CEDR Transnational Road Research Programme

Call: Safety

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Provision of Guidelines for Road Side Safety (PROGReSS) – Road side safety elements, state of the art report

WP1 Tech Review

Deliverable 1.2

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SWOV Institute for Road Safety Research

TRL The Future of Transport

ARUP

LNEC Laboratório Nacional de Engenharia Civil

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CEDR Call: Safety

Provision of Guidelines for Road Side Safety (PROGReSS) – Road side safety elements, state of the art report

WP1 Tech Review

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Glossary of Terms (WHO, 2015)

Abbreviated Injury Scale (AIS): anatomically-based, consensus-derived, global severity scoring system that classifies each injury by body region according to its relative importance on a 6 point ordinal scale.

"Bag-of-words" assumption: the order of words in a document can be neglected.

Barrier terminals: the ends of safety barriers which often need to be protected by crash cushions.

Bigrams: pairs of two consecutive words

Bridge pier: the support columns of bridges.

Clear zoning: the systematic removal of all hazardous features near the roadside, to minimize the chances of injury should a vehicle run off the road.

Correlation: The relationship (association or dependence) between two or more qualitative or quantitative variables.

Crash cushions: energy-absorbing applications that can be attached to barrier terminals and other sharp-ended roadside objects to provide crash protection on impact.

Crash Modification Factor: A Crash Modification Factor is the ratio of the crash frequency of a site under two different conditions and it represents the relative change in crash frequency due to change in one specific condition, such as the installation of a roadside barrier or change in the slope of a roadside embankment.

Crash Reduction Factor: A Crash Reduction Factor is the percentage reduction of the crash frequency of a site as a result in change in one specific condition.

Eigenvectors: characteristic vectors of a matrix.

Forgiving roadside objects: objects and structures designed and sited in such a way that they reduce the possibility of a collision and severity of injury in case of a crash as well as accommodating errors made by road users. Examples are collapsible columns, guard fences and rails, and pedestrian refuges.

Guard fences and rails: rigid, semi-rigid or flexible barriers which are situated at the edge of a carriageway to deflect or contain vehicles, or in the central reserve to prevent a vehicle crossing over and crashing into oncoming traffic.

Low-cost and high-return remedial measures: low-cost, highly cost-effective engineering measures applied at high-risk sites following systematic crash analysis.

Median barrier: safety barrier positioned in the centre of the road that divides the carriageway, deflects traffic and often has energy-absorbing crash-protective qualities.

Road infrastructure: road facilities and equipment, including the network, parking spaces, stopping places, draining system, bridges and footpaths.

Road side furniture: functional objects by the side of the road, such as lamp posts, telegraph poles and road signs.

Road traffic crash: a collision or incident that may or may not lead to injury, occurring on a public road and involving at least one moving vehicle.

Road traffic fatality: a death occurring within 30 days of the road traffic crash

Road traffic injuries: fatal or non-fatal injuries incurred as a result of a road traffic crash.

Road user: a person using any part of the road system as a non-motorised or motorized transport user.

Rumble strips: a longitudinal design feature installed on a roadway shoulder near the travel lane. Rumble strips are made of a series of indented or raised elements that alert inattentive drivers through their vibration or sound. They may also be used for speed reduction.

Safety barriers: barriers that separate traffic. They can prevent vehicles from leaving the road or else contain vehicles striking them, thus reducing serious injury to occupants of vehicles.

Safety performance standards: definitions or specifications for equipment or vehicle performance that provide improved safety. They are produced nationally, regionally, or internationally by a variety of standard-producing organisations.

Stop words: words that are not useful for an analysis, typically extremely common words such as “the”, “of”, “to”, and so forth in English.

Unforgiving roadside objects: objects and structures designed and sited in such a way that they increase the chances of collision and severity of injury in case of a crash. Examples are trees, poles and road signs.

Unsupervised learning: branch of machine learning that learns from test data that has not been labeled, classified or categorized.

Utility poles: poles at the roadside with a particular function, such as telegraph poles, road traffic sign poles and lighting poles.

List of Abbreviations

ADT	Average Daily Traffic
ALARP	As Low as Reasonably Practical
ASI	Acceleration Severity Index
CMF	Crash Modification Factor
CPM	Crash prediction model
CRF	Crash Reduction Factor
DI	Detailed Inspections
DMRB	Design Manual for Roads and Bridges
HCL	High Collision Location
ITS	Intelligent Transport System
LDA	Latent Dirichlet Allocation
MS	Member State
NSM	Network Safety Management
PCA	Principal Component Analysis
RISM	Road Infrastructure Safety Management
ROR	Run-off-road
RQI	Rijkswaterstaat Quality Index
RRRAP	Road Restraints Risk Assessment Process
RRS	Road Restraint System
RSA	Road Safety Audit
RSI	Road Safety Inspection
RSM	Road Safety Management
SI	Safety Inspections
SVROR	Single Vehicle Run off Road
TEN-T	Trans-European Network for Transport
THIV	Theoretical Head Impact Velocity
TII	Traffic Infrastructure Ireland
TRL	Transport Research Laboratory
TSMI	Temporary Safety Measures Inspection
VMS	Variable Message Signing
VRU	Vulnerable Road User
VRS	Vehicle Restraint System

1 Introduction

PROGReSS – Provision of Guidelines for Road Side Safety is a project funded within the CEDR 2016 Safety Call, in which the results of a status quo review of available EU roadside safety standards and guidelines are combined with the experiences from National Road Authorities in applying these in the design, operation and maintenance phases of EU high speed roads (speed limits higher than 70 km/h). A special emphasis is put on the six funding countries (Belgium-Flanders, Ireland, Netherlands, Slovenia, Sweden, and United Kingdom), plus Germany and Portugal which are included to increase the geographic representation of the results.

The primary objectives for PROGRESS are:

- To review existing roadside safety design, maintenance and operational requirements for clear (obstacle free) zones and also for road restraint systems (as defined by for e.g. EN 1317).
- To determine to what extent national road authorities in Europe and their contractors are capable of implementing and maintaining compliance with the standards and guidelines throughout the life cycle of roads.
- To develop recommendations for safe roadside design and management ensuring broad acceptance among member NRA's of CEDR.

1.1 Purpose of this deliverable

The purpose of this report is to describe and assess the findings of the literature review and to summarise the potential relationships between the design and operation (including maintenance) of road side elements and safety.

The objectives of WP1 are to:

- Review European and international literature on road side safety (see Chapter 1).
- Define the critical road side elements and their definitions from European studies (see Chapter 2 and 3).
- Establish best practices for safe road side design (see Chapter 3).
- Establish best practices for safe road side maintenance (see Chapter 3).
- Establish relationships between safety and clear road side zones versus road restraint systems (see Chapter 3).
- Review EU (CEN) standards for road and vehicle restraint systems relevant to safe road side design (see Chapter 4).
- Review road side safety design and management practices and country specific standards and guidelines in the six countries funding this CEDR research programme (Belgium-Flanders, Ireland, Netherlands, Slovenia, Sweden, United Kingdom) (see Chapter 5).
- Benchmark road side safety performance in the participating eight countries (see Chapter 6).

Within this Work-Package, Task 1.1 consisted of summarising the results of several roadside safety projects and collecting the most relevant studies related to the application of guidelines and standards in the improvement of roadside safety. This review focused on studies that explore and highlight the relationship between compliance to standards and guidelines and safety. The intention is to establish to what degree road authorities can determine the consequences of deviations from recommended standards and practice on safety when making design choices (Inception report, 2017).

Task 1.2 focused on identifying any quantified relationships between roadside design elements (which are featured in the road side design guidelines of the six funding countries) and the real world crashes. The aim was to evaluate the relevance of the road side design guidelines and standards and provide input to an eventual revision by making the relationships with safety explicit. To achieve this goal an in-depth literature review was carried out and a matrix was developed to illustrate all identified relationships between the different road side design elements with road safety in general and crashes in particular.

Task 1.3 reviewed the relationship between the design and management of road side elements and factors with road safety in general and crashes in particular. This task focused on the standards and guidelines for road side design and management of the six funding countries plus the relevant CEN standards.

Task 1.4 assessed the standards and guidelines that relate to specifically road side maintenance and operations to establish whether maintenance of road side furniture and equipment are related directly to road safety or whether these are inferred (i.e. preventive versus reactive). An overview as to what is current practice was obtained. Specific attention was given to road worker safety during maintenance of road sides.

Task 1.5 provided a benchmark of the roadside safety performance in the six funding countries plus Germany and Portugal based on crash data analysis. Also, the co-occurrence patterns of attributes related to the run-off-road (ROR) crashes were identified from road safety inspections' reports, as well as the interventions' patterns associated with these crashes.

Overall, Work package 1 consisted of a technical review of existing standards and guidelines in each of the contributing countries and a consolidation of knowledge on the design and management of rural road sides internationally. Results from this Work package will be used in Work package 3, to identify the effective, promising and innovative practices used by different road authorities and to prepare a complete assessment of roadside safety management in order to develop the intended roadside safety evaluation tool.

2 Road side safety research review and literature search on the application of guidelines and standards on road side design

2.1 Results from road side safety projects

2.1.1 RISER

The Roadside Infrastructure for Safer European Roads (RISER) was a 5th Framework "Growth" project co-sponsored by the European Commission Directorate General for Transportation and Energy (DG-TREN). The project started in January 2003 and was completed in December 2006. Ten contractors, representing nine European countries participated in the project (Austria, Belgium, Finland, France, Germany, Spain, Sweden, The Netherlands and United Kingdom).

The RISER project has made a significant contribution to the understanding of single vehicle crashes in Europe. During the duration of the project, two important data sources were developed to identify the characteristics of single vehicle crashes in Europe. This data became a foundation upon which further studies on the human factors, crash performance, and maintenance of roadside infrastructure elements could be developed.

The RISER documents provide a European reference that can be used to improve road safety levels through the improvement of roadside infrastructure. It is important to recognize that road infrastructure improvements benefit all road users and in most cases have no particular vehicle or driver requirements to be effective. Road infrastructure may be considered as a democratic component of the road network, serving all road users.

Definitions of roadside and median hazards have been produced during the RISER project, including minimum measures, impact speeds and set-backs that cause serious or fatal injuries for the crashes studied in RISER. Where possible, dangerous impact speeds have been identified from reconstructed cases in RISER detailed database.

Concerning the dimensioning of a safety zone, the data coming from RISER (2006a) appear to support information from France, the US, and the Netherlands which shows that the risk of contact with an obstacle drops dramatically after the first few meters and most impacts with roadside obstacles occur in the first 10 m.

Most safety zones in Europe are specified to be between 6-10 m for travel speeds around 100 km/h. Safety zones are smaller for lower speeds and for 80 km/h roads: usually, European countries use 4.5-7 m as a safety zone width (RISER, 2006a).

The RISER analysis provides two alternatives for designing the roadside safety zone (RISER, 2006a, RISER, 2006c):

1. Based on the risk of injury during an impact with a hazard, the safety zone can be dimensioned for allowable impacts with hazards.
2. The safety zone can be dimensioned as the risk for a fatal impact with an object of a given set-back. Based on the RISER database, the set-back distances can be

grouped into the categories based on the road characteristics, including road type, traffic, speed, side slopes, horizontal alignment and driving lane width.

The requirements for a well-designed clear zone (designated as safety zone in the project) are that (RISER, 2006c):

- The consequences of a run-off are only minor;
- The width should be so designed that most vehicles leaving the road do not leave the clear zone;
- There should only be slopes that do not cause rollovers;
- The surface should be homogenous and even to prevent rollover;
- There should be no unprotected fixed objects located within the safety zone;

Clear zones should also have load bearing capacity sufficient to prevent wheel blocking.

According to RISER (2006a), legislators and authorities should ensure that a safety zone only contains artificial structures that will collapse or break away on impact, without producing significant damaging.

RISER's analysis of different criteria for dimensioning the clear zone has shown that the design of roadside environments is complex. For a road designer, evaluating alternative designs and choosing among them is difficult because there are many levels of interaction between several road design components such as the road itself, speed, traffic volumes and terrain etc.

The information collected among RISER contributing partners' national policies show that the width of the recovery zone differs from country to country.

From the RISER's research findings, the recommended width of paved shoulders on non-motorway roads should be between 1.0 m and 1.5 m, values beyond which further widening does not seem to greatly improve safety. However, these values can be smaller, above all in the outside of curves, and still keep a significant efficiency. Speeds and subsequent accident rates may increase with paved shoulder widths greater than 1.5 m (RISER, 2006a).

As stated in RISER (2006a), the first step in selecting passive safety road equipment is to identify the hazards that must be addressed. This will determine which type of passive safety road equipment is necessary. The hazard may be a lighting pole that can be replaced with an energy absorbing column or a rock cutting that needs to be shielded by a safety barrier.

The second step is to determine the containment level, or strength of the system. In EN1317, safety barriers and crash cushions are classified by a combination of both the size of the largest test vehicle used in the crash testing program and the impact speed. Energy absorbing poles are classified in EN12767 by the amount of impact energy they absorb in the crash test. Both of these ratings identify the system's structural capacity.

The third step for selecting equipment is to identify the amount of space available for the systems dynamic performance. This is established by the proximity of the hazards being shielded. The location of the hazards is necessary to determine the working width of the system (for safety barriers), and the deflection classes for crash cushions.

The fourth and final step for determining the installation requirements of passive safety road equipment is to identify the length of the system, which is determined by the size and position of the hazard and the expected accident configuration for the specific location.

According to RISER (2006a), typical problems associated with road equipment are:

- Insufficient length of systems to shield hazards.
- Installations shielding hazards but neglecting neighbouring hazards.
- Insufficient free distances behind the system.
- Inappropriate barrier end terminals.

In order to ensure a high level of road side safety a maintenance and operations programme for roadside infrastructure has to involve inspections, data collection and analysis, training, and a repair plan.

The inspection part of the programme is necessary to achieve a high level of safety for all users on the road network. The frequency of inspections must be determined to suit local conditions and is irrespective of crash occurrence. It is crucial that high traffic volume roads (motorways and national roads) are inspected daily while minor roads have weekly inspections as a minimum. Infrastructure specific inspections should be adjusted to suit individual equipment performance requirements. Damage or repair issues arising from inspections or from other sources, e.g. police or the public should be prioritised according to their repair urgency. All repair works are planned in a repair management programme, in order to find the most cost and logistical effective way to perform the repair work within the repair time limit. It is important that repair times match the road section needs so that traffic safety is not jeopardized (RISER, 2006b).

A black spot approach is proposed in the RISER project using maintenance data that should be stored in a suitable computer database that will allow processing. The application of black spot methodologies to maintenance data can provide additional accident risk assessments for road sections and identify infrastructure weaknesses.

According to RISER (2006b), staff involved in the road maintenance sector should participate in some level of training suited for their involvement. Inspectors, supervisors, road workers, office support staff should all be provided initial training as well as refresher courses depending on the role of the employee.

The management plan for maintenance and operation is part of an overall road safety management plan and is strongly connected to the design guidelines being applied by the national authorities. The close interaction between design and maintenance guidelines is obvious and will influence the functional level of the road network itself. Harmonised European best practices for maintenance and operations are a major contribution to ensure that road safety is guaranteed regardless of road owner, operator, and user.

2.1.2 IRDES

IRDES (Improving Roadside Design to Forgive Human Errors) was a research project of the cross-border funded joint research programme “ENR SRO1 – Safety at the Heart of Road Design”, which is a trans-national joint research programme that was initiated by “ERA-NET ROAD – Coordination and Implementation of Road Research in Europe” (ENR), a Coordination Action in the 6th Framework Programme of the EC. The funding partners of this cross-border funded Joint Research Programme are the National Road Administrations (NRA) of Austria, Belgium, Finland, Hungary, Germany, Ireland, Netherlands, Norway, Slovenia, Sweden and United Kingdom. The aim of the IRDES project, completed in

November 2011, was to produce a forgiving roadside design guideline and a practical tool for effectiveness assessment with specific reference to a well identified set of roadside features (La Torre, 2012).

Within the IRDES project, and based on the inputs by the potential stakeholders gathered during the IRDES webinars, a practical and uniform guideline that allows the road designer to improve roadside forgivingness and a practical tool for assessing the effectiveness of applying a given roadside treatment have been produced for the following set of roadside features: barrier terminals, shoulder rumble strips, forgiving support structures for road equipment, and shoulder width (La Torre et al., 2012).

Each feature is analysed in a separate section of the guideline providing:

- General description;
- Design criteria;
- Effectiveness;
- Case studies/Examples;
- Key references.

Within the project, a Crash Modification Factor (CMF) has been developed to account for the number of unprotected terminals (terminals not in compliance with the EN1317) on rural single carriageway roads. A specific study was also conducted to evaluate the effectiveness of milled shoulder rumble strips in rural dual carriageway freeways in Sweden. The results showed an overall estimate of a 27.3% reduction of single-vehicle crashes, indicating a positive effect in the potential reduction in crashes. Finally, a specific procedure based on PC Crash simulations of black spots (with 90 km/h as departure speed and variable roadside features) was developed to evaluate the effectiveness of the outer shoulder width and shoulder type (paved/unpaved) and to assess the potential reduction in the MAIS (Maximum Abbreviated Injury Scale) value when different roadside treatments are applied. The results showed that the most effective treatment was the implementation of a hard shoulder, more effective than placing a safety barrier (see Figure 1). The implementation of a soft shoulder, on the other hand, was less effective than placing a safety barrier.

Scenario (Number)	MAIS	Effectiveness
No forgiving roadside (1)	6	0%
Soft shoulder (2)	2	70%
Hard shoulder (3,4,5)	0	100%
Tree (6)	6	0%
Safety barrier (7)	1	90%

Figure 1 – Example of results from the analysis of the effectiveness of having soft (unpaved) and hard shoulders on simulated ROR crashes (La Torre, 2012)

2.1.3 SAVeRS

SAVeRS (Selection of Appropriate Vehicle Restraint Systems) was a Research Project funded within the 2012 Call "Safety" of the Transnational Road Research Programme of CEDR (Conference of European Directors of Roads) by Belgium/Flanders, Germany, Ireland, Norway, Sweden, and the United Kingdom to produce a practical and readily understandable Vehicle Restraint System (VRS) guidance document and a user-friendly software tool that would allow users (designers and road administrations) to select the most appropriate solution for several road configurations and traffic conditions (La Torre et al., 2016a).

The first Work Package of the project was aimed at analysing the existing criteria for identifying the need for the placement of a vehicle restraint system and for the identification of the most appropriate performance class. For this, both the existing national standards and guidelines and literature documents from all member countries were analysed in detail. The comparative analysis of 33 national standards and guidelines, covering most of Europe and several non-European Countries, showed that there are many commonalities and that it is possible to identify the most frequently used parameters with reference to safety barriers. Whilst the majority of the countries have guidelines and/or standards related to safety barriers, there is generally limited guidance for other systems, such as crash cushions, transitions and motorcycle protection systems. Life-cycle cost models are usually not included in the standards; also, few such tools are available worldwide (La Torre et al., 2014).

Within the SAVeRS project a guideline for the selection of the most appropriate vehicle restraint system class and type was developed and a public tool was made available.

The SAVeRS tool is a free of charge public tool developed as an Excel Spreadsheet (downloadable at www.saversproject.com) that can be used by National Road Authorities, designers, road administrations directly involved in road management and researchers, for setting RRS requirements or for site specific risk assessments.

This tool allows designers to conduct risk assessments of specific situations and road administration directly involved in road management to set priorities in upgrade programmes. It will also support National Road Authorities to set new standards for minimum performance requirements.

In this tool, the likelihood of having a ROR crash can be calculated based on several models implemented in the tool as well as with locally derived models.

The tool allows the user to select predefined values as well as locally derived values for all the variables used in the different models (e.g. the impact energy distributions, the type of hazards and aggressiveness). User-defined values can be set at a national level by the National Road Authority to adapt the models to represent more accurately specific local conditions (La Torre et al., 2016).

2.1.4 SAFESIDE

A framework was developed at LNEC under a dedicated research project – SAFESIDE - roadside safety – for assisting in cost-effective decisions as regards roadside safety interventions, which is based on results from the analysis of registered data and the observation of in-service performance of installed equipment on Portuguese roads (Roque and Cardoso, 2015).

The aforementioned framework uses cost–benefit analysis (CBA) and statistical modelling methods to support recommendations about efficient roadside safety measures for Portuguese roads. CBA allows for comparing a safety treatment with the existing (baseline) condition and alternative safety treatments. CBA procedures can be used to study individual sites or to develop general guidelines.

The framework is applied through a computer-aided procedure. The prototype software for safety evaluation and simulation of roadside scenarios is intended to support decisions concerning both roadside design and the installation and selection of road restraint systems complying with the European Committee for Standardization standards (CEN-EN 1317).

Cross-sectional studies were used in this procedure to estimate crash modification factors (CMFs) of specific roadside measures applied to Portuguese roads. Injury crash frequencies were related with roadway characteristics, length and traffic volume. The coefficients of the variables in these equations were used to estimate the CMF associated with a roadside treatment.

Figure 2 presents the overall characteristics of a small road stretch (2.5 km long) used as a case study, to demonstrate the application of the aforementioned framework

Figure 2 – Portuguese single carriageway road with aligned trees along the roadside (Roque and Cardoso, 2015)

This example concerns the treatment of a set of aligned trees along the roadside of a single carriageway road stretch with annual average daily traffic of 1200 vehicles per day and an observed crash frequency of 2 run-off-road injury crashes in the previous four years. The period of analysis considered is 15 years and the applicable discount rate is 4%.

Three alternative interventions were considered (see Figure 3):

- Alternative 1: Remove existing trees and plant new trees and shrubs further away from the carriageway;
- Alternative 2: Install guardrails where needed;
- Alternative 3: Do both, i.e., on some stretches the trees are removed and on others, guardrails are installed.

Table 1 presents the costs and safety effects of each alternative, with details of how they were computed. The project costs and feature designs considered reflect current Portuguese design standards (Roque and Cardoso, 2010, Roque and Cardoso, 2011) and local construction costs.

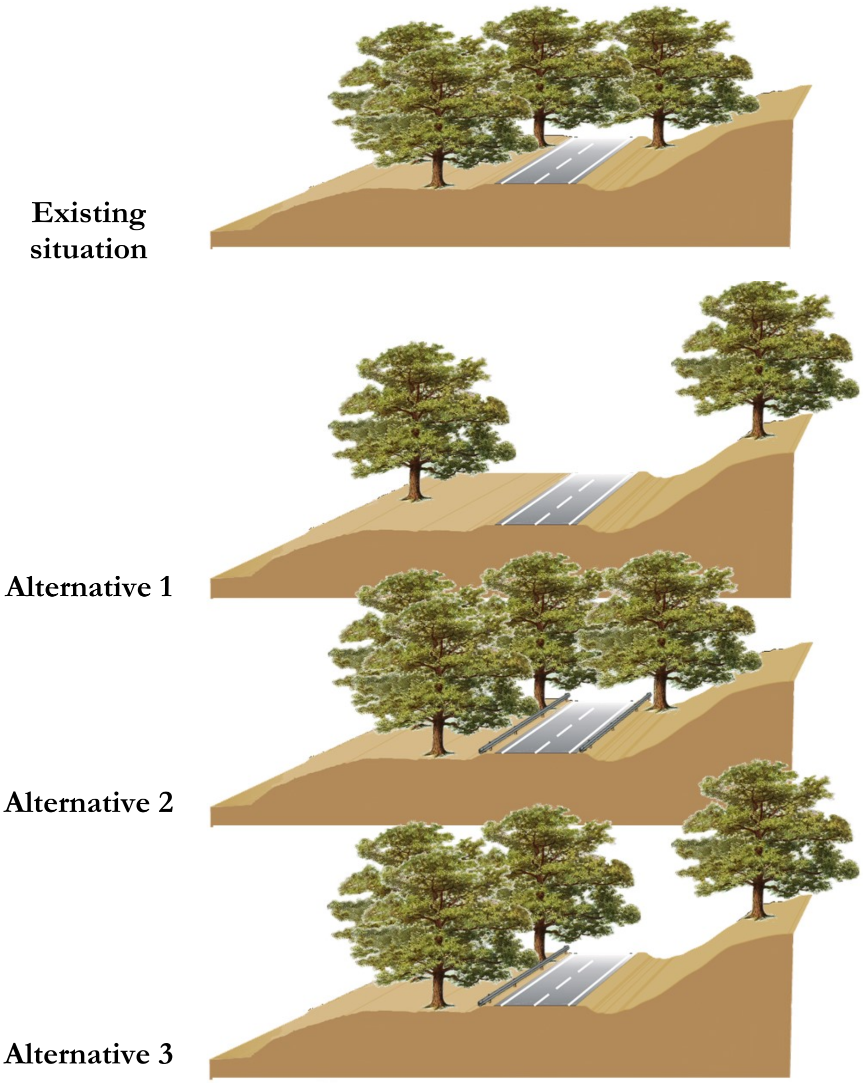

Figure 3 – Alternative roadside safety interventions (Roque and Cardoso, 2015)

Table 1 – Implementation costs and safety effects for each alternative considered (Roque and Cardoso, 2015).

