other roads and ways are dangerous when they are within 10m of the highway (GB). The IRRRS (chapter 5) for Great Britain states that for bridges that carry motorways over railways, the minimum height is given as 1.25m (1.5m for all other roads). A safety fence should be provided on each approach end of the parapet and on the departure end where necessary and be at least 30m long.

III.4.4 Pedestrians and cyclists

In most countries, there are no guidelines as such for treating the risks of pedestrians and cycle lanes on major trunk roads, mainly because pedestrians and cyclists are prohibited from using the roads classed as motorways or express roads in the trunk road network (GB, Netherlands, France).

For the roads these classes of road users are allowed to use, there appears to be little provision for their protection in Great Britain and France, apart from some recommendations (GB) for minimum lane widths, which states lane widths should be between 1.5 and 3.6 wide or for minimum hard shoulder widths (France).

Pedestrian subway entrances are protected according to the IRRRS, in Great Britain.

In the Netherlands, bicycle traffic is separated from quick traffic on high volume rural roads and pedestrians are not allowed on main roads.

III.4.5 Other factors of risks

In Great Britain, there are technical recommendations about:

- Central reserves of dual carriageways should be protected with barrier protection
- Curves less than 850m radius where the embankment is 3-6 in height should be protected either
- IRRRS states chemical/fuel storage tanks as hazards that may require barrier protection

In France, there are technical recommendations about safety zones

- At normal four-legged junctions
- At roundabouts (lighting poles and central island)
- At split-level junctions
- At towns and cities entrances

Boulders are dangerous when they are snagging > 0.2m above the carriageway level (Finland, Germany, Spain, Sweden).



Figure 19: Example of boulders in the roadside safety zone

Table 7: Summary of roadside hazards for selected European Countries

Distributed hazards							
	FI	FR	DE	GB	NL	ES*	SE
Ditches and V-ditches	0,5m ; >1:3	0,5m ; >1:4	yes	yes	>1:3	yes	yes
Slopes and embankments	2m ; >1:3	4m ; >2:3	yes	6m ; >1:1	yes	>8:1	yes
Earth banks				1:1 and >0,75m			
Rock face cuttings	7:1	yes	yes	>1:2 and < 1,5m	No	yes	yes
Retaining walls		yes		yes			
Rows of trees, forests	yes	yes		yes		yes	yes
Point hazards							
Trees (girth in cm)	>10cm	>10cm	>7cm	>50cm	>8cm	>15cm	>10cm
Tree stumps		>20cm					
Walls and buildings	yes	<0,7m offset <1/40	yes		yes		
Bridge piers & abutments	yes	yes	yes	yes	yes		yes
Tunnel entrances		yes	yes		yes	yes	
Parapets	yes	<1,1m high	yes	yes	yes		yes
Kerbs		>20cm	>7 cm			>10 cm	
Property fences		yes	No		yes	yes	
Road reference points		yes	yes		yes	yes	
Culverts and pipes	yes	yes	yes	yes	yes	yes	
Culvert ends	yes	slant 1:2		yes		slant 1:6	
Drainage culvert headwalls	yes	yes		yes			
Agricultural underpasses				yes			
Utility poles	yes	yes	yes			yes	yes
Vertical sign supports	yes	yes	yes	yes		yes	
Sign gantry legs	yes	yes		yes			
Posts of large signs		yes		<1,5m High			
Overhead sign supports	yes	yes	yes	yes			
Steel columns	yes	yes					
Luminaire supports	yes	yes	yes	yes			
Highmast lighting columns		yes		<10m from road			
non-breakaway poles	yes	yes		yes	yes		
Traffic sign supports	11,4cm Ø	yes	yes	15cm Ø			
High-voltage electricity columns	yes	yes					
Boulders	yes		yes			yes	yes
Electricity transformers		yes	No	yes	yes		yes
CCTV masts				yes			
Control cabinets				yes			
Pillars				yes			
Traffic counting stations		yes					
Any obstruction above carriageway level		> 20cm			>7cm		
Safety barriers							
Old barriers	yes	yes			yes	yes	
Barrier ends	yes	yes				yes	
Additional factors of risks							
Watercourses, canals	yes		yes	yes	1m	yes	yes
Rivers	yes			yes			
Reservoirs				yes			
Stilling ponds				yes			
Lakes				yes			
Railway tracks	yes		yes	yes		yes	yes
Other roads and ways	yes		yes	<10m from road		yes	yes
Pedestrian subway entrances				yes			
Vulnerable road users	yes	yes				yes	
Central reserves	yes			Yes			
Curves				R < 850 embankment = 3m		R < 1500m	
Hazardous storage				yes			
Control cabinets				yes			
Counting stations		yes					
Emergency call boxes		yes					
Pillars				yes			
4-legged junctions		yes					
Roundabouts		yes					
Town entrances		yes					