Alternative	Implementation costs				Safety effects	
	Unit	Investment unit cost (€)	Annual unit cost of operation and maintenance (€)	Quantity	First order effect	Adjusted combined effect
1	m^2	4	0	18000	0.38	-

2	m	22	1.2	3200	0.51	-
3	m^2	4	0	5000	0.38	0.44
	m	22	1.2	1450	0.51	

The expected numbers of injury crashes (total and run-off-road) were computed using Portuguese crash prediction models. After this, the empirical Bayes method was used and the expected number of crashes avoided per year was then calculated. In Table 2, Net Present Value (NPV) of costs and benefits are presented for each alternative.

Table 2 – Costs and Benefits of each alternative in Euros, 2010 prices (Roque and Cardoso, 2015).

# Intervention	Costs NPV	Benefits NPV	Benefit-Cost Ratio
Alternative 1	61 605	344 099	5.59
Alternative 2	110 962	432 156	3.89
Alternative 3	67 392	353 748	5.25

Finally, incremental benefit-cost ratios have been calculated, and the resulting values for each alternative are compared in Figure 4.

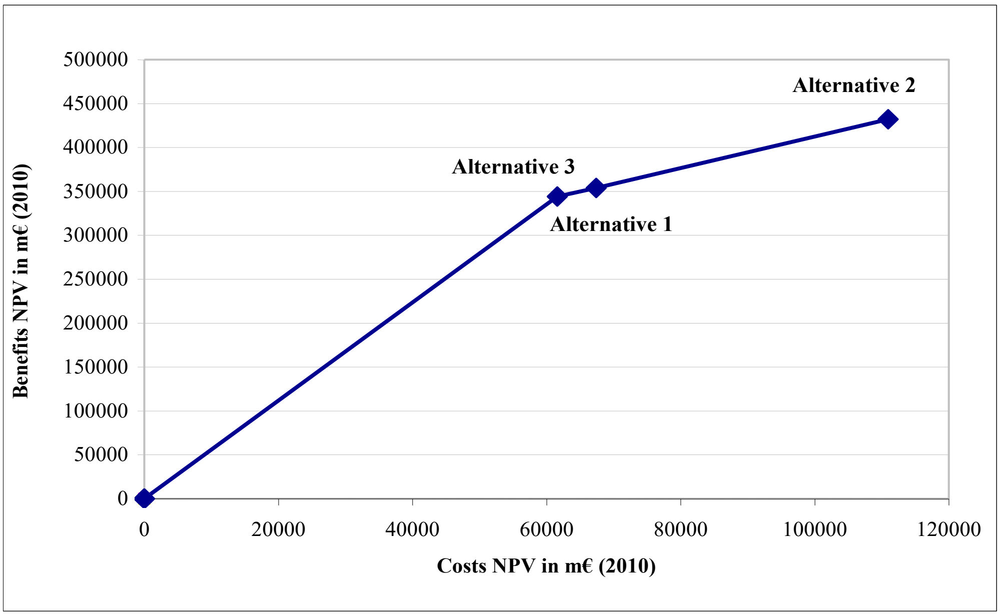

Figure 4 – Incremental benefit-cost selection (Roque and Cardoso, 2015)

In this example, Alternative 1 has the highest Benefit-Cost Ratio (5.59); however, Alternative 2 would be preferred, as it is the one with the highest incremental BCR.

2.1.5 PRACT

The PRACT Project (Predicting Road ACcidents - a Transferable methodology across Europe) aimed at developing a European accident prediction model structure that could be applied to different European road networks with proper calibration. PRACT is funded by the National Road Authorities of Germany, Ireland, UK and Netherlands within the Conference of European Directors of Roads (CEDR) 2013 Transnational Research Programme - Safety.

The core principles behind the PRACT project structure are that:

- it is unrealistic to think that one unique Crash Prediction Model (CPM) model with a unique set of Crash Modification Factors (CMFs) can actually be developed, valid for all Europe and for all the different types of road networks;
- the development of a specific CPM model and a set of CMFs based on local data is extremely time consuming and expensive and requires data and experience that most road administrations do not have;
- the development of "local" CMFs only based on historical local data prevents the possibility of evaluating the effectiveness of new technologies.

The PRACT project addresses these issues by developing a practical guideline and a user-friendly tool intended for an easier implementation of CPMs and CMFs in different countries and on different road networks (La Torre et al. 2016b).

A questionnaire was specially designed and dispatched to several National Road Administrations (NRAs) in Europe and worldwide, in order to collect detailed information on CPMs developed and used by them. Furthermore, a review of relevant international literature was carried out, with focus particularly on identifying those modelling approaches and specific models that may be applicable in or transferable to the European context.

On the basis of the questionnaire data and of the literature review results, a synthesis of current practices regarding CPMs has been developed, as a basis for the identification of the most usable models as well as for the implementation of a web based CPM repository. In total, 23 questionnaires were collected from 18 European countries, USA and Australia, and were analysed with the aim of reviewing and assessing existing CPMs, in terms of theoretical approaches, characteristics of the models in use, implementation conditions, data requirements and available results, with focus on motorways and higher ranked rural roads. It was found that, despite recent advances, most NRAs and other organisations do not systematically use such methods during decision making for the implementation of road safety treatments (Yannis et al., 2016).

The PRACT project developed some key CMFs that were currently missing or underrepresented in the literature: the presence of a work zone, average speed enforcement (section control) and high friction wearing course for Italian motorways; traffic composition, road width, horizontal curvature and vertical gradient for German two-way two-lane rural roads; and traffic composition, horizontal curvature and vertical gradient for English two-way two-lane rural roads. These CMFs were developed for motorways and 2-way rural roads using data from Italy, England and Germany (Karathodorou et al. 2016). Several others were identified only, including roadside features like clear zone width, crash cushions and traffic barriers.

2.1.6 SafetyCube

The SafetyCube – Safety Causations, Benefits and Efficiency is a research project funded by the European Commission under the Horizon 2020 research framework programme, involving 17 partners from 12 EU countries. The project started in May 2015 and finished in April 2018. SafetyCube aims to generate new knowledge about accident risk factors and the effectiveness of measures relevant to Europe, and to structure this information in a Decision Support System (DSS) that enables policy-makers and stakeholders to select and implement the most appropriate strategies, measures and cost-effective approaches to reduce casualties and crash severity for all road users (Papadimitriou et al., 2016).

The core of the project includes a comprehensive analysis of accident causation factors combined with newly estimated data on the effectiveness and cost-effectiveness of safety measures, in relation to reducing not just the number of fatalities but also the number of injured victims. The project outputs are framed according to the specific policy and stakeholder areas – infrastructures, vehicles and road user behaviour – so that the measures developed in the project can be most readily applied. A systems approach ensures effective coordination between these areas. The close involvement of road safety stakeholders of all types at national and EU levels, and wider, will enable the DSS to be focused on the most appropriate policy-making procedures and ensure the project outputs have global reach (Thomas et al., 2016).

The Deliverable (D5.1) of SafetyCube (Filtness and Papadimitriou, 2016) describes the identification and evaluation of infrastructure related risk factors (including risks related to roadside deficiencies). It outlines the results of Task 5.1 of WP5 of SafetyCube, which identify and evaluate infrastructure related risk factors and related road safety problems by:

- presenting a taxonomy of infrastructure related risks;
- identifying “hot topics” of concern for relevant stakeholders;
- evaluating the relative importance for road safety outcomes (crash risk, crash frequency and severity etc.) within the scientific literature for each identified risk factor.

To help achieve this, Task 5.1 exploited current knowledge (e.g. existing studies) and, where possible, existing accident data (macroscopic and in-depth) in order to identify and rank risk factors related to the road infrastructure. This information helped to identify countermeasures for addressing these risk factors and to undertake an assessment of the effects of these countermeasures (Filtness and Papadimitriou, 2016).

In spite of a comprehensive collection and review of literature on safety interventions, no mention is made to reporting on relations between compliance (or non-compliance) with standards and safety outcomes.

2.1.7 Richtlijnen voor wegontwerp tegen het licht gehouden

The project 'D-2013-05 Richtlijnen voor wegontwerp tegen het licht gehouden' (Guidelines for road design assessed; The validity of existing guidelines for the design of urban and rural distributor roads and the design of through roads) discusses the development, the application, and the validity of guidelines for road design in the Netherlands (Schermers et al., 2013). This is done on the basis of a questionnaire survey that was held in four countries: Germany, the United Kingdom, Ireland and the United States. Furthermore, the three most important guidelines in the Netherlands: ASVV (urban traffic facilities) (CROW, 1988), HWO - the Handbook for Road Design (CROW, 2002); and NOA (Guideline for the Design of Motorways) (Directorate General for Public Works and Water Management, 2007) are reviewed and the experiences of users of these guidelines (road designers and road managers) are investigated (Schermers et al, 2013).

The ultimate goal of this project was to provide a scientific basis for the relationships between road safety and road design. To this end, each of the above guidelines was assessed to determine which design elements were inadequately supported from a road safety perspective and required further study. These elements were then prioritised and a research programme developed.

The study concludes that in all the assessed countries the road design guidelines are mostly based on experience of the designers and not on scientific research. Moreover, designers can deviate from the guidelines if there is a valid motivation and, in some cases, with the condition that compensatory measures to guarantee road safety are applied.

The main problems regarding the application of guidelines and road safety are:

- The fact that roadside design guidelines or standards are applied does not imply that the design is safe. For instance, guidelines can show minimum design values whose road safety effects are not known.
- The guidelines should be used in accordance to concrete situations. Therefore, the designer may adapt the guidelines and that can imply a deviation from the standards due to a lack of space for example.
- Design guidelines and standards are mostly developed from expertise instead of being based on scientific research. This leads to a lack of research on the relationship between guidelines and road safety.

It is difficult to quantify the safety levels of road designs and they are often assessed by designers, based on their previous experience. Most of the guidelines do not explicitly use road safety as design criteria. For example, in Germany, environmental factors are often considered the most important factor, which leads to a higher budget for these factors and a lower budget for road safety measures.

The three main road design guidelines in the Netherlands: ASVV (CROW, 1988); HWO (CROW, 2002); and NOA (Directorate General for Public Works and Water Management, 2007)) were assessed by road safety experts and it was concluded that the road safety effects of the following designs require further investigation:

- NOA (Directorate General for Public Works and Water Management, 2007):
  - Actual speed approach
  - Speed limit approach
  - Stopping distance
  - Radii not recommended
  - Curves
  - Design speed approach
  - Deceleration
  - Obstacle-free zones
  - Minimum radius
  - Compatibility of two successive curves
  - Grade separation
- HWO (CROW, 2002):
  - Actual speed approach
  - Project planning to improve existing roads
  - Traffic conflict countermeasures for motor vehicles
  - Improvement of existing roads
  - Secondary traffic areas
  - Design speed approach
  - Traffic control mode
  - Traffic conflict countermeasures for vulnerable road users
  - Curves
  - Sight requirements
- ASVV (CROW, 1988):
  - Actual speed approach
  - Traffic safety records for intersection types
  - Project planning to improve existing roads
  - Obstacle-free zones
  - Improvement of existing roads
  - Internal defects of a bend
  - Coordination of horizontal and vertical alignments
  - Bicycle and pedestrian facilities
  - Bicycle facilities
  - Design vehicle characteristics
  - Safety distances

2.1.8 ASAP

The main objective of the ASAP (Appropriate Speed Saves all People) project was to gather knowledge on effective speed management measures over road works zones through literature review, information gathering from national expertise and practitioners, on-going research in Europe and abroad, and stakeholder consultations. The ASAP project was funded by the CEDR "TRANSNATIONAL ROAD RESEARCH PROGRAMME Call 2012 - Safety: Safety of road workers and interaction with road users" (Sorensen et al., 2015).

The work package 2, reported in Deliverable 2.1, contained a review of the national guidelines on work zone speed limits conducted for several European Countries, Canada, the United States and Australia. The review was the first technical activity in the ASAP project to establish the state-of-the-art of national criteria for speed management in work zones, to identify the effectiveness of different speed management methods reported in literature, and to evaluate enforcement strategies, especially graduated fixed penalties. Over 270 technical documents were collected and reviewed by the project team. A number of criteria used for assigning a work zone speed limit were identified. Some countries (such as USA and Canada) state that work zone speed limit reductions greater than 10 mph (16 km/h) should be avoided whenever possible, particularly when work activities are located in shoulder or roadside areas and when workers are not present.

The data analysis in work package 3 suggested that uniform European guidelines to strictly standardise work zones could be wished for but is no easy task given the diversity of rules, roads and traffic conditions between nations and regions. The stakeholder's consultation confirmed this result but in the same time expressed their interest for elements leading to more homogenous work zone layout between countries.

The ASAP project provided a guide for informing about the important decision on appropriate speed levels, about relevant criteria used across EU for setting the speed limit regime and for choosing the best speed managing methods that will result in appropriate speed behaviour in work zones.

The ASAP procedure of roadwork speed management is presented in Figure 5.

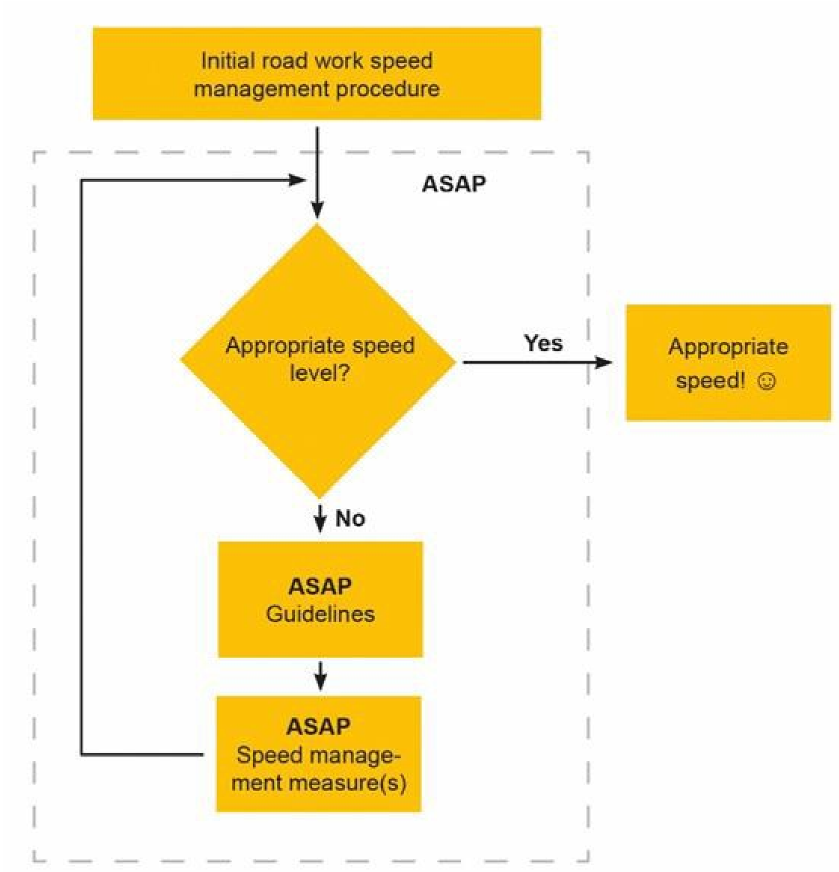

Figure 5 – The ASAP procedure of roadwork speed management (Sorensen et al., 2015).

2.1.9 BRoWSER

The aim of the BRoWSER (Baselining Road Works Safety on European Roads) project was to help National Road Authorities (NRAs) take a detailed approach to managing road worker safety. This knowledge of how road workers are exposed to risk from crashes and road user error was considered essential for effective safety management as it allows the real risks to be managed rather than those perceived to be the problem. The project was initiated as a response to the Description of Research Need (DoRN) for the CEDR Transnational Road Research Programme Call 2012 on Safety.

The BRoWSER project focused on the interaction between road workers and traffic and considered road worker crashes, incidents and near misses (where available) alongside data for road works practices, network characteristics and road user accident data at road works (Lawton et al., 2014).

Five recommendations were made from the work carried out for the BRoWSER project:

- NRAs need to adopt a common typology for road works.
- NRAs within Europe need to agree a common core approach for road works zone elements defined within the common typology.
- The common typology and core approach need to be supported at EU level to promote adoption and harmonisation across Europe.
- NRAs need to adopt the European Road Worker Casualty (EuRoWCas) database concept and specification and promote it to other appropriate in-country organisations.
- NRAs need to ensure they undertake regular and accurate collection of data, including duration of works to enable calculation of incident rate.

2.1.10 Safer Verges Scoping Study

Safer Verges Scoping Study was a roadside safety research project commissioned by Highways England and delivered by TRL in 2016 (Erginbas, Kennedy, Seidl, Robbins, Greene, & Leal, 2016).

In Britain VRS have been utilised as the main countermeasure to reduce the consequences of Run-off-Road (RoR) crashes since 1960s. Vehicle restraint systems have proven in-service use and can be an effective safety measure. However, Highways England felt the need to explore other concepts that may offer a greater level of safety to the occupants of vehicles that leave the roadside. Furthermore, it was felt that the concept of the forgiving roadside in general could be better understood.

The aim of Safer Verges Scoping Study was to obtain a better understanding of the roadside safety in Britain as a whole and identify new countermeasures, which could be introduced to improve it.

The selected analytical tool, as the underlying structure of this scoping study, was a modified version of a Haddon Matrix (Haddon Jr, 1968). The Safer Verges Matrix took the traditional Haddon Matrix and modified it from a roadside safety perspective. The three accident phases, i.e. pre-crash, crash and post-crash were replaced with the elements of a roadside safety risk model, which were “likelihood of a vehicle running off the road”, “likelihood of an errant vehicle reaching a hazard” and “consequences of a vehicle reaching a hazard”, as shown in Table 3.

Table 3 – The Structure of the Safer Verges Matrix (Erginbas, Kennedy, Seidl, Robbins, Greene, & Leal, 2016)

RISK PHASE	Contributory Factors	Mitigation Measures	Recommendations
Likelihood of a Vehicle Running off the Road	……….	……….	…………..
Likelihood of an Errant Vehicle Reaching a Hazard	……….	……….	……………
Consequences of a Vehicle Reaching a Hazard	……….	……….	……………

For each of these phases, the contributory environmental, human and vehicle factors as well as respective countermeasures through which these contributory factors can be mitigated were identified. This was achieved through a number of methods including:

- an in-depth literature review,
- consultations with local experts,
- consultations with international experts and
- statistical analysis of RoR crash data from 2010 to 2014.

To ensure a comprehensive analysis, contributory factors were identified and listed in branching levels of detail, as shown in Figure 6. In this example, the contributory factors shown are related to the consequences of an errant vehicle reaching a hazard. The major contributory factor in this case is VRS. In roadside safety design, VRS are also considered as hazards and they should only be used if the consequences of reaching/hitting the hazard behind are likely to be higher than hitting the VRS. VRS can become more dangerous if they are not designed, selected, installed or maintained properly. Column B delves into further detail of this issue and divides the contributory factors as the ones which are common for all types of VRS and the ones which are unique to specific types of VRS. (Note that Figure 6 shows only a portion of the general factors which affect all types of VRS). Finally, Column D presents the detailed contributory factors. In this example, only two of the many potential contributory factors are shown. These are “VRS not being designed for Sports Utility Vehicle (SUV) impacts” and “VRS not having a motorcycle friendly design”. These factors can have a significant effect on the consequences of RoR accidents involving SUVs or motorcyclists.

	A	B	C	D	
1	RISK Contributors	Contributory Factors			
2–3		Type	Reason	Detail	
95	CONSEQUENCES OF REACHING THE HAZARD	Vehicle Restraint Systems	VRS in General (Roadside & Median Barriers, Parapets, Terminals, Transition & Crash Cushions)	Impact by SUVs (Barrier not designed for SUVs)	N Ba
96				Not motorcycle friendly	Mot
97					

Figure 6 – Example of Contributory Factors in Safer Verges Matrix

Similarly, to ensure a comprehensive analysis, mitigation measures were divided into two types, i.e. the ones utilised in the UK and the ones utilised in other countries, as shown in Figure 7.

	E	F	G	
	Mitigation Measures			
	Type	Measure		
		in UK	International	
rrier not Vs)	New Generation of Barriers and EN1317 Update		Introduction of SUV Class into EN1317	Iden
			Use of barriers tested to MASH Test Level 3	Iden
endly	Motorcyclist Protection Systems	Installation of MPS	Wider use of MPS and more detailed standards and requirements for the provision of MPS	Fin

Figure 7 – Example of Mitigation Measures in the Safer Verges Matrix

Safer Verges Matrix was designed to ultimately generate objective recommendations for Highways England to improve roadside safety. The recommendations were generated through an algorithm as shown in Figure 8. As can be seen from the figure, in order for the algorithm to work, first a series of assessment questions were answered for each contributory factor and mitigation measure combination. To ensure the generation of objective recommendations the matrix was populated only with information, which could be referenced to research papers, statistics, standards or physical phenomena. To ensure a consistent approach, the algorithm was automated via computer script.

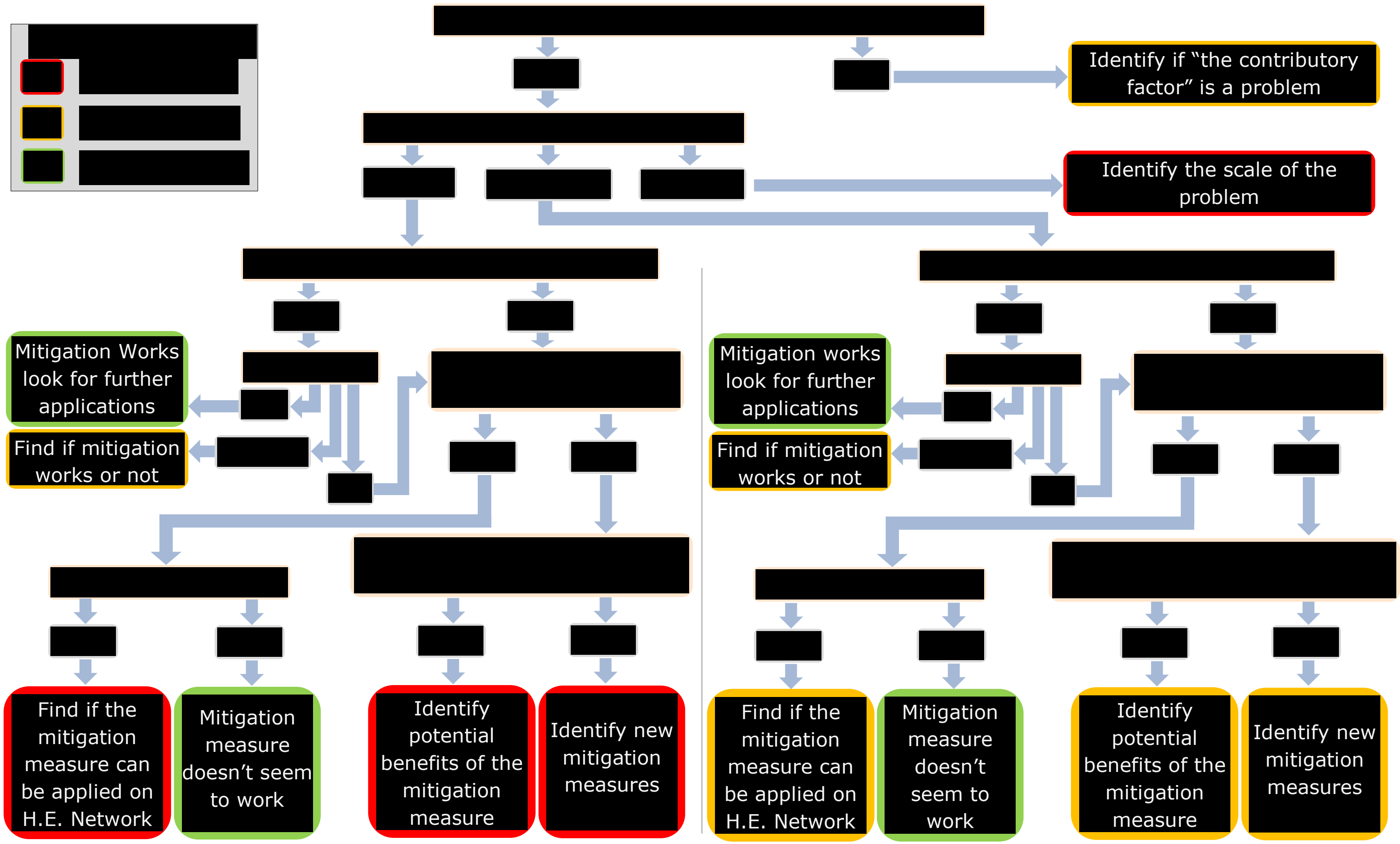

Figure 8 – Safer Verges Recommendation Generation Algorithm (Erginbas, Kennedy, Seidl, Robbins, Greene, & Leal, 2016)

As a result, 84 different recommendations were generated for Highways England, through which improvements to roadside safety can be achieved or the roadside safety issues observed on the Highways England Road Network can be better understood. These recommendations were categorised into three levels as 'high', 'medium' and 'low' priority.

Among the 84 recommended actions resulting from the Safer Verges Scoping Study, Highways England Vehicle Restraint and Temporary Traffic Management (VRTTM) has later chosen to pursue three further. These were:

- The use of centreline and edge rumble strips on the SRN single carriageways,
- Further research to develop a better understanding of the scale of risk posed by wooden boundary fencing to road users, and
- Further research to develop a better understanding of the existing and future effects of the change in vehicle fleet on Vehicle Restraint System (VRS) performance.

The common feature of these three actions was that they were all identified as high priority actions and they all relate to contributory factors which are shown to be a problem within the Highways England Road Network through either research or accident statistics. They were also all related to countermeasures which are used successfully in other countries but not yet in Britain.

2.2 Impact of guidelines and standards on road side safety

Candidate studies were obtained from a literature search in international scientific literature databases such as Scopus and TRID (Transport Research International Documentation). The literature on roadside safety was searched for on 7 September 2018. Scopus is the largest abstract and citation database of peer-reviewed literature indexing scientific journals, books and conference proceedings from over 5 000 publishers. TRID (Transport Research International Documentation) is the world's largest and most comprehensive bibliographic resource on transportation research information. It is produced and maintained by the Transportation Research Board of the US National Academies with sponsorship by State Departments of Transportation, the various administrations at the U.S. Department of Transportation, and other sponsors of TRB's core technical activities. TRID provides access to more than 1.1 million records of transportation research worldwide.

For Scopus the following queries were used to select papers about road safety:

a) ((roadside AND casualt* AND EN 1317) OR (roadside AND injur* AND EN 1317) OR (roadside AND accident* AND EN 1317) OR (roadside AND crash* and EN 1317)) AND (LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "SOCI"));
b) ((roadside AND casualt* AND "safety barrier*" AND survey*) OR (roadside AND injur* AND "safety barrier*" AND survey*) OR (roadside AND accident* AND "safety barrier*" AND survey*) OR (roadside AND crash* AND "safety barrier*" AND survey*)) AND (LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "SOCI"));
c) ((roadside AND casualt* AND clear zone AND guideline*) OR (roadside AND injur* AND clear zone AND guideline*) OR (roadside and accident* AND clear zone AND guideline*) OR (roadside and crash* AND clear zone AND guideline*)) AND (LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "SOCI"));

For TRID the following query was used: (collision* or crash* or accident* or injur* or casualt* or run-off-road*) AND (guideline* or standard* or requirement*) AND (roadside or clear zone* or EN 1317 or road restraint system* or safety barrier*) AND (questionnaire or survey*) AND (Italy or Ireland or Hungary or Greece or Germany or France or Finland or Estonia or Denmark or Czech or Cyprus or Croatia or Bulgaria or Belgium or Austria or Scotland or England or Britain or United Kingdom or Sweden or Spain or Slovenia or Slovakia or Romania or Portugal or Poland or Netherlands or Malta or Luxembourg or Lithuania or Latvia).

Both for Scopus and TRID all search results were filtered on English language only. The number of hits for Scopus and TRID are presented in Table 4.

Table 4 – Literature search strategy.

Database	Hits
Scopus	
a)	60
b)	21
c)	30
TRID	26
Total number of studies to screen title/ abstract	**137**

Following the initial selection of relevant publications, a new selection of publications was made. Only publications from trusted sources and most recent publications were selected. From this selection all abstracts were reviewed. From reviewing the abstracts a total of 59 publications were selected as the most promising. For 4 of these the full text version could not be retrieved and these were not considered further. The remaining 55 publications were reviewed and 13 of these were judged suitable in terms of relevance for PROGReSS.

A paper was retained for a more detailed review if it dealt with the application of guidelines and standards in the improvement of roadside safety in some way.

Each paper was rated in terms of its relevance to the subject of the review, as defined above. Ratings applied were ‘high’, ‘moderate’, and ‘low’ (where ‘low’ is to be distinguished from ‘none’). The criteria for these ratings were as follows:

- ‘High’: paper reports actual observations of the interaction between the application of European guidelines and standards and roadside safety
- ‘Moderate’: paper reports actual observations of the interaction between the application of other guidelines and standards and roadside safety
- ‘Low’: either (1) Paper includes some reference to underlying guidelines roadside safety interaction mechanisms, though not on the basis of actual observation; or (2) Paper focuses on useful neighbouring roadside safety issues rather than directly on issues of review.

As a result 41 of the total of 55 papers were rated ‘none’, meaning that when reviewed in detail the paper did not deal specifically with the interaction between the application of guidelines and standards and roadside safety.

2.2.1 List of selected studies

1. Bambach, M.R., Grzebieta, R.H., Olivier, J., McintoshMcIntosh, A.S., 2011. Fatality risk for motorcyclists in fixed object collisions (2011) Journal of Transportation Safety and Security, 3 (3), pp. 222-235.
2. Grzebieta, R., Bambach, M., McIntosh, A., 2013. Motorcyclist impacts into roadside barriers. Transportation Research Record, (2377), pp. 84-91.
3. Jalayer, M., Zhou, H., 2016. Evaluating the safety risk of roadside features for rural two-lane roads using reliability analysis. Accident Analysis and Prevention, 93, pp. 101-112.
4. La Torre, F., Erginbas, C., Thomson, R., Amato, G., Pengal, B., Stefan, C., Hemmings, G., 2016. Selection of the Most Appropriate Roadside Vehicle Restraint System - The SAVeRS Project. Transportation Research Procedia, 14, pp. 4237-4246.
5. Montella, A., 2001. Selection of roadside safety barrier containment level according to European Union Standards. Transportation Research Record, (1743), pp. 104-110.
6. Osoba, M; Tubic, V; Mertner, J, 2007. First experience on road safety auditing in Serbia - is it cost-effective? Proceedings of The European Transport Conference (ETC). 17-19 October, Leiden, The Netherlands.
7. Pardillo-Mayora, J.M., Domínguez-Lira, C.A., Jurado-Piña, R., 2010. Empirical calibration of a roadside hazardousness index for Spanish two-lane rural roads. Accident Analysis and Prevention, 42 (6), pp. 2018-2023.
8. Roque, C., Jalayer, M. 2018. Improving roadside design policies for safety enhancement using hazard-based duration modelling. Accident Analysis & Prevention, Volume 120, pp. 165–173.
9. Tomasch, E., Sinz, W., Hoschopf, H., Gobald, M., Steffan, H., Nadler, B., Nadler, F., Strnad, B., Schneider, F., 2011. Required length of guardrails before hazards. Accident Analysis and Prevention, 43 (6), pp. 2112-2120.
10. Wang, J., Hu, X., Dong, T., Yan, L., 2017. Evaluation on low-grade highways roadside safety in mountainous area by projection pursuit model. 2017 4th International Conference on Transportation Information and Safety, ICTIS 2017 - Proceedings, pp. 516-521.
11. Wang, Y.G., Chen, K.M., Ci, Y.S., Hu, L.W., 2011. Safety performance audit for roadside and median barriers using freeway crash records: Case study in Jiangxi, China. Scientia Iranica, 18 (6), pp. 1222-1230.
12. Xie, L.-F., Liao, X.-F., Wang, Z.-R., 2011. Roadside safety audit for three expressway facilities in China. CCIE 2011 - Proceedings: 2011 IEEE 2nd International Conference on Computing, Control and Industrial Engineering, 2, art. no. 6008064, pp. 50-55.
13. Zou, Y., Tarko, A.P., Chen, E., Romero, M.A., 2014. Effectiveness of cable barriers, guardrails, and concrete barrier walls in reducing the risk of injury. Accident Analysis and Prevention, 72, pp. 55-65.

The abstracts from the relevant papers are presented in Appendix A.

2.2.2 Summary of results of the review

As mentioned earlier, 13 studies were selected on the basis of being the most recent, relevant and published in recognized scientific journals or conferences. All of these studies were analysed in detail.

The effect of the application of guidelines and standards on roadside safety has not been sufficiently studied or reported in scientific journals in Europe or the rest of the world. In fact none of the studies analysed investigated the relationship between the application of European guidelines and standards and roadside safety, rendering a meta-analysis unfeasible.

Only three studies focused on that relationship based on international guidelines, within the scope of road safety audits (Roque and Jalayer 2018; Wang et al., 2011; Xie et al., 2011). Roque and Jalayer (2018) investigated the distance travelled by an errant vehicle in a run-off-road crash and compared it with the clear zone distances of American Association of State Highway and Transportation Officials' Roadside Design Guide. The Wang et al. study (2011) described a roadside safety audit process, including the analysis of traffic collision records and the evaluation of the performance of Chinese roadside barrier designs. The paper by Xie et al. (2011) also presents the results of a routine road safety audit process, with the review and evaluation of roadside and median barriers in three freeways in Jiangxi, China, where several critical issues were identified, and safety improvement suggestions were recommended. The results of these studies are very specific and the validity would need to be tested by applying the model on other road networks. Transferability to other contexts is an unaddressed issue.

All other studies that have been undertaken are focused on neighbouring roadside safety issues rather than directly on the application of guidelines and standards (Bambach et al., 2011; Grzebieta et al., 2013; Jalayer and Zhou, 2016; La Torre, et al.; 2016; Montella, A., 2001; Osoba et al., 2007; Pardillo-Mayora et al., 2010; Tomasch et al., 2011. Wang, et al., 2017; Zou et al., 2014)

Methodologically the studies vary in quality and although generally sound, certain assumptions or omissions weaken the applicability of the results. The results of the few existing studies are site specific which prevents direct transferability of their results.

In light of these results, it is recommended that more systematic research on the relationship between the application of European guidelines and standards and roadside safety should be conducted, starting with a template for registering relevant design decisions as characteristics of operating roads. The PROGReSS project will contribute explicitly to this objective.

3 Literature review and relationship between road side elements and safety

3.1 Introduction

The aim of Task 1.2 was to identify any established quantifiable relationships between road side design elements and their effects on road safety. To identify these relationships, an in-depth literature review was carried out.

3.2 Methodology

The design elements and related parameters under focus in this task were the ones which are often referenced in roadside design and management guidelines and standards of European countries, including the 6 CEDR countries funding the PROGReSS project. Majority of these elements and parameters were previously identified under RISER and SAVeRS projects.

The literature review focused on identifying roadside design elements and parameters, of which the effect on accident frequency and severity has been quantified. Naturally, majority of the identified relationships came in the form of Crash Modification Factors[1] (CMFs) and/or Crash Reduction Factors[2] (CRFs).

In-line with scope of the PROGReSS project, focus of the review was kept limited to identifying the crash effects of 'roadside' elements. It is possible to identify relationships between roadside crashes and other factors such as human factors, vehicle factors or the design of the road itself; however these were not seen as a focus for this literature review.

All quantified relationships identified through the literature review were collated in a matrix, which is presented in Section 3.4.

Within the matrix, roadside design elements and related parameters were grouped into three categories, with regards to their relation to the risk model from a roadside safety perspective, as shown in Figure 9. For example, a shoulder rumble strip is classified as a roadside element which contributes to reduction of run-off-road (RoR) accidents by decreasing the

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[1] A CMF is the ratio of the crash frequency of a site under two different conditions and it represents the relative change in crash frequency due to change in one specific condition, such as the installation of a roadside barrier or change in the slope of a roadside embankment. With no change of conditions at a site, the value of CMF is 1.00. A CMF value less than 1.00 means the treatment alternative reduces the estimated average crash frequency in comparison to the base condition. For example, a CMF of 0.73 corresponds to a 27%, reduction in expected average crash frequency.

[2] A CRF is the percentage reduction of the crash frequency of a site as a result in change in one specific condition. A CRF of 27 represents a reduction of 27% in expected average crash frequency.

likelihood of vehicles leaving the carriageway; whereas a roadside barrier is classified as an element which affects the crash severity by reducing the consequences of reaching a hazard.

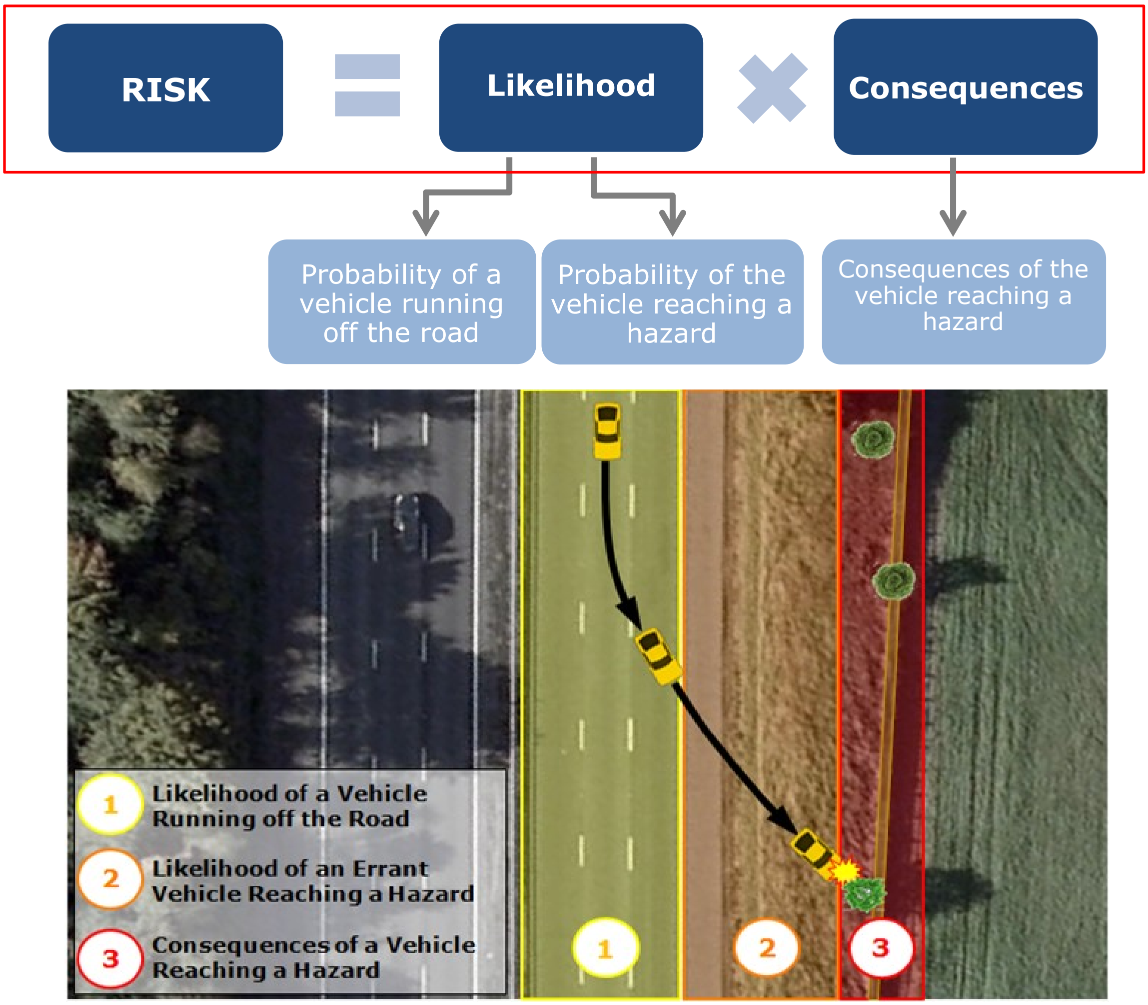


Figure 9 – Risk from a roadside safety perspective

For most roadside elements more than one quantified relationship were identified from different sources. These were listed separately within the matrix, and the following information was included for each (where information was available):

- **Roadside element:** This data field describes the main roadside element or parameter for which the crash effect is presented,
- **Original condition:** This data field describes the original condition of the roadside element or parameter, relative to which the crash effect has been identified,
- **Compared to:** This data field describes the change in original condition of the roadside element or parameter, which causes the crash effect.

- **Effect:** This data field shows the quantified effect of the change in roadside element or parameter in crash frequency,
- **CMF:** This data field shows the Crash Modification Factor associated with the effect of change in roadside element,
- **Severity Level:** This data field shows the severity level of the crashes, for which the effect was quantified. The severity levels used in the matrix can be one of or a combination of the following categories:
  - Fatal
  - Serious Injury
  - Slight Injury
  - Property Damage Only (PDO)
  - All (all of the above)
- **Crash Type:** This data field shows the types of the crashes, for which the effect was quantified. Due to the diversity of the research studies referenced, there is a number of different crash types listed in this field. Some of these are:
  - **All crash types** - All crash types (run-off-road and other types) regardless of the number of vehicles involved.
  - **Run-off-road (RoR)** – Only run-off-road crashes, where at least one vehicle left the road, regardless of the number of vehicles involved (single and multiple vehicle crashes included),
  - **Single Vehicle Run-off-Road (SVROR)** – Only run-off-road crashes, where a single vehicle was involved
  - **Single Vehicle** – Includes all crash types (run-off-road and other types), where only a single vehicle was involved
  - Etc.
- **Road Area:** This data field shows the types road area, for which the crash effect was quantified. This field is either populated as “Rural” or “Not Specified”. Quantified effects which were specific to urban areas were not included in the matrix, as these were seen as out of scope for PROGReSS project.
- **Road Type:** This data field shows the classification of the type of road, for which the crash effect was quantified. While there are other more specific descriptions of road type used, most effects were quantified for one of the following categories:
  - Two-lane undivided (or single carriageway)
  - Multi-lane divided (or dual carriageway)
  - Not-specified.
- **Source:** This data field shows the reference to the research study, through which the crash effect was quantified.

3.3 Roadside Safety Research Projects Reviewed

This task started with the review of previous European roadside safety research projects RISER (Thomson, et al., 2006), SAVeRS (LaTorre, et al., 2014) and Safer Verges Scoping Study (Erginbas, Kennedy, Seidl, Robbins, Greene, & Leal, 2016). These projects were also reviewed under Task 1.1 activities and a detailed summary of each is provided within Section 2 of this report. The focus of Task 1.2 however is specifically on any quantified relationships between roadside design elements and crashes. Therefore, the deliverables of these three projects were reviewed again to identify any of these types of relationships.

Review of the RISER (see Section 2.1 for more detail) deliverable 06 (Thomson, et al., 2006), was helpful in identifying some of the key road side design elements and related parameters which are often referenced in roadside design and management guidelines and standards of European countries. The deliverable includes some valuable statistics from a cross-border run-off-road accident database collated as part of the project. These statistics include characteristics of hazards involved in the fatal and serious injury accidents within the database. Even though valuable information is provided with regards to the parameters which define a roadside feature as a potential hazard, the deliverable does not include any quantified relationships between these parameters and their effect on frequency and severity of accidents.

Similar to the RISER the SAVERS WP1 deliverable, was also useful in identifying some of the key road side design elements and related parameters which are referenced in roadside design and management guidelines and standards of European countries. Furthermore, the literature review summarised in WP1 deliverable included a few quantified relationships between roadside design features and their effect on accident frequencies and severities. These were all included in the matrix.

Safer Verges Scoping Study (Erginbas, Kennedy, Seidl, Robbins, Greene, & Leal, 2016) identified many quantified relationships between the crashes and not only roadside elements, but also human and vehicle factors as well. Of all the identified relationships, ones which were related to the effect of roadside elements were added to the matrix.

Following the review of the European projects, only a limited number of quantified relationships between roadside design elements and accidents could be identified. The next project to be reviewed was Safer Verges Scoping Study (Erginbas, Kennedy, Seidl, Robbins, Greene, & Leal, 2016), which was delivered by TRL to Highways England in 2016. The aim of this project was to identify new roadside safety applications, which may be beneficial for Highways England Road Network. To achieve this goal, a comprehensive literature review, and RoR accident data analysis were carried out to identify as many contributory factors and as many corresponding mitigation measures as possible, which has an effect on an injury outcome as a result of a RoR accident. This project identified many quantified relationships between the accidents and not only roadside elements, but also human and vehicle factors as well. Of all the identified relationships, ones which were related to the effect of roadside elements were added to the matrix.

Another European research project EURSI (McCarthy, 2011), was also reviewed under Task 1.2 activities. The EuRSI project aimed to explore new approaches to collecting and processing road environment data in order to help identify and understand risk within the context of a Road Safety Inspection (RSI) for rural roads. The main outputs from the project included a new approach to assessing risk using various static road factors, and the concept of a safe profile velocity V_{sp} (average safe driving profile under ideal, traffic-free conditions). There were a number of deliverables resulted from this project, however Deliverable 3.2 – Risk assessment review (McCarthy, 2011), was perhaps the most relevant to this literature review. This deliverable included a number of CMFs for different road parameters. Unfortunately, none of the CMFs referenced in the document was related to roadside design elements, but rather they were related to the design parameters of the road itself, such as gradient, superelevation, etc. Furthermore, these CMFs were developed for all accident types, rather than targeting the RoR accident. These were seen as out of scope and therefore not included in the final matrix.

A valuable resource in identification of further quantified relationships was the Crash Modification Factors Clearinghouse. Crash Modification Factors Clearinghouse is a regularly updated online database of published CMFs. It is funded by U.S. Department of Transport Federal Highway Administration and maintained by University of North Carolina Highways Safety Center. A considerable number of roadside design related CMFs were identified through this online database, which are included in the final matrix. For each of these CMFs, the referenced publication was obtained and reviewed to ensure all the data fields in the matrix could be populated accurately for each quantified relationship.

Another useful source of quantified effects was the Improving Roadside Safety Stage 4 Interim Report (Jurewicz, Steinmetz, Phillips, Veith, & McLean, 2014) by Austroads. This report included findings of a large literature review into roadside safety related CMFs. As a result, there were many CMFs identified and referenced. These were also featured in the final matrix.

Another useful resource was the Handbook of Road Safety Measures (Elvik, Hoye, Vaa, & Sorensen, 2009). This is a well-known resource in the area of road safety meta-analysis and provides summaries of current knowledge regarding the quantified effects of 128 road safety measures. Even though the book covers all areas of road safety, only those effects which are related to roadside design were added in the final matrix.

A review of the above sources provided evidence-based results with regards to the relationship between different road side elements and safety.

These roadside elements are related to;

- Clear/Safety zones
- Hazards reduction
- Side slopes
- Shoulders
- Drainage structures
- Passively safe poles and
- Roadside and Median barriers

3.4 Results

A review of the sources described in Section 3.3 provided evidence based results with regards to the relationship between different road side elements and safety. A number of road side safety features were identified to contribute to road safety by the frequency and/or severity of crashes in this literature review.