When available, values are given for defining the hazard
 * Depends on speed, see Orden Circular 321/95

For 'yes' answers, the hazard is considered but no values are provided

IV TECHNICAL TREATMENT OF ROADSIDE HAZARDS FOR NEW CONSTRUCTIONS

New road construction should provide more freedom for the road designer for identifying and protecting roadside obstacles. Providing that sufficient funds are available to secure the adjacent land, the safety zone can be dimensioned according to the national guidelines. Surveying the road section prior to construction should allow all hazards to be identified and moved. However, there should be no technical difference in safety levels between new roads and existing roads. The only restriction is that older roads may be more restrictive in redesign solutions due to the neighbouring inhabitants, industries, and natural areas.

In this section, a brief overview is provided to identify national practices that may differentiate new road constructions from existing road redesign.

- SWEDEN: There is no distinction between new constructions and existing roads.
- FINLAND: there are guidelines for the treatment of roadside hazards for new constructions. Hazards must be removed from the safety zone. If it is not possible, they should be protected by safety barriers.

The European standard EN 12767 is quoted in Finnish guides for energy-absorbing luminaire supports and vertical sign supports, whereas traffic sign supports (diam 114mm maxi) are not supposed to be breakaway structures.

Culverts at junctions should be positioned 5 to 10m away (not in the roadside ditch). Culverts which are transverse to the road should have the terminal bevelled with gradient 1:1 to 1:4.

Rock cuts are also treated in the Finnish guidelines with a foreslope of 1:4 and a backslope of 1:2. The safety distance should be 9m for 2-m high rock face cuttings.

- FRANCE: the French guideline for the treatment roadside obstructions (TOL) provides with technical recommendations for new projects in terms of safety zone dimensions in order to secure an obstacle-free zone and gives several corrective measures for existing roads.
- GREAT BRITAIN: the IRRRS states that “safety barriers shall be installed on all new, as well as improved, trunk roads where the design speed or imposed speed limit is 50mph (80km/h) or greater” and when the roadside and median hazards as seen in previous sections are present. It also states that hazards should be protected which are closer than 4.5m from the edge of the carriageway.

There are also procedures in Great Britain for undertaking three-staged road safety audits to evaluate highway schemes during design and construction to identify potential safety hazards.

- **THE NETHERLANDS:** a guideline written for building new roads states that a 13 m safety zone must be designed. If impossible, it recommends separating the danger zone from traffic using safety equipment. The guideline has been developed to avoid the use of guardrails as much as possible. For example, it is preferred to use earth walls in the middle of the carriageway, for median protection. If obstacles that are present within the 13 m safety zone will lead to personal injury, the hazard must be separated by a safety system
- **SPAIN:** the Recommendation on Road Restraint Systems Orden. Circular 321/95 is used for new road constructions. For new constructions in all countries, there should not remain any obstacle in the safety zone otherwise shielded by a restraint system.

For new constructions in all countries, there should not remain any obstruction in the safety zone otherwise shielded by a restraint system.

V TECHNICAL TREATMENT OF ROADSIDE HAZARDS ON EXISTING ROADS

The treatment of roadside hazards is the basic problem for the RISER research project. This section describes any methodologies employed by the reviewed countries in Europe.

V.1 Classification of the hazards

Table 8 represents the types of classifications of roadside hazards and roadside sections that are explicitly described in national documents.

Table 8: Classification strategies for various countries

<u>Classification</u>	FI	FR	DE	GB	NL	ES	SE
Road class	Yes				Yes		
Traffic flow	Yes	Yes	Yes		Yes	Yes	Yes
Type of obstacle	Yes	Yes	Yes		Yes		
Distance from edge		Yes	Yes	Yes	Yes	Yes	Yes
Position in curves or straight lines		Yes	Yes			Yes	
Design speed				Yes*			Yes
Risk assessment		Yes		Yes		Yes	
Estimation of the safety effect	Yes						
Severity of potential accident						Yes	

* speed limits above 50mph

In Great Britain, the IRRRS state that all the hazards previously mentioned should be protected by a safety barrier.

In Finland, there is no general classification of different obstacles. In Finnra recommendations of specific technical treatments there is a rough classification according to traffic flow and sometimes also by road type (motorways and other divided road / other main roads). The recommendations include the estimation of the safety effect (estimated reduction in fatal and injury accidents) and the Finnra gives the priorities.

In France, there is a classification to help the road managers and the decision-makers in setting up their road safety policy, including traffic flows, type of obstacles, distance from the carriageway edge, the presence of obstructions in curves and risk assessment.

In Sweden, treatment of obstacles is required for certain ADT and lateral distance and posted speed. Single obstacles are accepted in the safety zone if these conditions are met.

In the Netherlands, there is not much specific information on the subject.

Traffic flow, type of vehicles, distance of obstacle from the edge of carriageway and position in curve or in a straight road are the most frequent parameters used to treat the roadside obstacles on existing roads.

V.2 Methodology for the treatment of hazards on existing roads

There are various methods of redesigning a roadside environment. The examples in Figure 20 show the most commonly used approaches for treating roadside hazards. This process (listed below) is more or less used by France, Finland, the Netherlands, Germany and Spain:

- 1) Remove the obstacle (all countries)
- 2) Redesign the obstacle so that it can be safely traversed (FI, FR, DE, GB, NL, SE)
- 3) Relocate away the obstacle (all countries)
- 4) Reduce impact severity by using an appropriate break-away device (FI, GB, NL, SE) (*)
- 5) Protect from the obstacle with a restraint system (all countries)
- 6) Delineate the obstacle (FI, FR, DE, GB, NL, ES) (**)

(*) Reduce impact severity is an optional item in Germany and France, where shielding the obstruction is the preferred measure. It is not in use in Spain.

(**) Delineation of the hazard is a transitory guideline in France which is being phased out. Delineation is not discussed in Sweden.

In Sweden, the abovementioned process is implicitly discussed in guidelines but no explicit procedure is provided. Instead, there is another global approach:

- 1) Determine road type
- 2) Determine traffic expectations
- 3) Determine reference speed
- 4) Determine type of separation for vulnerable road users
- 5) Determine different road sections
- 6) Determine needs for mass transit (bus stop, etc)
- 7) Determine needs for parking (if need is appropriate, only in urban areas)
- 8) Determine lighting needs
- 9) Determine need for noise protection
- 10) Determine width of safety zone, roadside type
- 11) Determine snow plowing requirements, other maintenance needs
- 12) Evaluate the possible alternative designs

In Great Britain, the methodology for treatment is based on local accident studies plus what has already been discussed in IRRRS, but the Highways

Agency is currently looking at the potential to introduce risk assessment techniques on existing roads.

In all the countries which implemented energy-absorbing road equipment for passive safety (Finland, Sweden, Netherlands, GB), EN 12767 is the standard.

In France, there is a written procedure prior to the detection and the subsequent treatment to obstacles, which includes also a risk assessment on the road network.

In Spain, on existing roads, the selection for the treatment of obstacles is based on the study of the circumstances of every road section: traffic, road layout, severity of accident to avoid.