The resulting matrix is presented in Table 5, which demonstrates the relationship between different road side design elements and parameters and crashes.

Table 5 – Road side design elements / parameters and their effects on crashes

	Roadside Design Element	Original Condition	Compared to	Road Area	Road Type	Crash Type	Severity Level	Effect	CMF	Source
Likelihood of Leaving Carriageway	**Shoulder Rumble Strips**									
	Provision of shoulder rumble strips (type unspecified)	No Rumble Strip present	Shoulder rumble strip installed	Rural	two-lane undivided	RoR	All	16% decrease	0.84	(Torbic et al., 2009)
					Multi-lane divided	RoR	Fatal, Serious & Slight injury	17% decrease	0.83	
					two-lane undivided	RoR	Fatal, Serious & Slight injury	36% decrease	0.64	
					Multi-lane divided	RoR Truck related	All	42% decrease	0.58	
					Multi-lane divided	RoR, wet road	All	18% decrease	0.82	
					Multi-lane divided	RoR, night time	All	27% decrease	0.73	
				Rural	two-lane undivided	RoR	All	13% decrease	0.87	(Patel et al., 2007)
							Fatal, Serious & Slight injury	18% decrease	0.82	
				Rural	two-lane undivided	RoR	All	26% decrease	0.74	(Sayed and P. deLeur, 2010)
				Rural	Not Specified	RoR	All	18% decrease	0.82	(El-Basyouny and Sayed, 2012)
		1.2m to 3.7m wide shoulder without rumble strip	Shoulder rumble strip installed	Rural	Multi-lane divided	All crash types	All	24% decrease	0.76	(Park et al., 2014)
						All crash types	Fatal, Serious & Slight injury	36% decrease	0.64	
						SVROR	All	35% decrease	0.65	
						SVROR	Fatal, Serious & Slight injury	38% decrease	0.62	
	Provision of continuous milled-in shoulder rumble strips	No Rumble Strip present	Shoulder rumble strip installed	Not Specified	Multi-lane divided	SVROR	All	79% decrease	0.21	(Perillo, 1998)
				Rural	Multi-lane divided	SVROR	All	10% decrease	0.9	(Carrasco, et al. 2004)
							Serious & Slight injury	22% decrease	0.78	

Table 5 – Road side design elements / parameters and their effects on crashes (continued)

	Roadside Design Element	Original Condition	Compared to	Road Area	Road Type	Crash Type	Severity Level	Effect	CMF	Source
Likelihood of Leaving Carriageway	**Edge line markings**									
	Provision of edge line markings	no edge lines present	edge lines markings installed	Rural	Not Specified	All crash types	Fatal, Serious & Slight injury	33% decrease	0.67	(BTE, 2001)
				Rural	horizontal curved sections of two-lane undivided	RoR	All	13% decrease	0.87	(Tsyganov et al. , 2009)
					tangent sections of two-lane undivided			13% decrease	0.87	
Likelihood of Reaching a Hazard	**Shoulder, hardshoulder & hardstrip**									
	Provision of shoulder	no shoulder present	a shoulder of 0.6m installed	Not Specified	Not Specified	All crash types	All	19% decrease	0.81	(Ksaibati and Crowe, 1999)
			a shoulder of 1.8m installed					47% decrease	0.53	
			a shoulder of 3.0m installed					66% decrease	0.34	
	Provision of hard strip	no hard strip present	hard strip present (same road width)	Rural	two-lane undivided	All Crash Types	Fatal, Serious & Slight injury	20 - 25% decrease	N/A	(Walmsley et al., 1998)
	Shoulder width (unpaved)	unpaved shoulder with a width less than 1.5m (5ft)	unpaved shoulder widened to over 1.5m (5ft)	Rural	two-lane undivided	All Crash Types	All	29% decrease	0.71	(Zeng et al. , 2013)
							Fatal, Serious & Slight injury	35% decrease	0.35	
						Head-on, RoR, Side Swipe	All	21% decrease	0.21	

Table 5 – Road side design elements / parameters and their effects on crashes (continued)

	Roadside Design Element	Original Condition	Compared to	Road Area	Road Type	Crash Type	Severity Level	Effect	CMF	Source
Likelihood of Reaching a Hazard	**Shoulder, hardshoulder & hardstrip (continued)**									
	Shoulder width	shoulder width 1.2m to 3.7m (4 to 12ft)	shoulder widened	Rural	Multi-lane divided	SVROR	All	39% decrease	0.60	(Park et al., 2014)
						SVROR	Fatal, Serious & Slight injury	43% decrease	0.57	
						All Crash Types	All	23% decrease	0.77	
						All Crash Types	Fatal, Serious & Slight injury	31% decrease	0.69	
	Shoulder surface (sealing)	shoulder not sealed (gravel)	shoulder sealed	Rural	Not Specified	All Crash Types	Fatal, Serious & Slight injury	29% decrease	0.61	(Scully et al. 2006)
				Rural	Not Specified	All Crash Types	Fatal, Serious & Slight injury	29% decrease	0.61	(BTE, 2001)
	Shoulder colouring	Shoulder in natural colour	shoulder painted in red to give contrasting surface	Rural	Multi-lane divided	All Crash Types	Fatal, Serious & Slight injury	no effect	N/A	(Summersgill et al. , 1997)
	Clear / Safety Zone Related									
	Hazard location (relative to clear zone)	hazard located within clear zone	hazard moved outside of clear zone	Not Specified	Not Specified	RoR	Fatal, Serious & Slight injury	71% decrease	0.29	(Gan *et al.*, 2005)
				Not Specified	Not Specified	RoR	All	55% decrease	0.45	(Agent *et al.*, 1996)

Table 5 – Road side design elements / parameters and their effects on crashes (continued)

	Roadside Design Element	Original Condition	Compared to	Road Area	Road Type	Crash Type	Severity Level	Effect	CMF	Source
Likelihood of Reaching a Hazard	Clear / Safety Zone Related (continued)									
	Hazard (utility pole) lateral offset	existing offset	hazard offset increased by 1.5m	Not Specified	Not Specified	RoR crashes into utility poles	Serious & Slight injury	33% decrease	0.67	(Zegeer, 2001) referenced in (Jurewicz et al. ,2014)
	Provision of Clear Zone from edge of carriageway	no clear zone present	a clear zone of 9.0m provided	Not Specified	Not Specified	RoR	All	80% decrease	0.20	(AASHTO, 1974)
	Clear zone width	3.0m	increased to 10.5m	Not Specified	Not Specified	Fixed Object Impact	All	10% decrease	0.90	(Insurance Institute for Highway Safety USA, 2003)
	Roadside recovery distance	existing recovery distance	increased by 1.5m	Rural	straight sections of two-lane undivided	RoR	All	13% decrease	0.87	(Zegeer et al., 1987)
			increased by 2.4m					21% decrease	0.79	
			increased by 3.0m					25% decrease	0.75	
			increased by 3.6m					29% decrease	0.71	
			increased by 5.0m					35% decrease	0.65	
			increased by 6.0m					44% decrease	0.56	
			increased by 1.5m		curved sections of two-lane undivided			9% decrease	0.91	
			increased by 2.4m					14% decrease	0.86	
			increased by 3.0m					17% decrease	0.83	
			increased by 3.6m					19% decrease	0.81	
			increased by 5.0m					23% decrease	0.77	
			increased by 6.0m					29% decrease	0.71	
	Lateral clearance	3.0m (10ft)	increased to 12.2m (40ft)	Rural	tangent sections of two-lane undivided	Single Vehicle RoR	Fatal, Serious & Slight injury	32% decrease	0.68	(Peng et al., 2012)
					horizontal curve sections of two-lane undivided			51% decrease	0.49	

Table 5 – Road side design elements / parameters and their effects on crashes (continued)

	Roadside Design Element	Original Condition	Compared to	Road Area	Road Type	Crash Type	Severity Level	Effect	CMF	Source
Likelihood of Reaching a Hazard	**Hazard frequency**									
	Number of poles per km	38 poles per km	reduced to 25 poles per km	Not Specified	Not Specified	All crash types	All	25% decrease	0.75	(Zegeer *et al.*, 1987)
		25 poles per km	reduce tod 13 poles per km					25% decrease	0.75	
		38 poles per km	reduced to 13 poles per km					50% decrease	0.50	
	Roadside Slope (embankments)									
	Roadside Slope (embankment)	1V:2H	flattened to 1V:4H	Rural	two-lane undivided	Single Vehicle	All	10% decrease	0.90	(AASHTO, 2010)
			flattened to 1V:5H					15% decrease	0.85	
			flattened to 1V:6H					21% decrease	0.79	
			flattened to 1V:7H					27% decrease	0.73	
		1V:3H	flattened to 1V:4H					8% decrease	0.92	(Zegeer and Council, 1992)
			flattened to 1V:5H					14% decrease	0.86	(AASHTO, 2010)
			flatten to 1V:6H					19% decrease	0.81	(Zegeer and Council, 1992)
			flattened to 1V:7H					26% decrease	0.74	(AASHTO, 2010)
		1V:4H	flattened to 1V:5H					6% decrease	0.94	
			flattened to 1V:6H					12% decrease	0.88	(Zegeer and Council, 1992)
			flattened to 1V:7H					19% decrease	0.81	(AASHTO, 2010)

Table 5 – Road side design elements / parameters and their effects on crashes (continued)

	Roadside Design Element	Original Condition	Compared to	Road Area	Road Type	Crash Type	Severity Level	Effect	CMF	Source
Likelihood of Reaching a Hazard	**Roadside Slope (embankments) (continued)**									
	Roadside Slope (embankment)	1V:5H	flattened to 1V:6H	Rural	two-lane undivided	Single Vehicle	All	6% decrease	0.94	(AASHTO, 2010)
			flattened to 1V:7H					14% decrease	0.86	
		1V:6H	flattened to 1V:7H					8% decrease	0.92	
		1V:7H	steepened to 1V:6H		Multi-lane divided			5% increase	1.05	
			steepened to 1V:5H					9% increase	1.09	
			steepened to 1V:4H					12% increase	1.12	
			steepened to 1V:2H or steeper					18% increase	1.18	
		1V:3H	flattened to 1V:4H	Rural	two-lane undivided	All Crash Types	Serious & Slight	42% decrease	0.58	(Elvik and Vaa, 2004)
							PDO	29% decrease	0.71	
				Rural	two-lane undivided	RoR	All	18% decrease	0.82	(Miaou, 1996)
		1V:4H	flattened to 1V:6H	Rural	two-lane undivided	All Crash Types	Serious & Slight	22% decrease	0.78	(Elvik and Vaa, 2004)
							PDO	24% decrease	0.76	
				Rural	two-lane undivided	RoR	All	24% decrease	0.76	(Miaou, 1996)

Table 5 – Road side design elements / parameters and their effects on crashes (continued)

	Roadside Design Element	Original Condition	Compared to	Road Area	Road Type	Crash Type	Severity Level	Effect	CMF	Source
Likelihood of Reaching a Hazard	**Drainage Structures**									
	Drainage structure location	existing location	lengthened or extended further away from the road	Not Specified	Not Specified	RoR	All	44% decrease	0.56	(Arizona Department of Transportation, 2009) (Gan et al., 2005)
							Fatal	27% decrease	0.73	
							Fatal, Serious & Slight injury	36% decrease	0.64	
				Not Specified	Not Specified	All Crash types	All	41% decrease	0.59	(Gan *et al.*, 2005) (Bahar *et al.*, 2007)
				Not Specified	Not Specified	Not Specified	Serious & Slight injury	10% decrease	0.90	(VicRoads, 1990) referenced in (Jurewicz et al. 2014)
	Culvert outlet design	typical design	widened and flattened	Not Specified	Not Specified	All crash types	Fatal, Serious & Slight injury	100% decrease	0.00	(Corben and Newstead, 2001)
	Passively Safe Poles									
	Use of passively safe poles (slip-base, impact absorbing, etc.)	rigid poles present	Replace with passively safe poles (slip-base, impact absorbing, etc.)	Not Specified	straight sections of road	RoR	All	40% decrease	0.60	(Roads and Traffic Authority, 2004)
				Not Specified	Not Specified	All crash types	Fatal	60% decrease	0.40	(Gan *et al.*, 2005)
				Not Specified	Not Specified	All crash types	Serious & Slight injury	30% decrease	0.70	(Gan *et al.*, 2005)
	Utility line location	located over ground (poles)	buried underground	Not Specified	Not Specified	All crash types	All	40% decrease	0.60	(Gan *et al.*, 2005), (Bahar *et al.*, 2007)

Table 5 – Road side design elements / parameters and their effects on crashes (continued)

	Roadside Design Element	Original Condition	Compared to	Road Area	Road Type	Crash Type	Severity Level	Effect	CMF	Source
Consequences of Reaching a Hazard	**Roadside Barriers**									
	Semi-rigid roadside barrier installation	no roadside barrier present	semi-rigid roadside barrier installed	Not Specified	Not Specified	RoR	All	30% decrease	0.70	(Arizona Department of Transportation, 2009) (Gan et al., 2005)
							Fatal	56% decrease	0.44	
							Serious & Slight injury	23% decrease	0.77	
							Fatal, Serious & Slight injury	26% decrease	0.74	
							PDO	34% decrease	0.66	
				Not Specified	Not Specified	RoR	All	70% decrease	0.30	(Gan *et al.*, 2005)
				Not Specified	Not Specified	All Crash Types	All	11% decrease	0.89	
							Fatal	65% decrease	0.35	
							Serious & Slight injury	40% decrease	0.60	
				Not Specified	Not Specified	All Crash Types	All	5% decrease	0.95	(Agent *et al.*, 1996)
							Fatal	65% decrease	0.35	
							Serious & Slight injury	40% decrease	0.60	
	Semi-rigid roadside barrier installation along embankment	no barrier present along embankment	semi-rigid roadside barrier installed along embankment	Not Specified	Not Specified	RoR	All	7% decrease	0.93	(Elvik *et al.*, 2009)
				Not Specified	Not Specified		Serious & Slight injury	47% decrease	0.53	
				Not Specified	Not Specified		Fatal	44% decrease	0.56	

Table 5 – Road side design elements / parameters and their effects on crashes (continued)

Consequences of Reaching a Hazard

Roadside Design Element	Original Condition	Compared to	Road Area	Road Type	Crash Type	Severity Level	Effect	CMF	Source
Roadside Barriers (continued)									
Semi-rigid roadside barrier installation on inside of horizontal curves	no barrier present on inside of horizontal curve	semi-rigid roadside barrier installed on inside of horizontal curve	Not Specified	Not Specified	All Crash Types	Fatal, Serious & Slight injury	28% decrease	0.72	(Gan *et al.*, 2005)
Semi-rigid roadside barrier installation on outside of horizontal curves	no barrier present on outside of horizontal curve	semi-rigid roadside barrier installed on outside of horizontal curve	Not Specified	Not Specified	All Crash Types	Fatal, Serious & Slight injury	63% decrease	0.37	(Gan *et al.*, 2005)
Barrier rigidity	barrier present along embankment	barrier along embankment is replaced with a less rigid type	Not Specified	Not Specified	RoR	Serious & Slight injury	32% decrease	0.68	(AASHTO, 2010), (Elvik *et al.*, 2009), (Scully *et al.*, 2006)
						Fatal	41% decrease	0.59	
Median Barriers									
Median barrier Installation (any type)	no barrier present on the median	median barrier installed	Not Specified	Not Specified	All Crash Types	All	36% decrease	0.64	(Arizona Department of Transportation, 2009) (Gan et al., 2005)
						Serious & Slight injury	26% decrease	0.74	
						Fatal, serious & Slight injury	28% decrease	0.72	
						PDO	39% decrease	0.61	
					RoR	All	35% decrease	0.65	
						PDO	46% decrease	0.54	
			Rural	Multi-lane divided	All Crash Types	Fatal	43% decrease	0.57	(AASHTO, 2010), (Elvik *et al.*, 2009)
						Serious & Slight injury	30% decrease	0.70	
						All	24% increase	1.24	

Table 5 – Road side design elements / parameters and their effects on crashes (continued)

	Roadside Design Element	Original Condition	Compared to	Road Area	Road Type	Crash Type	Severity Level	Effect	CMF	Source
Consequences of Reaching a Hazard	**Median Barriers (continued)**									
	Rigid median barrier installation	no barrier present on the median	rigid median barrier installed	Rural	Multi-lane divided	All Crash Types	Serious & Slight injury	15% increase	1.15	(Elvik *et al.*, 2009)
	Semi-rigid median barrier installation	no barrier present on the median	semi-rigid median barrier installed	Not Specified	Not Specified	All Crash Types	Fatal	48% decrease	0.52	(Gan *et al.*, 2005)
							Serious & Slight injury	36% decrease	0.64	
				Rural	Multi-lane divided	All Crash Types	Serious & Slight injury	35% decrease	0.65	(AASHTO, 2010), (Elvik *et al.*, 2009)
	Median barrier installation (flexible)	no barrier present on the median	flexible median barrier installed		Freeway	Cross-median head-on	Fatal	75% decrease	0.25	(Ray *et al.*, 2009)
				Rural	Multi-lane divided	All Crash Types	Fatal	42% decrease	0.58	(Alluri et al., 2012)
							Serious	20% decrease	0.80	
							Slight	12% decrease	0.88	
							PDO	88% increase	1.88	
							Possible Injury	53% increase	1.53	
				Rural	Multi-lane divided	All Crash Types	Serious & Slight injury	29% decrease	0.71	(AASHTO, 2010), (Elvik *et al.*, 2009)
	Median barrier installation on undivided road (flexible)	no barrier present in between lanes	flexible barrier installed on the centre of undivided road	Rural	two-lane undivided	All Crash Types	Fatal & Serious Injury	46% decrease	0.54	(Gan *et al.*, 2005)
							Fatal & Serious Injury	74% decrease	0.26	
							Fatal, Serious & Slight injury	79% decrease	0.21	(Carlsson, 2009)
						RoR to right and head-on	Fatal, Serious & Slight injury	70% decrease	0.30	(Austroads, 2009)
						All Crash Types	Casualty Crashes	28% decrease	0.72	

Table 5 – Road side design elements / parameters and their effects on crashes (continued)

Consequences of Reaching a Hazard

Roadside Design Element	Original Condition	Compared to	Road Area	Road Type	Crash Type	Severity Level	Effect	CMF	Source
Median Barriers (continued)									
Flexible barrier on roadsides and in medians	no barrier present	Flexible barrier installed on median and/or roadside	Rural	Multi-lane divided (only 100km/h and 110km/h sections)	All crash types	Fatal, Serious & Slight injury	77% decrease	0.23	(Candappa *et al.*, 2009)
						Fatal & Serious Injury	77% decrease	0.23	
					RoR and cross-median head-on	Fatal, Serious & Slight injury	79% decrease	0.21	
						Fatal & Serious Injury	87% decrease	0.13	
Crash Cushions									
Crash Cushion installation	No crash cushion present	Crash cushion installed in front of fixed roadside feature	Not Specified	Not Specified	Fixed object Impacts	Fatal	69% decrease	0.31	(Bahar et al., 2007), (Elvik *et al.*, 2009)
						Serious & Slight injury	69% decrease	0.31	
						PDO	46% decrease	0.54	
			Not Specified	Not Specified	RoR	All	45% decrease	0.55	(Arizona Department of Transportation, 2009), (Gan *et al.*, 2005)
						PDO	58% decrease	0.42	
			Not Specified	Not Specified	All crash types	All	41% decrease	0.59	(Arizona Department of Transportation, 2009)
						Serious & Slight injury	55% decrease	0.45	
						Fatal, Serious & Slight injury	50% decrease	0.50	
						PDO	36% decrease	0.64	
			Not Specified	Not Specified	All crash types	All	29% decrease	0.71	(Gan *et al.*, 2005)
						Fatal	83% decrease	0.17	
						Serious & Slight injury	50% decrease	0.50	

4 Evaluation of design standards and guidelines

This chapter summarises a review of existing design standards and guidelines related to road side design and management. It includes an analysis of relevant CEN standards, the Directive 2008/96/EC, and the relevant guidelines for the six funding countries; Belgium (Flanders), Ireland, Netherlands, Slovenia, Sweden and United Kingdom.

4.1 CEN Standards

4.1.1 Road Restraint Systems (RRS)

The European Standard for RRS is EN 1317 (European Committee for Standardization, CEN, 2010). It defines common testing and certification procedures for RRS. The requirement for RRS to be CE marked, as specified in Part 5 of the standard, has been mandatory for each EU nation since 2011.

All RRSs installed on the European Road Network must comply with the requirements of EN 1317. This standard does not state which restraint systems should be used in certain circumstances. It states which tests a product should undergo to be in a certain performance class, what the safety levels are (ASI, THIV, etc.) and the classes of performance (based on different parameters). This standard classifies and evaluates the performance of the road restraint systems by means of full-scale crash tests.

EN 1317 is a six-part standard that comprises the following:

- EN 1317-1 Road Restraint Systems - Part 1: Terminology and general criteria for test methods.
- EN 1317-2 Road Restraint Systems - Part 2: Performance classes, impact test acceptance criteria and test methods for safety barriers and vehicle parapets.
- EN 1317-3 Road Restraint Systems - Part 3: Performance classes, impact test acceptance criteria and test methods for crash cushions.
- ENV 1317-4 Road Restraint Systems - Part 4: Performance classes, impact test acceptance criteria and test methods of terminals and transitions of safety barriers
- EN 1317-5 Road Restraint Systems - Part 5: Product requirements and evaluation of conformity for vehicle restraint systems
- TS 1317-8, Road Restraint Systems – Part 8: Motorcycle road restraint systems which reduce the impact severity of motorcyclist collisions with safety barriers (under preparation).

It is noted that:

- EN 1317-6 Road Restraint Systems - Part 6: Pedestrian restraint systems - Pedestrian parapets has been superseded by PD CEN/TR 16949:2016 Road restraint systems - pedestrian restraint system - pedestrian parapets.
- prEN 1317-7 Performance classes, impact test acceptance criteria and test methods for terminals of safety barriers is being developed for the testing and approval of terminal systems.

RRS must be installed under conditions similar to those applied in the test and complying with the specifications in the manufacturer's installation manual. The parameters that determine the qualities of a RRS and classify it within EN 1317 are:

- Containment level;
- Working width;
- Dynamic deflection;
- Vehicle intrusion;
- Impact severity; and
- Redirection.

4.1.1.1 *Containment Level*

Containment level indicates the containment capacity of the system. Each containment level is defined by the crash tests that the road barrier has to withstand. The containment levels are classified according to the growing energy of impact of the heaviest vehicle tested.

From the results of these crash tests, all parameters defining the performance of the system are calculated. In order to pass the crash test, a restraint system needs to fulfil a series of requirements:

- The safety barrier shall contain and redirect the vehicle without complete breakage of the principal longitudinal elements of the system

- Elements of the safety barrier shall not penetrate the passenger compartment of the vehicle

- Deformations of, or intrusion into the passenger compartment that can cause serious damage are not permitted

- The centre of gravity of the vehicle shall not cross the centreline of the deformed system

- The vehicle must not roll over (including rollover of the vehicle onto its side) during or after impact, although rolling pitching and yawing are acceptable

- For tests with Heavy Good Vehicles (HGV), no more than 5% of the mass of the ballast shall become detached or be split during the test, until the vehicle comes to rest.

- Following impact into the safety barrier or parapet, the vehicle when bouncing back is not permitted to cross a line parallel to the initial traffic face of the system (see the definition of 'redirection' for more detail)

It is up to national regulations (and not EN 1317) to define the containment level (at least the minimum) to be used in different situations according to specific criteria (traffic type, speed limit, presence of hazards on the roadside etc.). **Fout! Verwijzingsbron niet gevonden.** presents the containment class and containment levels as per EN 1317-2.