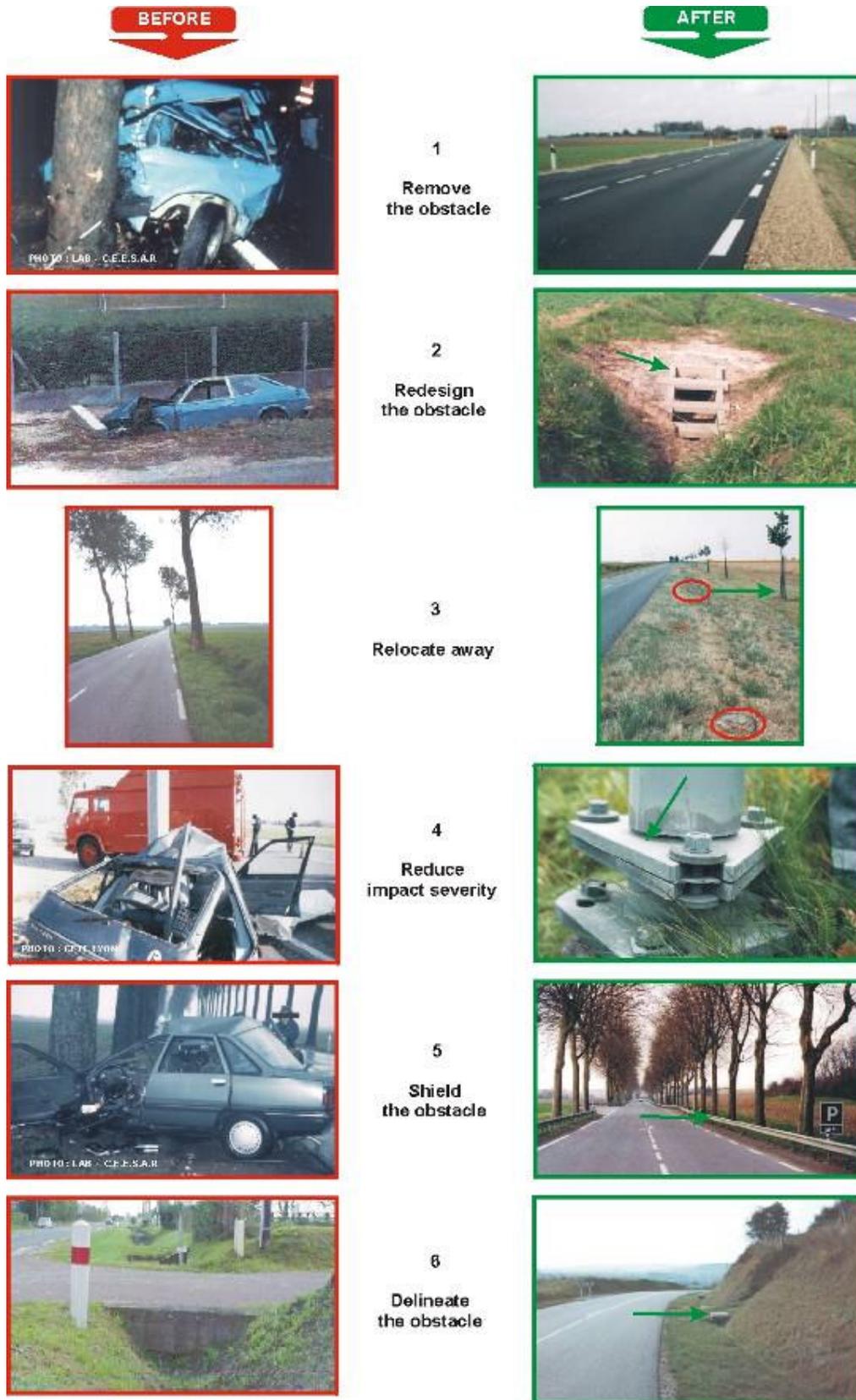


Figure 20: Common methods for treating roadside safety issues

VI - RESTRAINT SYSTEMS

Road restraint systems are used to protect the vehicle from the roadside environment. The underlying requirement is that the restraint system will result in a collision severity that is lower than a collision with the roadside environment.

The European requirements for Road restraint systems are covered in the test standard EN1317. The road restraints can be broadly divided into the following groups:

- Longitudinal barriers (contain and redirect vehicles) eg: guardrail
- Crash Cushions (energy absorbing structures for point obstacles)
- Transitions (connection between 2 different types of road equipment)

The test standard describes performance characteristics for different products following into these categories. However the standard does not describe the application of these products.

Several restraint systems are treated in the national documents:

- Safety fences and safety barriers (all countries)
- Crash cushions and impact attenuators (all countries)
- Noses of island (the UK)
- Arrester beds (the UK)
- Wire rope safety fences (the UK, Sweden)
- Railings (the Netherlands)
- Low concrete walls (France)

VI.1 Safety barriers

V1.1.1 Definition of a safety barrier

According to all partners, a safety barrier is a restraint system designed and installed to reduce the consequences of vehicles leaving the carriageway and entering areas where it would be unsafe to travel.

In English standards (NPSBS) there are two types of safety barriers: a deformable safety barrier (normally steel) is intended to absorb some of the energy impact caused by an errant vehicle striking it and to redirect the vehicle within a narrow angle to follow the line of the fence so that it does not gyrate or overturn, whereas rigid safety barrier (normally concrete barrier) is to provide containment without significant deflection of deformation under impact and to redirect errant vehicles along the line of the barrier in the direction of traffic movement.

Similar types of barriers are found in French recommendations.

Two types of safety barrier :

1. a deformable safety barrier intended to absorb some of the energy impact caused by an errant vehicle striking it
2. a rigid safety barrier providing containment without significant deflection under impact

VI.1.2 Technical characteristics of safety barriers

In all countries reviewed, safety barriers should conform to acceptance criteria contained in national European standards EN 1317 part 1 and 2, which contains terminology general criteria for test methods including definitions of the various types of road restraint systems, measurement of the acceleration severity index (ASI) and number of other measurements such as the theoretical head impact velocity (THIV) and post-impact head deceleration (PHD) (part 1). Part 2 contains performance classes, impact test acceptance criteria and test methods for safety barriers:

- Containment level (T, N or H) with low angle, normal, higher or very high containment
- Impact severity level (A for $ASI \leq 1.0$ and B for $ASI \leq 1.4$)
- Working width (W1 to W8) with deformation levels from 0.6m up to 3.5m

VI.1.3 Selection criteria of safety barriers

Apart from European standards EN 1317 1 and 2, almost all countries have national references for their safety barriers:

- Ty 3/51 Ty3/53, EN1317-4 and NCHRP 350 (Finland)
- TLSB (Germany)
- IRRRS and NPSBS (Non-Proprietary Safety Barrier Systems, to be read in conjunction with IRRRS (GB)
- NEN 51/91 (Netherlands)
- Instructions of 1998, 1993 related to safety barriers and fences, motorcyclist-friendly devices (France)
- Recommendation on Road Restraint Systems Orden. Circular 321/95 (Spain)
- Vägutrustning 94 (*Road Equipment*) (Sweden)

In Finland, the technical characteristics retained are:

- Containment level N2
- Impact severity level A
- The durability against corrosion and snow removal must be known
- The working width of the guardrail depends on the guardrail type

All public Finnish roads: the standard in use is EN 1317-2 N2 with some exceptions:

- On motorways and other very busy roads the end of the guardrail must be turned to the side ditch or to the median (Finnra standard drawing Ty3/53) or the crashworthy terminal must be used (tested according to EN 1317-4 or NCHRP 350, impact speed 100 km/h)
- Other roads, ramped ends (12m length)

In Germany, German guidelines specify safety levels required at a site according to the type of vehicles, the type of obstacles and the type of road infrastructure. The German TLSB provides selection criteria for roadside and median safety barrier models.

In Great Britain, NPSBS defines the types and uses of safety barriers:

- TCB and RHS are not used on when length between anchorage <45m or curves with radius <120m
- Single sided OBB are not used when length between anchorage <45m or on curves with radius <6m (convex) or <20m (concave) (radius <50m when double railed)
- Double sided OBB are not used when length between anchorage <37.5m or on curves with radius <50m

In the Netherlands, the safety barrier in the Dutch regulation covers different types of restraint systems like guardrails, barriers and railings, a third type used on artificial works like bridges or viaducts. The standard in use is EN 1317 H2, which present good ratios of strength and costs. It is possible to choose a heavier class in case of higher danger. For the ASI, the standard choice for constructions is class A, an $ASI \leq 1.0$ but ASI can be neglected in special cases when barriers need to be very strong.

In Sweden the general application of guardrails requires N1 barriers for roads 70 km/h and under. N2 is to be used for roads with posted speeds above 70 km/h. Higher classes of barrier are listed (bridges, mix of heavy vehicles, etc.) but selection criteria are not provided.

Each country adopted a full range of national recommendations to implement safety barriers.

VI.1.4 Selection of roadside and median safety barrier models

In Finland:

- Roadside and median: basically any barrier that fulfils the requirements of EN 1317-2 N2
- In practise, the problem of the concrete barriers is snow drifting and snow removal
- The cable barriers are not recommended. The concern for motorcyclists has lead to the introduction of new barriers on the market.

- No wooden barriers

In the Netherlands:

- The choice of the material is not relevant, provided the barrier meets the performance criteria
- There are 2 types of barrier: Guardrail and barrier. The guardrail is in the Netherlands from steel. The barrier is of concrete or steel.
- Not many rules about motorcyclists. The only paragraph written is about poles along high accident risk sites. It is recommended to protect the poles.