Table 6 – Containment Class and Containment Levels (European Committee for Standardization, CEN, 2010)

Containment Class	EN 1317 Containment Level
Low Angle Containment	T1
	T2
	T3
Normal Containment	N1
	N2
High Containment	H1
	L1
	H2
	L2
	H3
	L3
Very High Containment	H4a
	H4b
	L4a
	L4b

NOTE 1 Low angle containment levels are intended to be used only for temporary safety barriers. Temporary safety barriers can also be tested for higher levels of containment.
NOTE 2 A successfully tested barrier at a given containment level should be considered as having met the containment requirements of any lower level, except that N1 and N2 do not include T3, H-Levels do not include L-Levels and that H1 – H4b do not include N2.

NOTE 3 Because testing and development for very high containment safety barriers in different countries has taken place using significantly different types of heavy vehicles, both tests TB 71 and TB 81 are included in the standard at present. The two containment levels H4a and H4b should not be regarded as equivalent and no hierarchy is given between them. The same holds for the two containment levels L4a and L4b.

NOTE 4 The performance of Containment Classes L is enhanced in respect to the corresponding H classes by the addition of Test TB 32.

Crash test specifications as per EN 1317-2 are presented in **Fout! Verwijzingsbron niet gevonden.**.

Table 7 – Crash Test Specifications (European Committee for Standardization, CEN, 2010)

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

4.1.1.2 *Working Width*

Normalised Working width is a measure of the deformation of the barrier under impact. It is usually considered as the main parameter to calculate the space needed behind the barrier in order for the system to work properly. It is calculated as the maximum distance between the traffic face of the barrier and the maximum deformation of its main components during the impact of the heavier vehicle. The working width is divided into 8 classes from W1 to W8 according to the growing deformation of the system. **Fout! Verwijzingsbron niet gevonden.** provides an overview of the different working width classes and the equivalent values in metres as per EN 1317-2.

Table 8 – Levels of Normalised Working Width (European Committee for Standardization, CEN, 2010)

Classes of normalised working width levels	Levels of normalised working width m
*W*1	$W_N \leq 0,6$
*W*2	$W_N \leq 0,8$
*W*3	$W_N \leq 1,0$
*W*4	$W_N \leq 1,3$
*W*5	$W_N \leq 1,7$
*W*6	$W_N \leq 2,1$
*W*7	$W_N \leq 2,5$
*W*8	$W_N \leq 3,5$

NOTE 1 In specific cases, a class of working width level less than *W*1 may be specified.

NOTE 2 The dynamic deflection, the working width and the vehicle intrusion allow determination of the conditions for installation of each safety barrier and also to define the distances to be provided in front of obstacles to permit the system to perform satisfactorily.

NOTE 3 The deformation depends on both the type of system and the impact test characteristics.

4.1.1.3 *Dynamic Deflection*

Dynamic Deflection is the second parameter to evaluate the deformation of the system under impact and is calculated as the distance between the traffic face of the system in its initial condition and its maximum displacement. The dynamic deflection is measured in metres. **Fout! Verwijzingsbron niet gevonden.** presents dynamic deflection and working width measured values as per EN 1317-2.

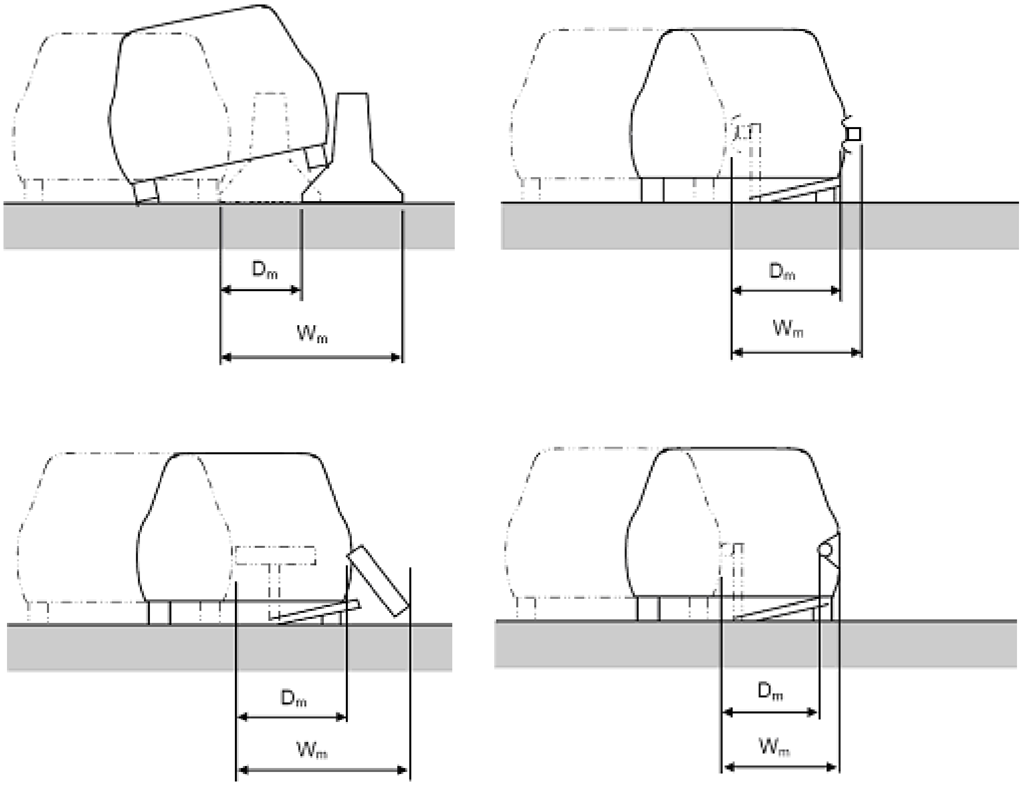


Figure 10 – Dynamic Deflection (D_m) and Working Width (W_m) Measured Values (European Committee for Standardization, CEN, 2010)

4.1.1.4 *Vehicle Intrusion (VI)*

The vehicle intrusion is the maximum vehicle deviation dimension of the impacting vehicle from the traffic face of the RRS.

Testing carried out in compliance with EN 1317-2 measured the VI to the maximum dynamic lateral position of the HGV (i.e. H1, H3, H4a and H4b vehicles), which may have had a flat bed, a curtain sided or a box sided construction, e.g. if a flat-bed vehicle was used then the VI would have likely been the same or slightly greater than the working width of the RRS. If the VI was recorded as a higher class than the working width, then the reported working width of the system would be based on this VI value.

Testing carried out in compliance with the updated EN 1317:2 measures the VI to the furthermost part of the HGV which includes a notional load having the width and length of the vehicle platform and a total height of 4m from the ground. This addresses the 'worst-case' lean scenario for H1, H3, H4a and H4b HGV's with different platform constructions.

The VI measurement for the H2 under EN 1317-2 remains unchanged from that in EN1317-2:1998, i.e. its maximum dynamic lateral position.

Hence in the testing of higher containment RRSs (excepting H2) there could be an increase in the VI for H1, H3, H4a or H4b than has been reported to EN 1317-2 when compared to the reported VI for an EN 1317-2 test. Vehicle intrusion measured values as per EN 1317-2 are presented in **Fout! Verwijzingsbron niet gevonden.**.

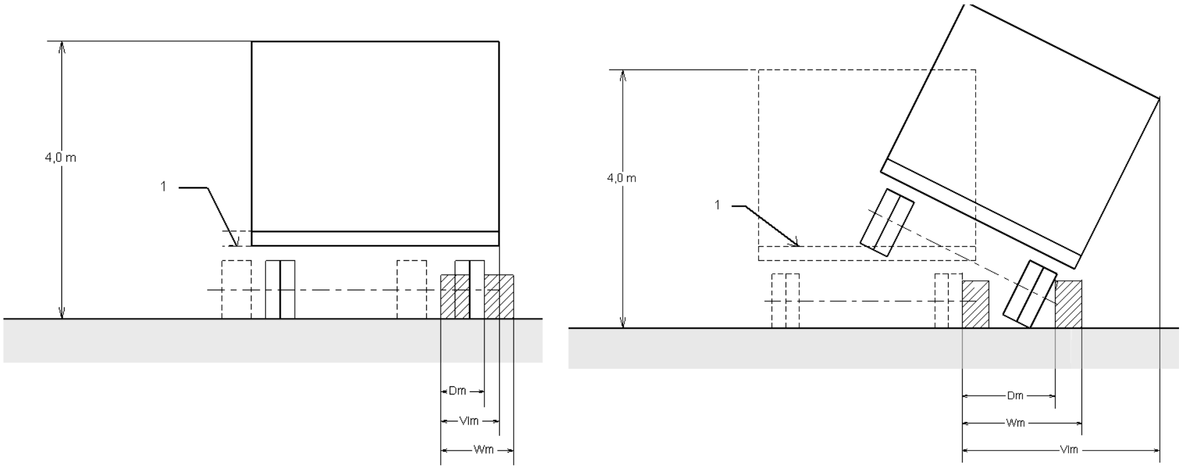


Figure 11 – Vehicle Intrusion (VIm) Measured Values (European Committee for Standardization, CEN, 2010)

4.1.1.5 *Impact Severity*

Impact Severity is an index that assesses the severity of an impact against the tested restraint system based on the results of different parameters. The impact severity is divided into three classes, from A to C, ranging from impact severity A which affords a greater level of safety for the car's occupants than level B. Level C offers the lowest level of safety for car occupants.

The Impact Severity is calculated by assessing two components: the Acceleration Severity Index (ASI) and the Theoretical Head Impact Velocity (THIV).

The ASI is probably the main parameter for the calculation of the Impact Severity and is calculated by placing an accelerometer in the centre of the mass of the car and recording the impact against the road restraint system. The ASI is computed before, during and after the impact and its maximum value is used to evaluate the severity of the impact.

The THIV has been developed for assessing the occupant impact severity for vehicles involved in collisions with road restraint systems. The occupant is considered to be a freely moving object (head) that, as the vehicle changes its speed during contact with the road restraint system, continues moving until it strikes a surface within the interior of the vehicle. The magnitude of the velocity of the theoretical head impact is considered to be a measure of the vehicle to road restraint system impact severity.

Fout! Verwijzingsbron niet gevonden. shows the different levels/classes of impact severity as well as the maximum ASI/THIV permissible values as per EN 1317-2.

Table 9 – Impact Severity Levels (European Committee for Standardization, CEN, 2010)

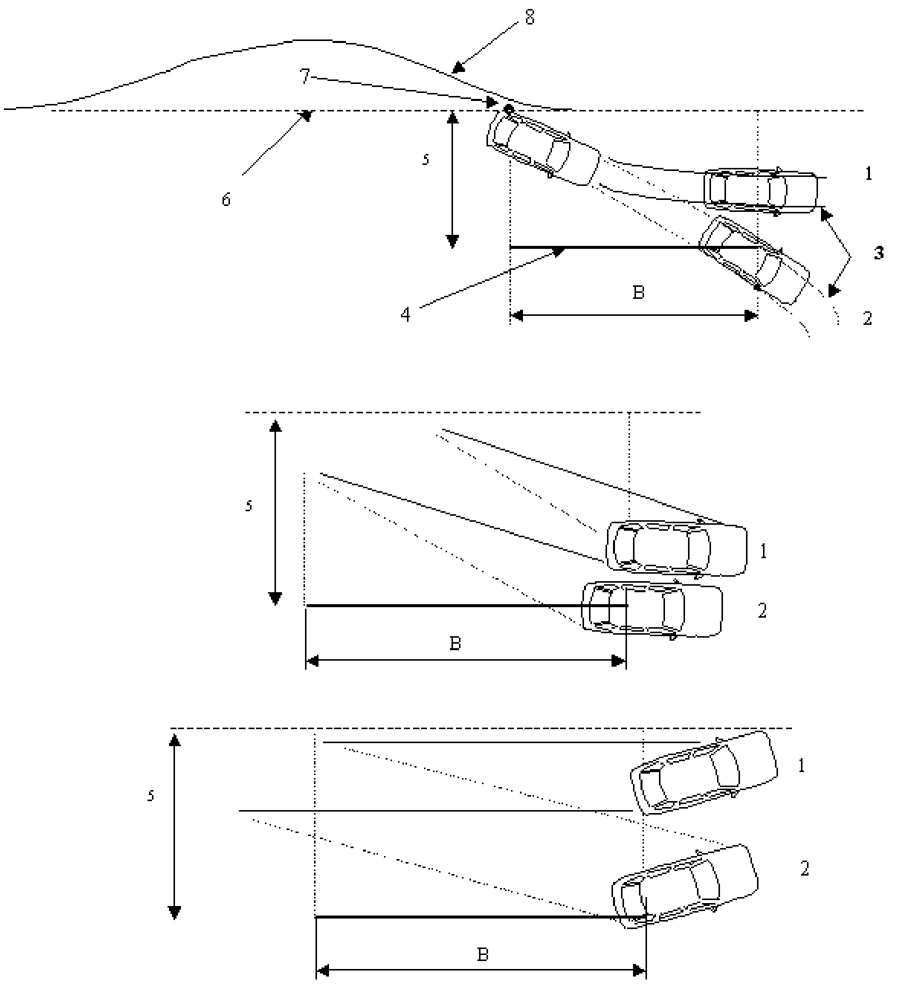
Impact severity level	**Index values**		
A	ASI ≤ 1,0	and	THIV ≤ 33 km/h
B	ASI ≤ 1,4		
C	ASI ≤ 1,9		

4.1.1.6 *Redirection*

Redirection is the capacity of a restraint system to return a vehicle to the road in a controlled manner following impact against that same restraint system. The exit box is the zone which the vehicle may not leave during the exit trajectory following impact against a restraint system. The dimensions of the zones are presented in **Fout! Verwijzingsbron niet gevonden.** and graphics relating to the zones are presented in **Fout! Verwijzingsbron niet gevonden.** as per EN 1317-2.

Table 10 – Distance for Exit Box Criterion (European Committee for Standardization, CEN, 2010)

Vehicle type	**A** **m**	**B** **m**
Car	2,2	10
Other vehicles	4,4	20



Key

1	"Pass"	5	A + Width of Vehicle + 16 % of Length of
2	"Fail"	6	Initial traffic face of safety barrier
3	Wheel tracks	7	Point *P*
4	Extent of Exit Box	8	Deflected form of safety barrier including parapet
B	Distance from the last (namely closest to the downstream end of the barrier) point *P*		

Figure 12 – Exit Box Trajectories (European Committee for Standardization, CEN, 2010)

4.2 European Directive 2008/96/EC

European Directive 2008/96/EC on Road Infrastructure Safety Management (RISM) (European Parliament and Council, 2008) at Article 1 requires the establishment and implementation of procedures relating to:

- Road Safety Impact Assessment (RSIA)
- Road Safety Audit (RSA)
- Network Safety Management (NSM)
- Road Safety Inspection (RSI)

RSIA, RSA and RSI are proactive measures that have the potential to improve the safety of road users across the national road network. NSM is a reactive measure that identifies high collision locations or clusters based on collision data over the preceding years. This enables the road authority to prioritise remedial measures at these locations which also has the potential to improve the safety of road users on the national road network.

The subject matter and scope of the Directive is defined in Article 1 as follows:

1. *This Directive requires the establishment and implementation of procedures relating to road safety impact assessments, road safety audits, the management of road network safety and safety inspections by the Member States.*

2. *This Directive shall apply to roads which are part of the trans-European road network, whether they are at the design stage, under construction or in operation.*

3. *Member States may also apply the provisions of this Directive, as a set of good practices, to national road transport infrastructure, not included in the trans-European road network that was constructed using Community funding in whole or in part.*

4. *This Directive shall not apply to road tunnels covered by Directive 2004/54/EC.*

4.2.1 Road Safety Impact Assessment (RSIA)

The RISM Directive includes the following definition: *road safety impact assessment means a strategic comparative analysis of the impact of a new road or a substantial modification to the existing network on the safety performance of the road network*. The following three points cite the regulations relating to the application of RSIAs as included in Article 3 of the Directive:

1. *Member States shall ensure that a road safety impact assessment is carried out for all infrastructure projects.*

2. *The road safety impact assessment shall be carried out at the initial planning stage before the infrastructure project is approved. In that connection, Member States shall endeavour to meet the criteria set out in Annex I.*

3. *The road safety impact assessment shall indicate the road safety considerations which contribute to the choice of the proposed solution. It shall further provide all*

relevant information necessary for a cost-benefit analysis of the different options assessed.

4.2.2 Road Safety Audit (RSA)

The RISM Directive includes the following definition: "*…road safety audit means an independent detailed systematic and technical safety check relating to the design characteristics of a road infrastructure project and covering all stages from planning to early operation/ opening to traffic"* (European Parliament and Council, 2008).

The following five points cite the regulations relating to the application of RSAs as included in Article 4 of Directive 2008/96/EC:

1. *Member States shall ensure that RSAs are carried out for all infrastructure projects.*

2. *When carrying out RSAs the Member States shall endeavour to meet the criteria set out in Annex II. Member States shall ensure that an auditor is appointed to carry out an audit of the design characteristics of an infrastructure project. The auditor shall be appointed in accordance with the provisions of Article 9(4) and shall have the necessary competence and training provided for in Article 9. Where audits are undertaken by teams, at least one member of the team shall hold a certificate of competence as referred to in Article 9(3).*

3. *RSAs shall form an integral part of the design process of the infrastructure project at the stage of draft design, detailed design, pre-opening and early operation.*

4. *Member States shall ensure that the auditor sets out safety critical design elements in an audit report for each stage of the infrastructure project. Where unsafe features are identified during the audit but the design is not rectified before the end of the appropriate stage as referred to in Annex II, the reasons shall be stated by the competent entity in an Annex to that report.*

5. *Member States shall ensure that the report referred to in paragraph 4 shall result in relevant recommendations from a safety point of view*.

4.2.3 Network Safety Management (NSM)

Article 2 of Directive 2008/96/EC includes the following definition: *network safety ranking means a method for identifying, analysing and classifying parts of the existing road network according to their potential for safety development and accident cost savings*. The following five points cite the regulations relating to the application of NSM as included in Article 5 of Directive 2008/96/EC (European Parliament and Council, 2008):

1. *Member States shall ensure that the ranking of high accident concentration sections and the network safety ranking are carried out on the basis of reviews, at least every three years, of the operation of the road network. In that connection, Member States shall endeavour to meet the criteria set out in Annex III.*

2. *Member States shall ensure that road sections showing higher priority according to the results of the ranking of high accident concentration sections and from network*

safety ranking are evaluated by expert teams by means of site visits guided by the elements referred to in point 3 of Annex III. At least one member of the expert team shall meet the requirements set out in Article 9(4)(a).

3. *Member States shall ensure that remedial treatment is targeted at the road sections referred to in paragraph 2. Priority shall be given to those measures referred to in point 3(e) of Annex III paying attention to those presenting the highest benefit-cost ratio.*

4. *Member States shall ensure that appropriate signs are in place to warn road users of road infrastructure segments that are undergoing repairs and which may thus jeopardise the safety of road users. These signs shall also include signs which are visible during both day and night time and set up at a safe distance and shall comply with the provisions of the Vienna Convention on Road Signs and Signals of 1968.*

5. *Member States shall ensure that road users are informed of the existence of a high accident concentration section by appropriate measures. If a Member State decides to use signposting, this shall comply with the provisions of the Vienna Convention on Road Signs and Signals of 1968.*

4.2.4 Road Safety Inspections (RSI)

Article 3 of Directive 2008/96/EC includes the following definition: "*safety inspection means an ordinary periodical verification of the characteristics and defects that require maintenance work for reasons of safety*".

The following four points cite the regulations relating to the application of RSIs as included in Article 6 of Directive 2008/96/EC (European Parliament and Council, 2008):

1. *Member States shall ensure that safety inspections are undertaken in respect of the roads in operation in order to identify the road safety related features and prevent accidents.*

2. *Safety inspections shall comprise periodic inspections of the road network and surveys on the possible impact of roadworks on the safety of the traffic flow.*

3. *Member States shall ensure that periodic inspections are undertaken by the competent entity. Such inspections shall be sufficiently frequent to safeguard adequate safety levels for the road infrastructure in question.*

4. *Without prejudice to the guidelines adopted pursuant to Article 8, Member States shall adopt guidelines on temporary safety measures applying to roadworks. They shall also implement an appropriate inspection scheme to ensure that those guidelines are properly applied.*

4.3 National standards

The following includes an analysis of the standards relating to road restraint systems, road safety impact assessment, road safety audit, network safety management and road safety inspection in each of the funding countries.

4.3.1 Belgium (Flanders)

4.3.1.1 *Road Restraint Systems*

The Flanders and Walloon Regions of Belgium have developed guidelines for the choice and installation of RRS in the new manual "Forgiving Roadsides".

The Flanders region applies a risk classification model to evaluate the need to install a RRS and the appropriate performance requirements. Based on the installation location, the available space and the presence and type of obstacles, a risk category is determined. Two risk classification models exist; one for roads with an authorised speed equal to or greater than 90 km/h, shown in **Fout! Verwijzingsbron niet gevonden.**, and one for roads with authorised speed below 90 km/h.

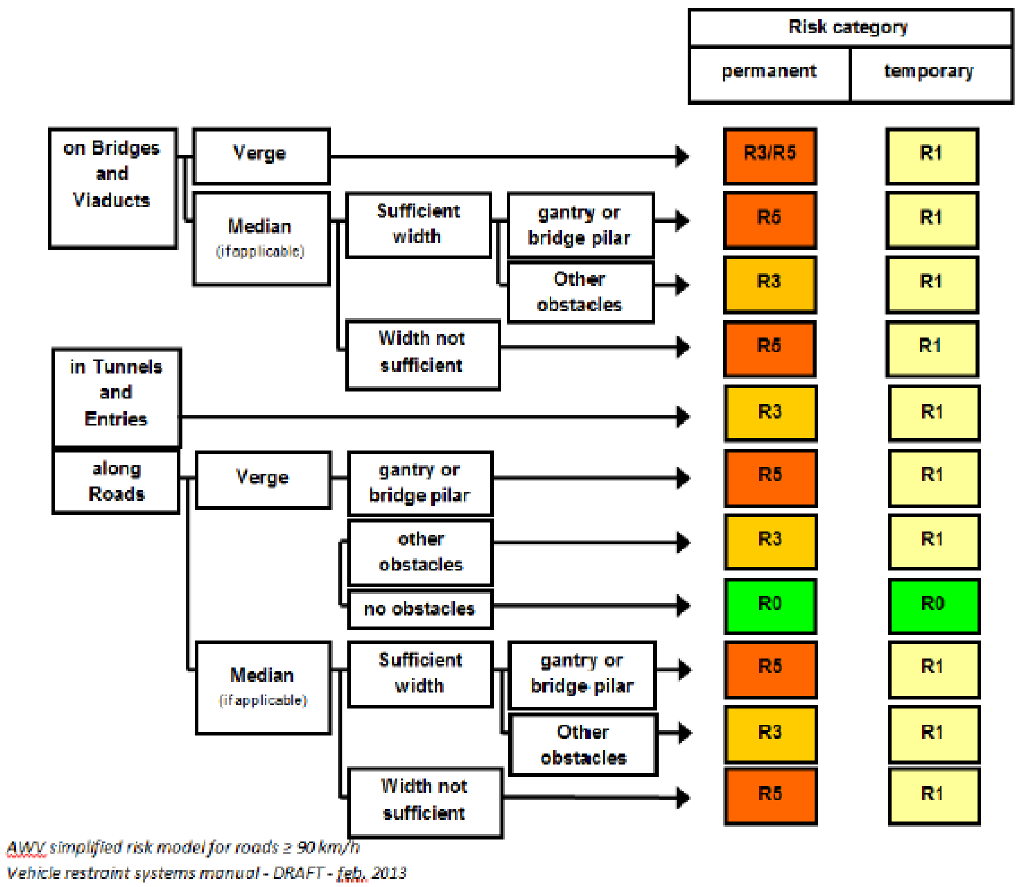


Figure 13 – Risk classification processes used in Belgium (Flanders), (Agency for Roads and Traffic, 2013)

For different risk categories and depending on the availability of the safety zone, different containment levels are subsequently recommended. The recommended safety zone dimensions, as seen in **Fout! Verwijzingsbron niet gevonden.**, are listed in the guidelines and depend on the authorised speed. The presence of slopes and / or motorcyclists modifies the recommended safety zone. For roads of a lower category, the recommended safety zone dimensions are reduced.