In Spain:

- The choice of the material is based on vehicle class, restraint level and crash severity
- The concern for motorcyclists is a part of a national research project and two guidelines about road restraint systems for motorcyclists have been published recently. The guidelines are:
 1. Terminology and Test Procedures
 2. Performance classes and acceptance criteria

In Sweden:

- Different types of barriers for different applications are provided in regional guidelines
- No explicit guidelines for motorcyclists.

VI.1.5 Implementation of barriers and modifying old barriers

VI.1.5.1 Implementation of barriers

Essentially all countries have a guideline that specifies the dimensions and location of road restraint systems. Table 9 identifies the different criteria available for safety barriers.

Table 9: National Criteria for the installation of road restraint systems

Criteria	FI	FR	DE	GB	NL	ES	SE
Length of barrier	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Height of barrier	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Longitudinal installation from carriageway	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Length of anchorage	Yes	Yes	Yes	Yes*	Yes	Yes	No
Distance from edge	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Installation from the obstacle	Yes	Yes	Yes	Yes**	Yes	Yes	Yes
Barrier end treatment	Yes	Yes	Yes	yes	Yes	Yes	Yes
Gap in safety barriers		Yes		Yes	Yes	Yes	

*Minimum anchorage length 45m or 37.5 (depending on barrier type)

** Known as Working Width in Great Britain

In Great Britain:

- Barrier length = <30m before hazard and 7.5m after (not less than 45m in total)
- Gap in safety barrier < 17m, gap should not be < 3km apart
- Normal set-back (on roads >80km/h) >1.2m
- Minimum clearance - known as Working Width - varies for each barrier type (the working width being measured the same as in EN 1317-2).
- General end treatment: ramped down to anchorage and flared away from carriageway

In Finland:

- Barrier height 0.70m
- Barrier length = after the hazard: on two-way travelled way 30 % shorter than before the hazard, on one-way travelled way (motorways) 20 m if the distance between the hazard and the guardrail is under 1,2 m - otherwise 5 m
- General end treatment: ramped down to 12 m

- Roadside: distance to the edge of the road (edge of shoulder) is 0,5 m (mini 0,25 m) ; if the shoulder is wider than 1,5 m the distance is zero
- Medians: normally 1,0 m from the edge of the road (shoulder) ; on narrow medians: 0,25 m from the edge of the road
- Positioning from the obstacle: on motorways and other busy roads (ADT > 3000): full working width of the barrier ; on other quite busy roads:
 - If there is the possibility of high impact angles the full working width is used
 - Otherwise the working width of small car (0,9 t) is used
 - On other roads (ADT < 1000 or speed limit = 60 km/h the working width of small car (0,9 t) is used if possible
- Longitudinal positioning, barrier end treatment and distance to the edge of the roadway are also detailed in the Finnish guidelines.

In the Netherlands, the placement of barriers must fulfil with the Dutch regulation NEN 5191.

- Height of the barrier = 0.75 meter
- Longitudinal positioning: special attention is paid to discontinuities, which must be handled carefully; otherwise the barrier will cause higher injuries rather than preventing them. The following specifications are defined:
 - o Begin/end
 - o Connection or dilatation for temperature differentials
 - o Split
 - o Width differences
 - o Opening to other road
 - o Stiffness change
 - o Connection joint at bridges
- Minimum length of anchorage = 10m according to NEN 5190 ; another alternative is a RIMOB (crash cushion).
- Barrier end treatment: a definition is given in NEN 5191.

In Sweden:

- Length of barrier is determined from the nature of the obstacle to be protected. However, standard levels for encroachment angles are provided to determine length of barrier
- Longitudinal positioning is determined from the obstacle
- Set-back is determined by roadside class and road
- Clearance is given by working width (EN1317)
- Barrier end treatment is given in Swedish guidelines

In Spain:

The installation procedures of W-beam are specified in Orden Circular 321/95 and the Spanish standard UNE 135124

VI.1.5.2 Modifying old guardrails

The presence of older equipment on the road is not unusual for most countries. The classification of this equipment as a hazard instead of a safety feature was discussed in Chapter III.

In Great Britain, old barriers should be modified if they no longer conform to the requirements, because of changes to the road (i.e. change in road class/structure), damage due to a collision or general weathering. This would be undertaken in accordance with BS7669-3 and the Trunk Road Maintenance Manual.

In Finland, same as for new barriers: top of guardrail 0,7 m over the edge of the pavement

- Longitudinal positioning: before the hazard: same requirement as for new barriers
- Minimum length of anchorage: distance to the edge of the roadway / positioning from the obstacle is not changed, but if needed extra posts will be installed to meet the present requirements:
 - normal spacing 4 m,
 - if there is a rigid obstacle and the distance between the obstacle and guardrail is less than 2,1 m (motorways) or less than 1,6 m (other roads) then 2 m spacing is needed 16 m before and after the obstacle
- Barrier end treatment: if speed limit is 80 km/h or over the old 8 m long ramped ends are replaced with 12 m long ramped ends ; replacing of existing ramped guardrail ends with crashworthy terminals or turning their ends to backslopes is recommended when ADT is over 6000 and speed limit is at least 100 km/h (motorways) or 80 km/h (undivided roads)
- Other guardrail construction improvements:
 - The idea is to modify the old strong post steel guardrails to weak-post ones (similar to the crash-tested new guardrails)
 - Joints of railings and anchorages are strengthened
 - Joints between the rails and the posts are weakened
 - Posts are weakened (e.g. by sawing)

In the Netherlands, it is recommended to renew old barriers as quickly as possible with high priority, particularly with insufficient stiffness.

In Sweden, there are no references for modifying old safety barriers.

In Spain, road restraint systems - orden circular 321/95 give special recommendations about the selection, implementation of safety barriers and for the replacement of old barriers.

In Germany, damaged sections of older guardrail types may be replaced with newer guardrail designs if it is technically feasible.

VI.2 Crash Cushions / Impact attenuators

Different types of impact attenuators are described in Great Britain's documents such as crash cushions, arrester beds, bull nose small radius safety fences and earth acoustic mounds.

VI.2.1 Definition of a crash cushion

Crash cushions are restraint systems that may be suitable for deployment in front of an isolated obstruction, which cannot be removed, relocated or be protected by an adequate length of longitudinal safety barrier. They are designed to reduce the severity of vehicle impact with a fixed object into a less severe collision.

VI.2.1 Technical characteristics of impact attenuators

Impact attenuators must fulfil with each country's European standards EN 1317 (all contributing partners).

The technical characteristics of crash cushions (both directive and non-redirective) are outlined in Part 3 of EN 1317 where performance levels are given, as are vehicle impact severity levels (ASI, THIV and PHD), which are (almost) the same as for safety barriers.

VI.2.2 Selection criteria of impact attenuators

Apart from European standards EN 1317, some countries have their own national references for impact attenuators:

- NCHRP 350 (Finland)
- IRRRS (chapters 9 and 11), PD6634 (GB)

For Finland, crash cushions are used on motorways or other similar roads when there is not enough room for the guardrail (when shielding a bridge pier, vertical sign supports or any rigid obstacle). There is also an alternative to shield the end of a concrete barrier instead of flaring it away from the carriageway and shielding with a steel guardrail.

For Great Britain, in IRRRS, the applications for use of crash cushions require economic and site justifications, and post implementation monitoring. On existing roads, an accident analysis is required. At present crash cushions in Europe are only designed for absorbing impacts from small and large cars, not substantially larger vehicles.

In the Netherlands, the crash cushion criteria are:

- Rejection performance: A guardrail is capable to reject a car and a bus, but the initial part of the guardrail is a danger zone. A side impact in a RIMOB is the same as a side-impact in a stiff guardrail.

- Accident change: The minimum length of a guardrail, exclusive the begin- and end point and the danger zone, has to be 58 meter. The RIMOB is 10 meter long
- Cost aspect : RIMOB costs are three times the cost of 100meter of guardrail

In Sweden, no technical applications are currently available.

In Spain, only vehicle class is taken into account.

VI.2.3 Implementation of impact attenuators

In Finland:

- On motorways, the crash cushions must fulfil the requirements according to EN 1317-3 speed level 100km/h, where NCHRP 350/100 can be also used if there is already the same kind of crash cushions on the same road section
- On other roads, the crash cushions must fulfil the requirements according to EN-1317-3 speed level 80km/h.
- Crashworthy terminals must be used according to EN 1317-4 or NCHRP 350, with impact speed of 100km/h.

In Great Britain, there are no guidelines for the dimensions (length, height) and positioning of crash cushions within the layout of a road. However, crash cushions in Great Britain must comply with the requirements in EN 1317-3 for speed limits both less and greater than 50mph (80km/h). Arrester beds should be considered on long hills where there has been a previous history of accidents involving errant vehicles (IRRRS chapter 11) and suggested lengths are given for a 380mm deep gravel arrester bed based on varying approach speeds (e.g. 85km/h = 68m).