Table 11 – Recommended Safety Zone Dimensions (Flanders) (Agency for Roads and Traffic, 2013)

		Gradient < 24/4					24/4 < gradient < 16/4				
			curve				continu ous	curve			
	median	contin uous	Standard situations		PTW protective measures			standard		PTW protective measures	
km/ h			100<R <1000	R<10 0	100<R <1000	R<100		100<R <1000	R<100	100<R <1000	R<10 0
50	5,00	1,50	2,08	2,67	3,54	3,83	3,00	4,17	5,33	7,08	7,67
70	10,00	3,00	4,17		7,08		6,00	8,33		14,17	
90	16,00	4,90	6,75		11,38		9,80	13,50		22,75	
120	29,00	8,60					17,20				

Fout! Verwijzingsbron niet gevonden., below, highlights the recommended minimum containment levels utilised in Belgium (Flanders) (Agency for Roads and Traffic, 2013).

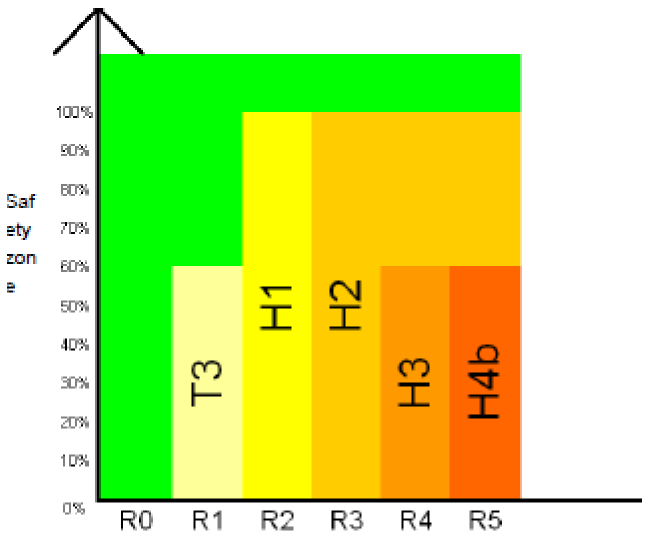


Figure 14 – Recommended Minimum Containment Levels (Flanders) (Agency for Roads and Traffic, 2013)

In addition, the following performance characteristics are also imposed:

- H2, W6 for permanent installations (W7 for double installations);
- T3, W2 for temporary installations;

- Only ASI A and ASI B are allowed.

4.3.1.2 *Road Safety Audits*

Road Safety Audits, known as '*verkeersveiligheidsaudit'* (VVA), are carried out in five stages of a typical road improvement/development scheme:

- Stage 1: Global planning (feasibility study, route selection)
- Stage 2: Preliminary design
- Stage 3: Detailed design reviewing all contract documents
- Stage 4: Completion of construction but prior to (re)opening of the scheme
- Stage 5: Early operation at a few months' post road (re)opening with live traffic

Regardless of the RSA stage in question, the auditors check if the safety measures proposed or already in place are satisfactory from all road users' perspectives and under all weather conditions.

These RSA stages are mandatory on major projects such as those that form parts of the TEN-T. These are quite extensive across Belgium (North Sea- Baltic; Rhine - Alpine; North Sea - Mediterranean). This requirement is as a result of the decree of 17 June 2011 on the management of traffic safety of road infrastructure in Belgium and effective from the 3rd of February 2012 following the approval of the Flemish Government for the implementation of this decree.

Following reviews of the added benefits of carrying out RSA throughout the various stages, the Flemish Mobility and Public Works Department (NRA equivalent) has the intention to make these mandatory for road infrastructure projects that form part of their secondary road network by the end of 2019.

4.3.1.3 *Road Safety Inspections*

In Belgium, there is a procedure similar to RSI, known as '*verkeersveiligheidsinspectie'* (VVI) (Flemish Road Safety Department (FRSD), 2018), which also uses checklists. However, this procedure is currently only compulsory to the TEN-T road network. It is intended that at some point in quarter 3 or quarter 4 of 2018 it will also be extended to all main roads and particularly at high accident concentration sections following a road safety classification and screening stage across the entire main road network.

The same procedure is used regardless of road type. No legal basis for RSI exists in Belgium. There are no consequences in the case of non-performance. The road administration is responsible for ordering, financing and carrying out safety inspections.

It is recommended that the RSI should be carried out by someone who was not involved in the original road project, so the inspector can be independent, providing a non-biased opinion. The qualification criteria for inspectors are not specified, but the inspector's knowledge base should be as broad as possible and should take into consideration all aspects of mobility.

4.3.1.4 *Directive 2008/96/EC Application*

Fout! Verwijzingsbron niet gevonden., below, acts as a summarising view for Belgium's application of Directive 2008/96/EC with information derived from Transport & Mobility Leuven (2014).

Table 12 – Belgium (Flanders) Application of Directive 2008/96/EC (Transport and Mobility Leuven, 2014)

Implementation	
Practical transposition into funding countries legislation	Replacement of pre-existing standards/ guidelines
Road Safety Impact Assessments (RSIAs)	
Presence of the procedure in country's legislation before/ after the Directive	No/ Yes
Applicable to non-TEN-T roads	No
Degree of coverage	TEN-T
Road type	All TEN-T Network
Party responsibilities	Regional Authority
Road Safety Audits (RSAs)	
Presence of the procedure in country's legislation before/ after the Directive	No/ Yes
Applicable to non-TEN-T roads	No
Degree of coverage	TEN-T
Road type	All TEN-T Network
Party responsibilities	Regional Authority

Table 12 – Belgium (Flanders) Application of Directive 2008/96/EC (Transport and Mobility Leuven, 2014) (continued)

Network Safety Management (NSM)	
Presence of the procedure in countries legislation before/ after the Directive	No/ Yes
Applicable to non-TEN-T roads	No
Frequency of application of procedure	Every 3 Years
Road type	All TEN-T Network
Party responsibilities	Regional Authority
Road Safety Inspections (RSIs)	
Presence of the procedure in country's legislation before/ after the Directive	No/ Yes
Applicable to non-TEN-T roads	No
Degree of coverage	TEN-T
Frequency of application of procedure	Every 2 Years
Road type	All TEN-T Network
Party responsibilities	Regional Authority
Training	
Training for auditors	Yes – RSA
Procedures requiring certified auditors	RSAs
Impacts	
Impacts on road planning/ design/ maintenance	No Information
Impacts on road equipment and component selection quality	No
Impact on road user communication	No

Table 12 – Belgium (Flanders) Application of Directive 2008/96/EC (Transport and Mobility Leuven, 2014) (continued)

Problems & Drawbacks	
Lack of coherent regulatory framework	No
Acceptance issues	No
Complexity issues	No
Funding issues	No

4.3.2 Ireland

Design standards and guidelines are the responsibility of Transport Infrastructure Ireland (TII). Safety barriers, terminals and transitions are covered in DN-REQ-03034 “Safety Barriers” (Transport Infrastructure Ireland, 2015) while bridge and pedestrian parapets are covered in DN-STR-03011 “The Design of Vehicle and Pedestrian Parapets” (Transport Infrastructure Ireland, 2017a). Crash cushions are not covered by TII Publications.

4.3.2.1 *Road Restraint Systems*

DN-REQ-03034 defines a safety barrier system as the complete installation of a length of safety barrier at any location and includes terminals, transitions and the individual components used to construct the barrier itself. The requirements state that a safety barrier is warranted if the consequences of a vehicle striking the barrier are considered less serious than those which would result if the vehicle were not to be contained by the safety barrier. A safety barrier is only to be utilised when a hazard in the clear zone cannot be removed. The clear zone is defined as the total width of traversable land on the nearside or offside which is to be kept clear of unprotected hazards and is based on the design speed, horizontal radius of the alignment and the terrain over which the vehicle passes. Required clear zone widths, required in Irish standards DN-REQ-03034, can be seen below in Tables 13, 14 and 15.

Table 13 – Required Clear Zone Width - DN-REQ-03034 “Safety Barriers” (Transport Infrastructure Ireland, 2015)

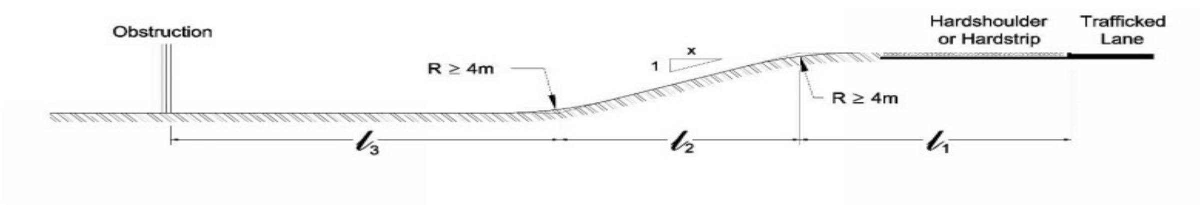
	Design Speed (km/h)		
	85	100	120
Horizontal radius (m)	**Required Width of Clear Zone (m)**		
Inside of bend or Straight	6.5	8.0	10.0
Outside of bend ≥ 1,000m	6.5	8.0	10.0
“ 900m	7.1	8.8	12.4
“ 800m	7.7	9.6	14.9
“ 700m	8.3	10.4	17.5
“ 600m	8.8	11.2	20.0
“ 500m	9.4	12.0	-
“ 400m	10.0	12.8	-
“ 300m	10.6	-	-

The Terrain Classes are defined as:

Class 1: Slope is equal to or less steep than 1:5 (falling) or 1:2 (rising).

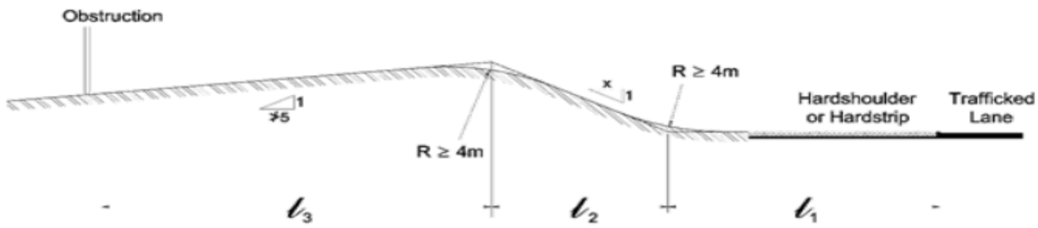
Class 2: Slope is between 1:3 and 1:5 (falling).

Class 3: Slope rises sharply (steeper than 1:2) or falls sharply (steeper than 1:3).



Embankment or Falling Terrain	Terrain Class	Clear Zone Width
Slope flatter or equal to 1:5	1	$l_1 + l_2 + l_3$
Slope between 1:5 and 1:3	**2**	$l_1 + l_3$
Slope steeper than 1:3	**3**	l_1

Table 14 – Land included in the Clear Zone – Embankments - DN-REQ-03034 "Safety Barriers" (Transport Infrastructure Ireland, 2015)



Cutting or Rising Terrain	Terrain Class	Clear Zone Width
Slope shallower or equal to 1:2	1	$l_1 + l_2 + l_3$
Slope steeper than 1:2	**3**	l_1

Table 15 – Land included in the Clear Zone – Cuttings - DN-REQ-03034 "Safety Barriers" (Transport Infrastructure Ireland, 2015)

Safety barriers are required in central reserves and where there is a hazard in the clear zone. On motorways and Type 1 dual carriageways (2 x 7m carriageways, 2 x 2.5m hard shoulders and 2 x 1m hard strips), a barrier in the central reserve is required to be constructed from reinforced concrete.

Regarding the Impact Severity Level of the barriers used, level A is required for verge applications, whilst a level no worse than B is required for the central reserve. For reserves greater than 7.5 m in width, level A is preferred. Where several hazards are located close to each other, the highest required containment level is to be provided throughout the length of the barrier as seen in **Fout! Verwijzingsbron niet gevonden.**.

Table 16 – Minimum Containment Levels - DN-REQ-03034 “Safety Barriers” (Transport Infrastructure Ireland, 2015)

Location		**Containment Level**
1. Within the Clear Zone		
Embankments:		
Slope Angle	Slope Height	
Steeper than 1:3	≥0.5	**N2**
From 1:3 and up to 1:5	≥6m	**N2**
Cuttings: At steep sided cuttings or earth bunds (steeper than 1:2) within Clear Zone		**N2**
Verges and Central Reserves:		
a) At individual hazards such as bridge piers or abutments, sin posts, gantry legs and trees, etc. (see Chapter 3) (see Note 3)		**N2**
b) At lighting columns that are not passively safe		**N2**
c) At substantial obstructions such as retaining walls which extend more than 150mm above the carriageway level (See Note 6).		**N2**
d) At underbridges or at retaining walls >0.5m high supporting the road, where a vehicle parapet or vehicle/pedestrian parapet of the required performance class is not provided		**N2**
Central Reserves:		
a) At central reserves up to 7.5m wide		**H2**
b) At central reserves greater than 7.5m wide		**N2**
c) Where the difference in adjacent carriageway channel levels exceeds 1.0m and the slope across the reserve exceeds 1:4		**H2**

Table 16 – Minimum Containment Levels - DN-REQ-03034 “Safety Barriers” (Transport Infrastructure Ireland, 2015) (continued)

Location	**Containment Level**

Location	Containment Level
Parapets (see BD 52)	
For a minimum of 30m in advance of the approach end and 15m after the departure end of a vehicle parapet or vehicle/pedestrian parapet (see Note 4). For a minimum of 30m in advance of the approach end and 15m after the departure end of a vehicle parapet or vehicle/pedestrian parapet over a railway. (see Note 4)	**N2** **H2**
2. Within or beyond the Clear Zone	
Verges: a) At locations where an errant vehicle may encroach onto an adjacent road (but see Note 5) or impact another significant hazard. b) At locations where an errant vehicle may encroach onto an adjacent railway c) At hazardous topographical features within the width defined in Table 4/1	**H2** **H2** **N2**

Vehicle parapets are covered in DN-STR-03011 (Transport Infrastructure Ireland, 2017a) and are required on all bridges designed to carry vehicular traffic. They are also required on the edges of retaining walls or similar structures where there is a vertical drop in excess of 1m and there is access for vehicles adjacent to the top of the wall.

Fout! Verwijzingsbron niet gevonden., below, includes the minimum parapet containment levels, as per DN-STR-03011. The standard also states that Vehicle parapets of Normal Containment Level (N1 or N2) should have Impact Severity Level A.

Table 17 – Minimum Parapet Containment Levels - DN-STR-03011 “The Design of Vehicle and Pedestrian Parapets” (Transport Infrastructure Ireland, 2017a)

Location	Minimum Parapet Containment Level
All structures not otherwise explicitly dealt with in this table.	**H2**
Structures in urban areas where the legal speed limit is 60km/h or less, except where: • The structure crosses or adjoins a road or railway • The structure is on a horizontal curve and/or gradient and the radius and/or gradient does not comply with relevant desirable minimum standards. Relevant desirable minimum standards are described in NRA TD9. All accommodation bridges serving a single landholding except accommodation bridges over the railway.	**N2**
All structures crossing or adjoining the railway	**H4a**

Parapets of higher or very high containment level may have impact severity level B. The Working Width shall be no greater than W4 for a vehicular parapet as per the guidelines. The form and aesthetics of the parapet are also to be considered at the initial stage of the design of the structure.

4.3.2.2 *Road Safety Impact Assessment*

RSIA requirements are provided in PE-PMG-02001 Road Safety Impact Assessment (Transport Infrastructure Ireland, 2017b) Road Safety Impact Assessment which sets out the procedures for undertaking RSIAs on National Road Schemes. The primary purpose of a RSIA is to demonstrate, on a strategic level, the implications on road safety of different planning alternatives of a road scheme. The RSIA indicates the road safety considerations which contribute to the choice of the proposed solution. It provides all relevant information necessary for the selection of the solution, including a comparative analysis of the road safety implications of each alternative considered and an evaluation of the road safety benefits and dis-benefits arising from each alternative. RSIA is undertaken at the initial planning stage of a project and is reviewed as necessary through the design phases until scheme approval.

4.3.2.3 *Road Safety Audit*

RSA requirements are provided in GE-STY-01024 Road Safety Audit (Transport Infrastructure Ireland, 2017c), which sets out the procedures for undertaking RSAs on National Road Schemes. The objective of this standard is to ensure that the road safety implications of all schemes are fully considered for all users of the road and others affected by the scheme. It defines the relevant schemes and stages in the design and construction at which RSAs shall be undertaken.

RSAs and subsequent actions shall in general be completed at five specific stages in the preparation of the scheme. These stages are:

- Stage F: Route selection, prior to route choice.

- Stage 1: Completion of preliminary design prior to land acquisition procedures.
- Stage 2: Completion of detailed design, prior to tender of construction contract. In the case of Design and Build contracts, a Stage 2 audit shall be completed prior to construction taking place.
- Stage 3: Completion of construction (prior to opening of the scheme, or part of the scheme to traffic wherever possible).
- Stage 4: Early operation at 2 to 4 months' post road opening with live traffic.

4.3.2.4 *Network Safety Analysis*

NSA requirements are provided in GE-STY-01022 Network Safety Analysis (Transport Infrastructure Ireland, 2017d), which sets out the procedures for undertaking NSAs on the National Road Network. The objective of this Standard is to identify sections of routes or specific locations on the national road network which have a high concentration of collisions. This process feeds into additional work carried out by the TII Road and Tunnel Safety section to identify issues at a macro level on the Network. A desktop study to identifying High Collision Locations (HCL's) is based on a spatial analysis of all reported injury collision data, exposure data typically in the form of vehicle kilometres travelled, and road lengths. Subsequently, collision rates can be calculated with these data inputs. The identification of HCL's enables the road authority to prioritise locations which will give the best rate of return from safety or engineering solutions.

4.3.2.5 *Road Safety Inspection*

RSI requirements are provided in AM-STY-06044 Road Safety Inspection (Transport Infrastructure Ireland, 2017e), which sets out the procedures for undertaking RSIs on National Road Schemes. The primary purpose of a RSI is to identify issues relating to road safety; it is not a check of compliance with design standards. The RSI only considers those matters that may have an adverse bearing on road safety under all operating conditions.

RSI is defined as "an ordinary periodical verification of the characteristics and defects that require maintenance work for reasons of safety". The terminology of this definition gives an indication of the scope of the RSI as follows:

a) The term 'ordinary' indicates that an in-depth, forensic investigation is not expected;
b) The measures to be carried out in response to the inspection are described as maintenance work; this suggests that major changes to the layout of the road, entailing high cost, are not envisaged as counter-measures; however, it is anticipated that engineering works are required to remediate the issues. It is not intended that routine maintenance issues will be identified as part of the inspection process as these issues will be addressed by ongoing maintenance programmes/cycles currently in place and overseen by TII.
c) The term periodical indicates the need for inspections to be repeated at intervals, rather than being a once-off event.

RSI is a pro-active process, in that it seeks to identify the safety defects of the road and enable counter-measures to be provided before the problem manifests itself.

4.3.2.6 *Implementation of the RISM Directive*

Transport Infrastructure Ireland published a series of standards to meet the legal requirements of the EU Road Infrastructure Safety Management Directive. In the majority of cases these standards formalised a number of well-defined procedures already in place or updated existing standards. Two new standards were developed where previously there was none. These related to Road Safety Inspections (RSI) on the national road network and Temporary Safety Measures Inspections (TSMI), both deployed on Irish roads designated part of the Trans-European Network for Transport (TEN-T) as per the RISM Directive. The standards have been extended to include the rest of the non-TEN-T roads that make up the 5,300 km of the national road network. The list below includes new standards that were published by TII to comply with the RISM Directive.

- Road Safety Impact Assessment (PE-PMG-02001)
- Road Safety Inspection (AM-STY-06044)
- Temporary Safety Measures Inspection (CC-STY-04002)
- Network Safety Analysis (GE-STY-01022)

Road Safety Audit has been mandatory on national road projects since 2001. The introduction of the RISM Directive lead to a minor revision to the existing standard, while new guidelines relating to the training requirements for auditors was also introduced. The list below includes the existing standard that was revised by TII in order to comply with the RISM Directive.

- Road Safety Audit (GE-STY-01024)

4.3.2.7 *The effect of RISM on roadside design and maintenance*

Road Safety Impact Assessment which is defined as "*strategic comparative analysis of the impact on the safety performance of the road network of different planning alternatives for a new road or a substantial modification to the existing network*" (Transport Infrastructure Ireland, 2017b) have been undertaken in Ireland since 2012. In that time, a total of 45 road schemes have been put forward for assessment. Following a review of these schemes 16 were deemed as not requiring RSIA as they were mostly online realignments.

There has been a total of 736 Road Safety Audits undertaken between the years of 2011 – 2017 according to TII statistics. As of September 2017, there were 231 registered auditors in Ireland including 52 with the necessary qualification to lead audit teams having completed the Certificate of Competence in Road Safety Audit. In 2016, TII commissioned a review of 167 road safety audit reports to identify common hazards that are frequently raised as problems in those reports. Following on from the review, TII revised some of their standards and developed a training course relating to road restraint systems in an effort to design out these problems and prevent them from reoccurring in the future. The common issues which resulted in revisions to the standards are described in **Fout! Verwijzingsbron niet gevonden.** below.

Table 18 – Common hazards identified during RSA and measures put in place.

Common roadside problems from the RSA review	**Measures put in place to prevent reoccurrence**
Safety barrier not provided where hazard exists and sign supports present a hazard to errant vehicles	Since November 2015 TII has been running a RRS course which aims to develop engineer's skills in design, installation and maintenance of RRS, including safety barrier and parapet systems, in accordance with relevant standards.
Objects within the working width of a safety barrier	
Drainage ditch at the edge of the carriageway presents a hazard to errant vehicles	TII has adopted the approach of applying a forgiving roadside at the start of the design process for a new section of national road or motorway. The aim of this approach is to reduce the need for road restraint systems by keeping the clear zone free from hazards.
Timber post and rail fences, which were permitted within the clear zone, were found to increase the severity of collisions when impacted and were the leading cause in a number of fatalities.	The safety barrier standard was revised to remove the option to include timber post and rail fences within the clear zone. A timber post and wire fence design was developed and is available for installation within the clear zone.

DN-GEO-03036 Cross Sections and Headroom (Transport Infrastructure Ireland, 2017f) was recently revised to include the requirements for clear zones and forgiving roadsides. Prior to this, clear zones were addressed in the Safety Barrier standard only and the forgiving roadsides concept was considered as good design advice. The inclusion of clear zone and forgiving roadsides in the Cross Sections and Headroom standard now requires the designer to consider these elements at the earliest stages of a project which should increase the safety benefits of new schemes.

Fout! Verwijzingsbron niet gevonden., below, acts as a summarising view for Ireland's application of Directive 2008/96/EC with information derived from Transport & Mobility Leuven (2014).

Table 19 – Ireland – Application of Directive 2008/96/EC (Transport and Mobility Leuven, 2014)

Implementation	
Practical transposition into funding countries legislation	Integrated with pre-existing standards/ guidelines
Road Safety Impact Assessments (RSIAs)	
Presence of the procedure in country's legislation before/ after the Directive	No/ Yes
Applicable to non-TEN-T roads	Yes
Degree of coverage	TEN-T (100%) and non-TEN-T (100%)
Road type	All TEN-T and Motorway, Dual Carriageway and Single Carriageway national roads on non-TEN-T roads
Party responsibilities	NRA for launching and financing. Competent consultants for performing procedures.
Road Safety Audits (RSAs)	
Presence of the procedure in country's legislation before/ after the Directive	Yes/ Yes
Applicable to non-TEN-T roads	Yes
Degree of coverage	TEN-T (100%) and non-TEN-T (100%)
Road type	All TEN-T and Motorway, Dual Carriageway and Single Carriageway national roads on non-TEN-T roads
Party responsibilities	NRA for launching and financing. Competent consultants for performing procedures.

Table 19 – Ireland – Application of Directive 2008/96/EC (Transport and Mobility Leuven, 2014) (continued)

Network Safety Management (NSM)	
Presence of the procedure in countries legislation before/ after the Directive	Yes/ Yes
Applicable to non-TEN-T roads	Yes
Frequency of application of procedure	Annually
Road type	All TEN-T and Motorway, Dual Carriageway and Single Carriageway national roads on non-TEN-T roads
Party responsibilities	NRA for launching and financing. Competent consultants for performing procedures.
Road Safety Inspections (RSIs)	
Presence of the procedure in country's legislation before/ after the Directive	No/ Yes
Applicable to non-TEN-T roads	Yes
Degree of coverage	TEN-T (100%) and non-TEN-T (100%)
Frequency of application of procedure	Every 5 Years
Road type	All TEN-T and Motorway, Dual Carriageway and Single Carriageway national roads on non-TEN-T roads
Party responsibilities	NRA for launching and financing. Competent consultants for performing procedures.
Training	
Training for auditors	Yes – RSIA, RSA, NSM, RSI
Procedures requiring certified auditors	RSIA, RSA, NSM, RSI

Table 19 – Ireland – Application of Directive 2008/96/EC (Transport and Mobility Leuven, 2014) (continued)

Impacts	
Impacts on road planning/ design/ maintenance	Minimal
Impacts on road equipment and component selection quality	None
Impact on road user communication	Not Directly
Problems & Drawbacks	
Lack of coherent regulatory framework	No
Acceptance issues	No
Complexity issues	No
Funding issues	No

4.3.3 Netherlands

4.3.3.1 *Road Restraint Systems*

The publication Richtlijn Ontwerp Autosnelwegen Veilige Inrichting van Bermen (Guideline for the safe design of verges) (Dutch Ministry of Infrastructure and the Environment, 2017) covers the safe design of roadsides of national arterial roads and motorways in the Netherlands.

Road restraint systems are required where a hazard is present in the obstacle free zone. The obstacle-free zone is the space to the left or right of a roadway which contains no obstacles or hazards that could create a safety risk for the occupants of vehicles. The obstacle-free zone is intended to limit or prevent the risks to occupants of a vehicle that has deviated from the carriageway. The obstacle distance is the horizontal, shortest distance between the inner side of the edge marking and an obstacle or hazard area.

The process of determining whether a road restraint system is required or not is assessed using a flow chart. The first step in the flow chart is to determine if third parties will be affected if a vehicle leaves the carriageway. Obstacle free zone dimensions are given for the median and outside verge based on the design speed. A translated version of the flow chart is presented in **Fout! Verwijzingsbron niet gevonden.**.

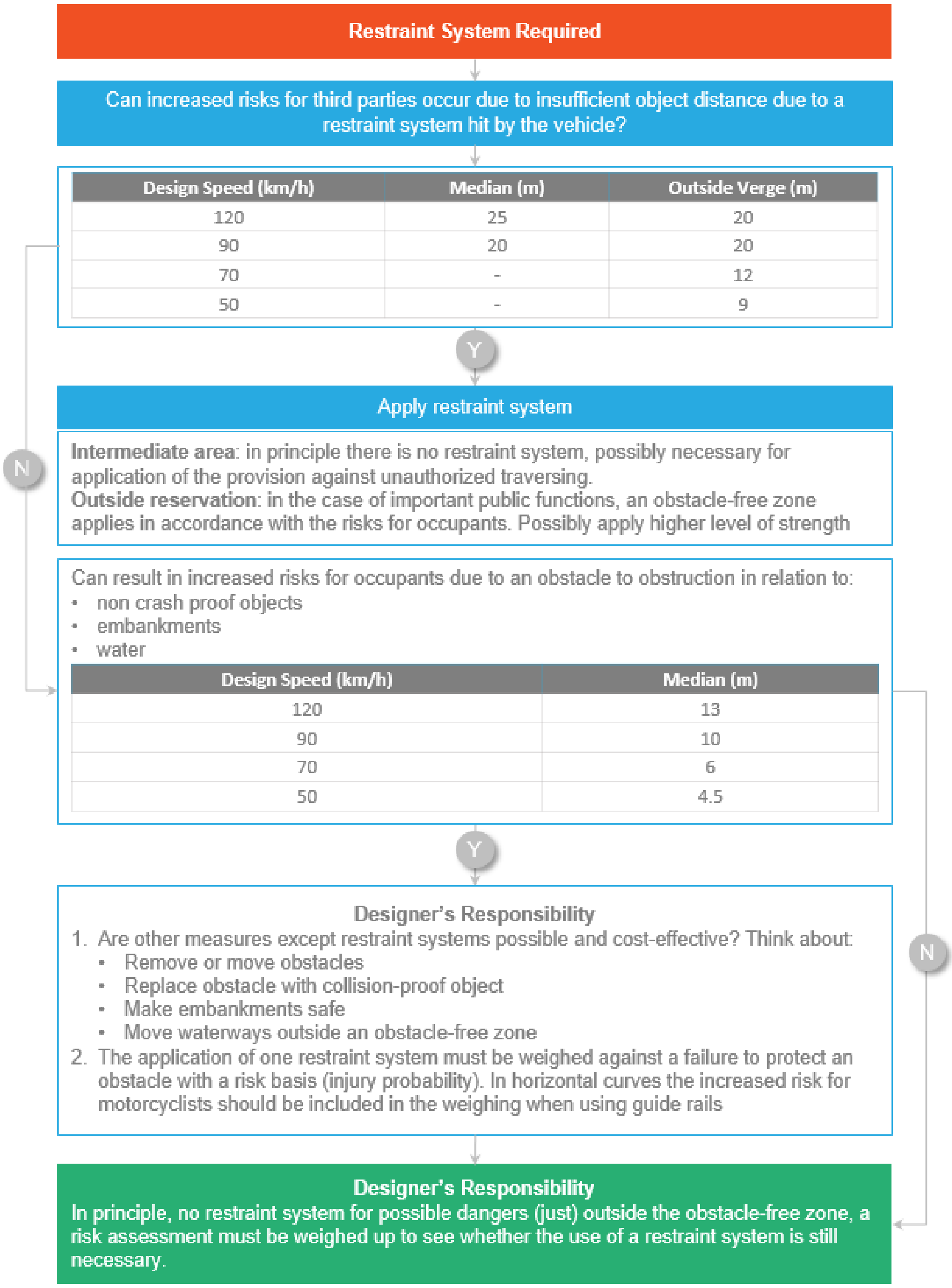


Figure 15 – Road Restraint System Flow Chart (Dutch Ministry of Infrastructure and the Environment, 2017)

National roads and motorways include three types of reservations as shown in **Fout! Verwijzingsbron niet gevonden.**:

• Middenberm (central reservation or median): section of the road between the two main carriageways with opposite directions of travel;

• Tussenberm (median): section of the road between a main road and a parallel or service road;

• Buitenberm (road verge or roadside): a part of the Right of Way (road reserve) next to the main, service or parallel roadways.

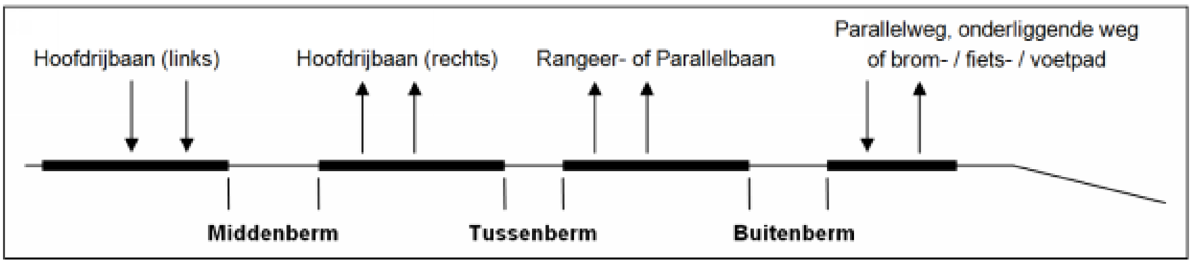


Figure 16 – Summary of roadside berms (Dutch Ministry of Infrastructure and the Environment, 2017)

In outer verges where there are important public functions adjacent to the road such as drainage or utility banks, the measurements in accordance with **Fout! Verwijzingsbron niet gevonden.** are applied. However, consideration can be given to the use of a shielding facility, or if there is already a shielding facility in place, a higher level of containment may be appropriate.

Breedte van de verkeersvrije zone (gemeten tussen de binnenkanten van de kantstrepen van beide rijbanen).	Het toepassen van een afschermingsvoorziening in de verkeersvrije zone (tussenberm) van een hoofdbaan van een autosnelweg met een...		
	rijbaan van een autosnelweg (bijv. rangeerbaan)		parallelweg of pad van lagere orde
	middenberm	tussenberm	buitenberm
> 25 m	nee	nee	nee
13 - 25 m	ja	nee	ja *)
< 13 m	ja	nee	ja

*) De afschermingsvoorziening kan achterwege blijven indien de intensiteit van de parallelweg, (brom)fietspad of voetpad gering is.

Figure 17 – The application of restraint systems for different road categories (Dutch Ministry of Infrastructure and the Environment, 2017)

The width of the obstacle free zone is dependent on the design speed of the road under investigation. **Fout! Verwijzingsbron niet gevonden.** shows the required width for obstacle free zones with third party risks.

Table 20 – Minimum dimensions for an obstacle-free zone with third party risks (Dutch Ministry of Infrastructure and the Environment, 2017)

Design speed (km/h)	Minimum space median strip (m)	Minimum space out berm (m)
120	25	20
90	20	20
70	na	12
50	na	9

Fout! Verwijzingsbron niet gevonden. shows the required width for obstacle free zones adjacent to hazards such as non-crash proof objects, embankments or water.

Table 21 – Minimum dimensions for an obstacle-free zone with a risk to vehicle occupants (Dutch Ministry of Infrastructure and the Environment, 2017)

Design speed (km/h)	Obstacle-free zone (m)
120	13
90	10
70	6
50	4.5

The width of the obstacle free zone at embankments or cuttings can vary depending on design speed of the road and the height of the embankment/cutting. This is presented in **Fout! Verwijzingsbron niet gevonden.** which shows the height of the embankment along the Y axis, the obstacle free zone width along the X axis and the relevant design speeds as the coloured lines.

The obstacle-free zone should be widened during descending slopes. When the slope is ascending, the obstacle free zone can be reduced, provided that the requirements of other safety zones (escape room, storage zone) are met.

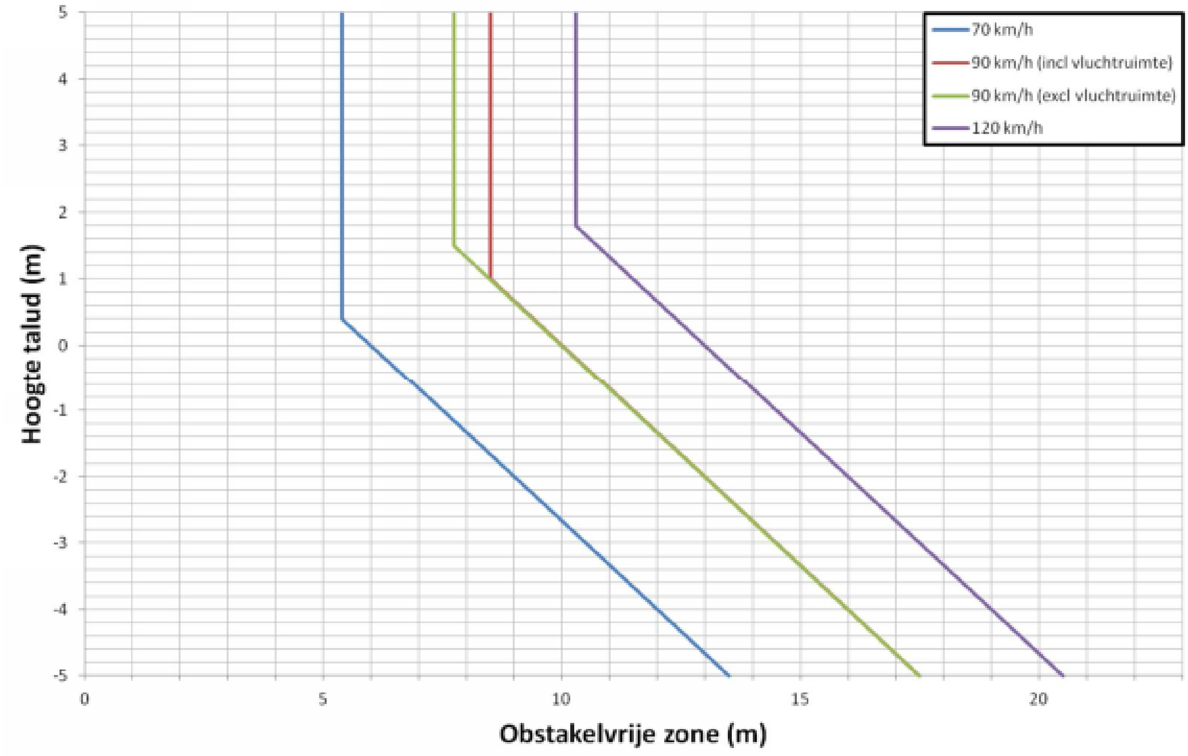


Figure 18 – Effects of the ascending and descending slopes to the size of the standard obstacle-free zone (Dutch Ministry of Infrastructure and the Environment, 2017)

4.3.3.2 *Road Safety Audit*

Guidance on road safety audits for national roads in the Netherlands is published by Kwaliteitsorgaan Verkeersveiligheidsaudits (Kova). The standard is called Voorschrift voor de Verkeersveiligheidsauditor (VVA) Rijkswegennet (Requirements for the Road Safety Auditor National Road Network) (Ministry of Transport and Environment, 2018)

RSAs are defined in the standard as "*An independent detailed systematic and technical safety check of the design of an infrastructure project from planning to early operation on the basis of the standards, guidelines, traffic management arrangements and behavioural components*".

RSAs are required for the following four stages of a project on a national road as per the Wet beheer rijkswaterstaatswerken (Directorate General for Public Works and Water Management, 2007).

- VVA1 Preliminary design
- VVA2 Detailed design
- VVA3 Pre-opening
- VVA4 Operation

VVA1: This is an audit of road design and alignment with respect to speed. Speed reduction and route selection (behavioural) analysis for all categories of traffic are also addressed.

VVA2: An integral audit of road design, layout and equipment. These elements define the clear road layout where the road user bases their behaviour. In this audit, the road elements which contribute to the safe operation and smooth flow of traffic are assessed giving consideration to human factors.

VVA3: Once the construction phase has been completed, a pre-opening audit is carried out. The audit considers the physical aspects of the road to determine if they are sufficient for road users. The audit needs to determine if signage and road makings are recognisable during the hours of darkness and are in the correct locations for safe use. The audit will also determine whether the actual construction on the ground corresponds to the approved plan. The opening of the road will be based on the findings of the audit.

VVA4: Three to four months after the road has been in operation, a practical test is performed. The audit on the physical state of the road use must decide whether the road meets the standards for safe use and if the details of the audit in the last stage lead to the desired, driver behaviour.

Each audit stage VVA1 to VVA4 will go through the same process between client and auditor. The steps and decisions of the audit process are shown in **Fout! Verwijzingsbron niet gevonden.**.

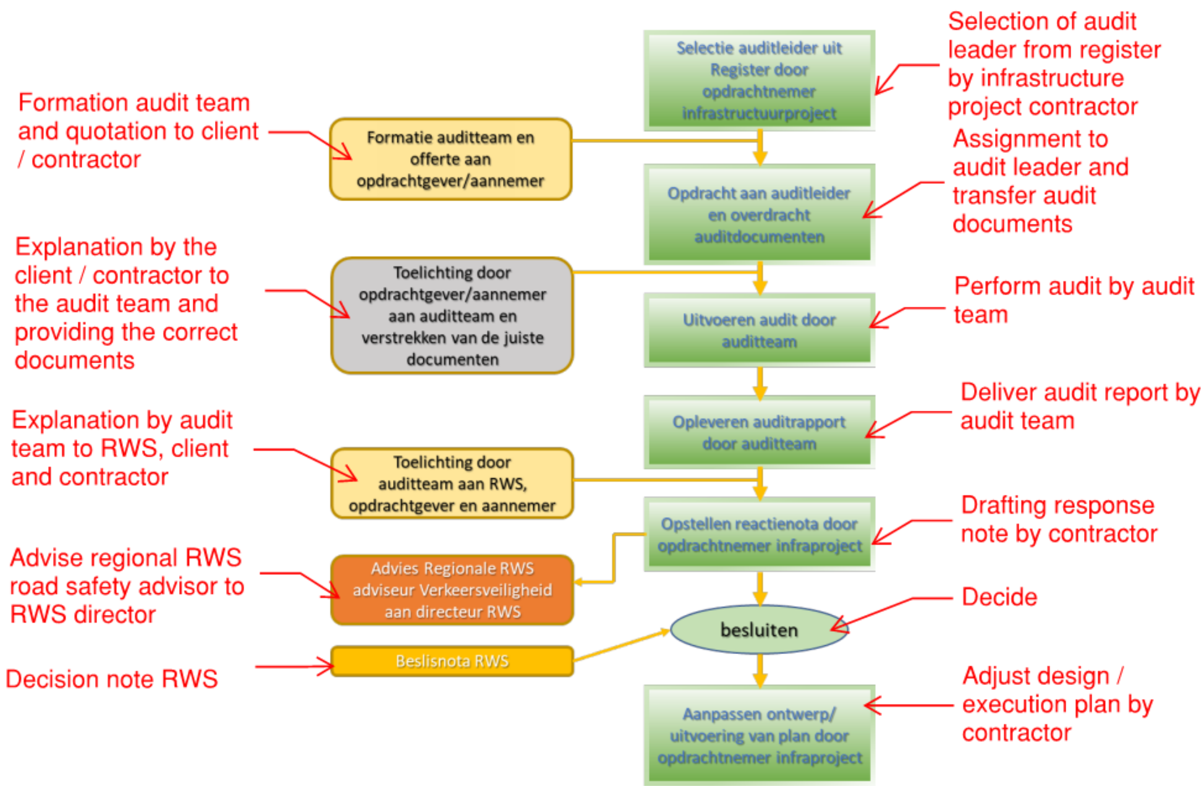


Figure 19 – Safety Audit Flow chart including decisions and steps of the audit process (Ministry of Transport and Environment, 2018)

4.3.3.3 *Road Safety Inspection*

In the Netherlands, RSI is compulsory on national roads which are maintained by Rijkswaterstaat (the Directorate General for Public Works and Water Management, 2007).

The objective of RSI in the Netherlands is the mapping of road safety risk of in-service roads of Rijkswaterstaat and contributes to structural measures for preventing and reducing traffic accidents. Guidance the RSI procedure is given in the document Kader voor het borgen van verkeersveiligheid bij Aanleg- en Onderhoudsprojecten op het Rijkswegennet.(Framework for guaranteeing road safety for Construction and Maintenance projects on the national road network) (Dutch Ministry of Infrastructure and the Environment, 2017).

Road safety inspections in the Netherlands are split up into 5 parts:

- Annual assessment of accident data (traffic accidents, risk figures)
- Analyses at locations with an unexpected increase in the number of traffic incidents based on incident notifications by Region
- Analysis of fatal incidents by Region
- Carry out 2 annual inspections until section 5 comes into force. This inspection considers the traffic flow and public focus on national roads.
- Perform 5 annual inspection to the road network. This is a follow-on inspection from the 2-year inspection and considers any risks that may arise during this period.

The inspection process is carried out by applying scores to the hazards depending on the severity. With the Rijkswaterstaat Quality Index (RQI), a deficiency point score is awarded depending on the severity of the shortcoming. As the influence on safety increases, so does the number points.

1 point is a flaw. A skewed sign or lamppost falls within this category;

5 points are granted for cases which are more serious than minor flaws but do not directly pose a security risk as incorrectly dimensioned markings or illegible signage;

10 points are granted for matters that can be characterised as serious. An example is a barrier located in an unpaved surface as they are not tested there and the behaviour in a collision is unpredictable;

20 points are granted as an unacceptable security risk, such as personnel within safety area at deposits. Inspection, whether an RSI, a measure traffic, incident management or an event inspection, with a total number of RQI points. Because of these points system is easy for the authorities to quickly identify the biggest problems and address (and quickly get the score down).

4.3.3.4 *Directive 2008/96/EC Application*

Fout! Verwijzingsbron niet gevonden., below, acts as a summarising view for Netherland's application of Directive 2008/96/EC with information derived from Transport & Mobility Leuven (2014).

Table 22 – Netherlands – Application of Directive 2008/96/EC (Transport and Mobility Leuven, 2014)

Implementation	
Practical transposition into funding countries legislation	Integration with pre-existing standards/ guidelines
Road Safety Impact Assessments (RSIAs)	
Presence of the procedure in country's legislation before/ after the Directive	Yes/ Yes
Applicable to non-TEN-T roads	Yes
Degree of coverage	TEN-T (90%) and non-TEN-T (90%)
Road type	All TEN-T and Motorway, some Single Carriageway national roads on non-TEN-T roads
Party responsibilities	Ministry of Infrastructure and the Environment
Road Safety Audits (RSAs)	
Presence of the procedure in country's legislation before/ after the Directive	No/ Yes
Applicable to non-TEN-T roads	Yes
Degree of coverage	TEN-T (95%) and non-TEN-T (95%)
Road type	All TEN-T and Motorway, some Single Carriageway national roads on non-TEN-T roads
Party responsibilities	Ministry of Infrastructure and the Environment and Independent Certified Contractors for performing procedure

Table 22 – Netherlands – Application of Directive 2008/96/EC (Transport and Mobility Leuven, 2014) (continued)

Network Safety Management (NSM)	
Presence of the procedure in countries legislation before/ after the Directive	Yes/ Yes
Applicable to non-TEN-T roads	Yes
Frequency of application of procedure	Annually
Road type	All TEN-T and Motorway, some Single Carriageway national roads on non-TEN-T roads
Party responsibilities	Ministry of Infrastructure and the Environment
Road Safety Inspections (RSIs)	
Presence of the procedure in country's legislation before/ after the Directive	No/ Yes
Applicable to non-TEN-T roads	Yes
Degree of coverage	TEN-T (100%) and non-TEN-T (100%)
Frequency of application of procedure	Every 2 Years
Road type	All TEN-T and Motorway, some Single Carriageway national roads on non-TEN-T roads
Party responsibilities	Ministry of Infrastructure and the Environment
Training	
Training for auditors	Yes – RSA
Procedures requiring certified auditors	RSAs
Impacts	
Impacts on road planning/ design/ maintenance	No Information
Impacts on road equipment and component selection quality	No
Impact on road user communication	Not Directly

Table 22 – Netherlands – Application of Directive 2008/96/EC (Transport and Mobility Leuven, 2014) (continued)

Problems & Drawbacks	
Lack of coherent regulatory framework	No
Acceptance issues	Yes
Complexity issues	No
Funding issues	No

4.3.4 *Slovenia*

4.3.4.1 *Road Restraint Systems*

Slovenian safety barrier standards are presented in the document Varnostne Ograje Pogoji In Nacin Postavitve (Safety Fencing Conditions and Layout Methods) (Ministry of Infrastructure and Spatial Planning, 2013a). Safety fences must also be in accordance with Slovenian regulations SIST EN 1317-1 (Slovenski Institut za Standardizacijo (SIST), 2010a) in SIST EN 1317-2 (Slovenski Institut za Standardizacijo (SIST), 2010b)

The most common type of barrier installed on Slovenian roads is the steel safety fence unless the occasion arises to use other types of barriers.

Concrete barriers are used:

- When the necessary containment levels can't be achieved by steel safety fences;
- On dual carriageways with at least one direction having AADT > 7000;
- On dual carriageways with at least two lanes travelling in the same direction having AADT > 39000.

Wooden safety fences are used mainly in low traffic roads, where nature conservation or aesthetic reasons do not allow for the use of other types of barrier.

In built up areas, safety fences are not required except in cases where the road runs:

- Parallel to a stream, with water depth 2m or more, which is less than 6m away from the edge of the carriageway;
- A high embankment, which is less than or equal to 6m from the edge of the carriageway;
- On a bridge over a river (with a mean water depth of 2m or more), a railway line or other transport route;
- A retaining wall which is less than 6m from the edge of the carriageway, while at the edge of the carriageway;
- If the edge of the shoulder or emergency lane is not defined by a kerb height of between 15cm and 18cm.