In the Netherlands the position of the RIMOB can be in principle just in front of the obstacle (eg concrete segment). The bigger the RIMOB the better the performance and the lower the risk of damage to the obstacle. Three standard types are available. The Design is according to NEN 1317-3. The impact attenuator is designed for passenger cars with crash speeds from 50 km/h until 110 km/h and a mass until 1500 kg. The system is not able in all cases to stop trucks or buses.

In Sweden, no technical applications are currently available.

In Spain the performance specifications are harmonised with EN 1317-3

VI.3 Wire rope safety fences

Cable type guardrail systems are not common to all European countries. The countries that are using cable systems are Great Britain and Sweden.

In Great Britain, TD 32/93 outlines limitations on the use of wire rope safety fences. They should not be used;

- Where fence length (at full height) would be less than 24m
- On horizontal curves less than 200m radius
- Vertical sag curves less than 3000m radius
- On central reserves of width less than 3.14m (although this depends on support post spacing)
- For closing Emergency Crossing Points
- Where height of kerb exceeds 110mm
- Within 10m of high mast lighting columns
- To connect to other safety fence or bridge parapet

Table 10:Layout requirements for wire rope safety fences (GB)

Dimension	Normal requirement
Set back at verge	Minimum 1.2m
Set back at central reserve	Minimum 1.5m
Clearance	1.5m, 1.3m, 1.1m (depending on support post spacing)
Length	Not less than 30m in advance of obstruction and no less than 7.5m beyond
Anchors	Not less than 30m apart
Length of Ropes	Not more than 627m

Swedish guidelines do not separate the installation of cable barriers from other road restraint systems. The working width and containment class for the system as defined by EN1317-2 is used. The use of cable barriers in median applications has been reviewed in national investigations.

CONCLUSIONS

The roadside safety guidelines of seven European countries were reviewed. There was general agreement between the countries in terms of general practices. For example, all countries promote the safety zone and use the European Normatives to describe the performance of safety equipment. The general methodology to improve roadside safety is also largely the same among the countries. However the technical specification of each roadside safety element varies between the countries. For example, safety zones are much wider in the Netherlands than in the Great Britain and few countries treat the recovery zone as a separate entity.

The core information for designing a roadside design guideline can be distilled from the information collected in this document. The synthesis of the seven

national policies into a common language document will be useful for the further development of road infrastructure safety practices.

APPENDIX A: INFORMATION SOURCES

Main references quoted by the contributing partners	
Country	Titles
Finland	National Policy of Finland by the Finnish Road Administration (Finnra)
Great Britain (1)	Interim Requirements for Road Restraint Systems (IRRRS) Highway Link Design TD9/93 Non-Proprietary Safety Barrier Systems NPSBS TD27/96 Cross-sections and headrooms
France	Guide for the treatment to roadside obstructions TOL Management of main roads ARP Instructions of technical conditions for the management of rural motorways ICTAAL
Germany	Richtlinien für passiven Schutz an Straßen durch Fahrzeug-Rückhaltesysteme, RPS 2003
Netherlands (2)	Safe Design of Roadsides, Guideline for Motorways, CROW Road Restraint Systems Handbook, CROW Road Design Handbook, Part: Distributor Roads, CROW Road Design Handbook, Part: District Access Roads, CROW
Spain	Recommendation on Road Restraint Systems. Orden Circular 321/95 Instrucción_5_2-IC_Drenaje Superficial Norma 3.1-IC_Trazado Instrucción_8_1-IC_Señalización Vertical
Sweden	Road and roadside design standard and all safety road equipment in Vägutrustning 94 (VU 94) in particular: Section 5 – Road section Section 15 – Road equipment

- (1) Although the guidelines in IRRRS are for roads in Great Britain, other Highways Authorities also make use of it (e.g. Wales, Scotland, Northern Ireland)
- (2) In the Netherlands for motorways there are specific guidelines for roadside design. For the other types the Road Design Handbook contains information on roadside design (such as safety zone width). Specific guidelines on roadside design for non-motorways are under construction.

Some references to American standards and guidelines (AASHTO, NHRCP) are also quoted.

Two European countries (France and the Netherlands) have set up technical recommendations on roadside infrastructure into a specific roadside design and redesign guideline.

This is also the case in the USA and Canada.