The decision on whether to install a safety barrier in the median, or not, is based on AADT and median width, as shown in **Fout! Verwijzingsbron niet gevonden.**.

The installation of barriers in the median is mandatory for motorways and expressways with median widths less than 8m, irrespective of the AADT.

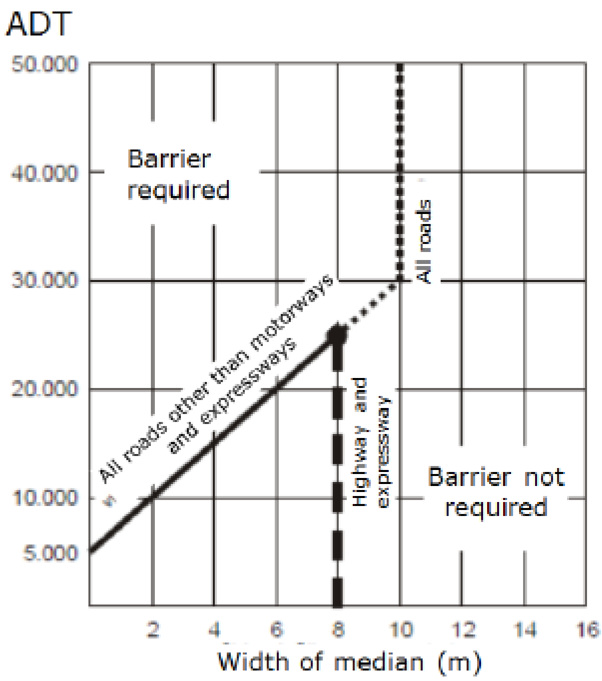


Figure 20 – The Parameters Which Determine the Installation of Barriers in the Median (Ministry of Infrastructure and Spatial Planning, 2013a)

The decision to install a barrier on an embankment, or not, is based on the embankment slope and height. Installation of a barrier is not required if the distance between the beginning of the slope and the edge of the carriageway or shoulder or emergency lane is:

- Greater than 10m and the permitted speed V ≥ 70 km/h, and
- Greater than 6m and the permitted speed V < 70 km/h.

A safety barrier is required if the distance between the dangerous obstacles and the edge of shoulder or emergency lane is less than the value specified in **Fout! Verwijzingsbron niet gevonden.**.

In Table 22, hazardous obstacles of type A are:

- Streams of water with depth of 0.5m in the middle;
- Particularly dangerous buildings with hazardous chemicals and flammable substances, etc.; Gantry or sign posts with a pole diameter greater than 76mm or box-shaped side profile of at least 18cm and a wall thickness greater than 2.9mm;
- Poles or other supporting structures of buildings.

In Table 22, hazardous obstacles of type B are:

- Lines of trees with a diameter greater than 15cm,

- Road lighting columns or other fixtures, except passively safe designs to EN 12767.

Table 23 – Limits of Distance from the Edge of the Carriageway Edge or Emergency Lane to Dangerous Obstacles (Ministry of Infrastructure and Spatial Planning, 2013a)

Road Axis	Carriageway road with two or more lanes		
	Embankment slope	**Top of Form** **Dangerous obstacle type A Bottom of Form**	**Top of Form** **Dangerous obstacle type B Bottom of Form**
Prema curvature R>1500m inside of the curve regardless of the size of the radius	Top of Form In the plane, the cut irrespective of the slope and embankment slope <1:8 Bottom of Form	10m	6m
	Top of Form Embankment slope 1:8 to 1:5 Bottom of Form	12m	8m
	Top of Form Embankment slope > 1:5 Bottom of Form	14m	10m
Top of Form Road in a curve with R>1500m Bottom of Form	Top of Form In the plane, the cut irrespective of the slope and embankment slope <1:8 Bottom of Form	12m	10m

Table 23 – Limits of Distance from the Edge of the Carriageway Edge or Emergency Lane to Dangerous Obstacles (Ministry of Infrastructure and Spatial Planning, 2013a) (continued)

Road Axis	**Carriageway road with two or more lanes**		
	Embankment slope	**Top of Form** Dangerous obstacle type A Bottom of Form	**Top of Form** Dangerous obstacle type B Bottom of Form
	Top of Form Embankment slope 1:8 to 1:5 Bottom of Form	14m	12m
	Top of Form Embankment slope >1:5 Bottom of Form	16m	14m
Prema curvature R>500m inside of the curve regardless of the size of the radius	Top of Form In the plane, the cut irrespective of the slope and embankment slope <1:8 Bottom of Form	7.5m	4.5m
	Top of Form Embankment slope 1:8 to 1:5 Bottom of Form	9m	6m
	Top of Form Embankment slope > 1:5 Bottom of Form	12m	8m
Top of Form Road in a curve with R<500m Bottom of Form	Top of Form In the plane, cut irrespective of the slope and embankment slope <1:8 Bottom of Form	12m	10m

Table 23 – Limits of Distance from the Edge of the Carriageway Edge or Emergency Lane to Dangerous Obstacles (Ministry of Infrastructure and Spatial Planning, 2013a) (continued)

Road Axis	Carriageway road with two or more lanes		
	Embankment slope	**Top of Form** **Dangerous obstacle type A Bottom of Form**	**Top of Form** **Dangerous obstacle type B Bottom of Form**
	Top of Form Embankment slope 1:8 to 1:5 Bottom of Form	14m	12m
	Top of Form Embankment slope > 1:5 Bottom of Form	16m	14m

A barrier should be placed along the roadside:

- If the distance to an adjacent road, which is used by motor vehicles, is less than 10m;
- If the distance between the outer edge of the shoulder, and an adjacent cycle path is less than 1.5m;
- If the distance between the outer edge of the shoulder, and an adjacent cycle path is less than 10m and the cycle path is located along the outer edge of the road in a curve with a radius less than or equal to 175 m;
- If the road runs parallel to the railway line and the distance between the edge of carriageway, shoulder or emergency lane and the nearest rail is less than 10m;
- If there is a railway, or another surface transport line located at the bottom of an embankment, which has a slope steeper than 1:3; and the distance between the edge of the carriageway or shoulder or emergency lane and the nearest railway or other type of transport line is less than 30m; with the distance of the lower edge of the embankment from the first track and the other edge of the road surface is less than 10m; and a height difference between the level roadway edge, the edge of the shoulder or emergency lane and the other edge of the road surface or the top of the nearest rail is larger than 3m.

The selection of the minimum vehicle containment level for a safety barrier is determined by the category of the road. Highways, expressways, regional roads and roads with physically separated carriageways are all issued with a minimum containment level of N2.

All other public roads are given a minimum containment level of N1 to N2. The minimum containment level is increased in specific roadside areas on dangerous sections of road and in the vicinity of bridges and other structures as per the standard.

4.3.4.2 *Road Safety Audit*

The following documentation is used for Road Safety Audits in Slovenia:

- Rules on Road Infrastructure Road Traffic Safety Auditing and Road Safety Road Traffic Safety Training (Ministry of Infrastructure, 2017a)
- Rules on amendments and supplements to the Rules on road safety, road safety inspection and the training of road safety auditors (Ministry of Infrastructure, 2017b)
- Rules amending the Rules on road safety, road safety inspection and the training of road safety auditors (Official Gazette of the Republic of Slovenia, (Ministry of Infrastructure and Spatial Planning, 2017c).

Slovenia started training road safety auditors in 2011, with an initial batch of 23 auditors receiving their auditing licences. Pilot projects in the fields of RSI's, RSA's and RSIA's were carried out to determine the typical deficiencies associated with typical Slovenian roads. The study identified traffic signs, intersections and road cross section, to name a few as the main deficiencies found on Slovenian roads.

The Public Agency of the Republic of Slovenia for Transport Safety is responsible for penning the training for Road Safety Auditors. The agency was created in 2010 in accordance with the Road Traffic Act 2010. It is an independent agency but financially linked to the Ministry of Infrastructure and Spatial Planning.

A single auditor shall be designated within 10 days of the audit request to carry out an RSA. At least two auditors are required if the length of road exceeds 30km for motorways or 5km for other public roads. All auditors must be a member of the Fatal Accident Factors Research Group as established by The Public Agency of the Republic of Slovenia for Transport Safety. A combination of 3 peer reviewers must be utilised to review the audit. These peer reviewers must have at least 12 years' experience in road safety and are classed as an "expert".

An impact assessment must be created independently from the road safety audit, depending on the size of the scheme The Public Agency of the Republic of Slovenia for Transport Safety may designate this task to an individual group separate to that of the auditor(s). This assessment must be concluded within 30 days of a contract ending.

The assessment report on the safety impact on traffic shall be transmitted by the auditor to the contracting authority and to the Agency. Based on the report received, the contracting authority shall prepare a written reply specifying:

- which remarks will be considered during the design phase of the variants,
- which observations in the report will be considered when planning a validated variant, and
- with which the comments from the report disagree and why they cannot take them into account.

The auditor then has 15 days to confirm or reject the findings in the response penned by the client.

The basic and periodic professional training of auditors shall be organised and implemented by The Public Agency of the Republic of Slovenia for Transport Safety.

Potential auditors must have a university degree in the field of road infrastructure, traffic engineering and (or) traffic safety, have at least 10 years' experience in their field and also pass an RSA/ RSI examination.

Training providers or "Lecturers" are at least higher education teachers in accordance with the regulations on higher education with degrees in the subject areas of civil engineering, traffic engineering and (or) transport technology and be classed as an "authorised / chartered engineer". Work experience is also required. Trainers of basic professional training shall be appointed by the minister responsible for transport on the proposal of The Public Agency of the Republic of Slovenia for Transport Safety. The quality of the implementation of basic and periodic vocational training programs and other tasks under this Regulation is supervised by the ministry responsible for transport.

Road Safety Auditors and Road Safety Inspectors use a manual for road safety auditors which includes detailed instructions and specifications relating to both RSAs and RSIs. This manual is known as *"Prirocnik – za osnovno strokovno usposabljanje presojevalcev varnosti cest"* (Ministry of Infrastructure and Spatial Planning, 2015).

In Slovenia, depending on the context and scope of the project an RSA is generally carried out in two stages, namely: pre- construction (stage 1 and 2) and construction stage (stage 3 and 4). For each stage a checklist is provided for the auditor's use. These checklists comprise of commonly reoccurring issues to be found in RSA's and allow the auditor to use a systematic approach when completing an audit. According to Smernica Za Preverjanje Varnosti V Prometu (Manual - for basic professional training of road safety auditors) (Ministry of Infrastructure and Spatial Planning, 2012) the main "shortcomings" identified are included in **Fout! Verwijzingsbron niet gevonden.** below. Deficiencies relating to road side safety are shaded grey.

Table 24 – Typical Shortcomings, Requiring Special Considerations in Slovenian RSA (Ministry of Infrastructure and Spatial Planning, 2012)

Design Element	Deficiencies
Horizontal Alignment	Inconsistent sequence radii
	Small radii on high design speed sections
	Sudden alignment changes without gradual transition
Vertical Alignment	Gentle climbs with limited visibility
	Lane for slow moving vehicles on climb missing
	Optical impressions (holes in road)
Intersections/ Junctions	Lack of correlation between the route and type of intersection
	Drivers not noticing crossing
	Lack of visibility due to vegetation, infrastructure etc.
	Dangerous junction geometry
	Lack of signage on roads with high traffic volumes
	Dangerous vulnerable user crossings
Traverse Profiles	Lane width not in accordance with function of road
	Use of lane on a two-lane toad with cross sectional width of 11-12m causing high level of accident risk due to overtaking
	Insufficient transverse slope
	Lack of free space (clear zone)
	Inadequate drainage
	Inappropriate size of inclination of trenches
	Lack of “groomed” and hard shoulder
	Lack of passive safety devices
	Lack of physically separate areas for vulnerable users

Table 24 – Typical Shortcomings, Requiring Special Considerations in Slovenian RSA (Ministry of Infrastructure and Spatial Planning, 2012) (continued)

Design Element	Deficiencies
Urban/ Rural Common Deficiencies	Choice of maximum speed is unsuitable
	Lack of special conditions on entering a village (traffic calming)
	Lack of physical actions to lower speeds upon entering village/ town
	Traffic light stages do not take into account needs of all users
	Lack of protection of vulnerable users on areas other than intersections/ junctions
	Inadequate area for parking/ deliveries in villages/ towns
	Inadequate width of elements of the cross section (too wide, promoting speeding)

4.3.4.3 *Road Safety Inspection*

Road safety inspections are covered in training for road safety audits. A full day of training is dedicated to those undertaking the road safety audit training course allowing the auditors to learn of the road safety audit inspection process.

The following documentation is used for Road Safety Inspections in Slovenia:

- Rules on Road Infrastructure Road Traffic Safety Auditing and Road Safety Road Traffic Safety Training (Ministry of Infrastructure and Spatial Planning, 2017a),
- Rules on amendments and supplements to the Rules on road safety road safety inspection and the training of road safety auditors (Ministry of Infrastructure and Spatial Planning, 2017b),
- Rules amending the Rules on road safety road safety inspection and the training of road safety auditors (Ministry of Infrastructure and Spatial Planning, 2017c).

Inspection of road safety is an overview of an existing road in terms of design and technical elements of the road and its surroundings and the impact of human factors in order to ensure road safety in a way that eliminates factors that present a proven risk for the occurrence of traffic accidents.

Road safety reviews shall be carried out at least every five years. Auditors are responsible for approximately 120km of motorways and express roads in Slovenia. As per 2008/96/EC, only TEN-T roads are included in the RSI process at present. It is the intention of the Agency to include other national roads in the future.

A road safety review shall be mandatory in the event of a significant number of incidents or identified hazardous situations.

The auditor shall carry out a safety check in accordance with the guidelines for carrying out road infrastructure inspection in terms of traffic safety. The auditor shall also draw up a report on their findings and forward it to the contracting authority and The Public Agency of the Republic of Slovenia for Transport Safety. In the report, the auditor shall state all the irregularities and potential risks identified and propose measures to eliminate or mitigate the detected irregularities in the inspected road section. The report shall be signed by the auditor or, all the auditors who participated in the group.

Training to be a RSI inspector and a “lecturer” is the same process as the training discussed above in *Section 4.6.2* for a road safety auditor.

Road Safety Inspectors use a manual for RSIs which includes detailed instructions and specifications relating to both RSAs and RSIs. This manual is known as *“Prirocnik – za osnovno strokovno usposabljanje presojevalcev varnosti cest”* (Manual for basic professional training of road safety auditors) (Ministry of Infrastructure and Spatial Planning, 2015). This is the same document that is used for Road Safety Audits.

In Slovenia, the standard that governs RSI’s is Smernica Za Pregledovanje Varnosti Cest (Guidelines for Survey Road Safety (RSI)) (Ministry of Infrastructure and Spatial Planning, 2012a). EU Directive 2008/96 states only roads on the TEN-T network require RSI’s although this standard is to be used for all roads in Slovenia.

Fout! Verwijzingsbron niet gevonden. highlights the key elements that are important when carrying out RSI’s in Slovenia. Deficiencies relating to road side safety are shaded grey.

Table 25 – Key Elements to be Examined (Ministry of Infrastructure and Spatial Planning, 2012a)

Design Element	Reasoning
Road Function	Function of the road corresponding role, role of transport, mixed role etc.
Course Road	Number of horizontal curves, rounded verticals, straightness of route etc.
Import/ Export	Properties of running surface and drainage
Services	Petrol stations, restaurants, parking etc.
Traffic Signalisation	Traffic signs and road equipment, public lighting etc.

Table 25 – Key Elements to be Examined (Ministry of Infrastructure and Spatial Planning, 2012a) (continued)

Design Element	Reasoning
Features	Objects on road and next to it, vegetation etc.
Passive Safety Equipment	Ensures safety and prevents greater damage
Needs of Vulnerable Users	Including motorcyclists

It is recommended that the RSI is completed at day and night time, in varying weather conditions and varying rush hour times. These variables will allow the inspectors to grasp the greatest representation of the road possible. Checklists are provided to both ensure that the inspectors follow a systematic approach and do not overlook anything when completing the RSI.

Slovenian standards for Road Safety Impact Assessments (RSIA) are known as Smernice Za Izdelavo Ocene Ucinka Na Varnost V Prometu (RSIA) (Guidelines for making the Impact Assessment on Road Safety) (Ministry of Infrastructure and Spatial Planning, 2012b). The vision of road safety is defined by the National Road Safety Program 2012-2021 (NPVCP). By implementing RSIA in the early stage of the planning process, potentially dangerous solutions which contribute to the objectives set out in NPVCP can be eliminated. To perform a RSIA, data on the number and type of accidents on the existing road network is required and this is obtained from the Network Safety Management (NSM) process.

In Slovenia, guidelines state that RSIA is required at the planning process stage or the process design stage. The RSIA is then integrated with other processes arising from the EU Directive and implemented by way of the Slovenian Directive as shown in **Fout! Verwijzingsbron niet gevonden.**.

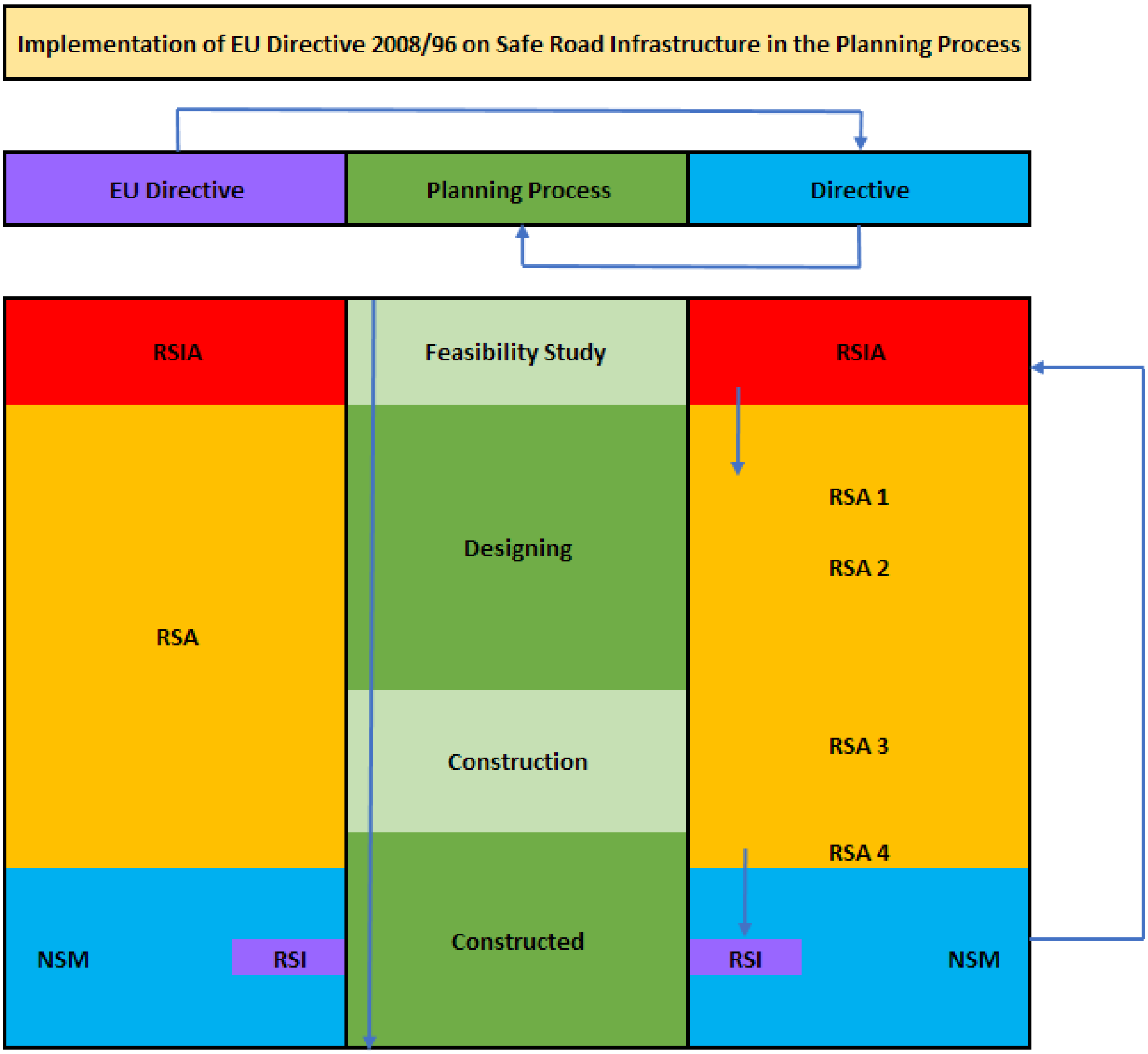


Figure 21 – RSIA Procedure in the Planning Process (Ministry of Infrastructure and Spatial Planning, 2012b)

A flowchart is provided within Smernice Za Izdelavo Ocene Ucinka Na Varnost V Prometu (RSIA) (Ministry of Infrastructure and Spatial Planning, 2012b) to determine the need for completing an RSIA and can be seen in **Fout! Verwijzingsbron niet gevonden.**.

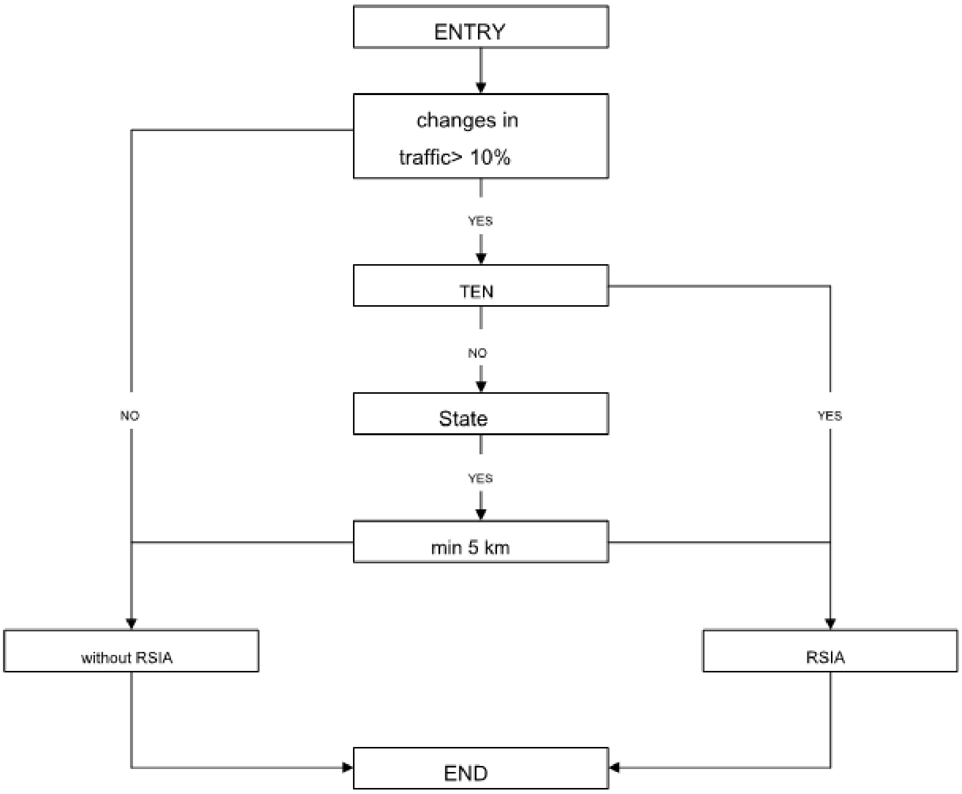


Figure 22 - Selection Methodology for RSIA (Ministry of Infrastructure and Spatial Planning, 2012b)

The Slovenian Ministry of Infrastructure and Spatial Planning, managers of trans-European roads on the territory of Slovenia and the Public Agency for Traffic Safety all use the methodology established in the document “Road Safety Impact Assessment, A Proposal for Tools and Procedures for a RIA”.

Smernice Za Izdelavo Ocene Ucinka Na Varnost V Prometu (RSIA) (Ministry of Infrastructure and Spatial Planning, 2012b) also provides guidance on the presentation of the results and states that it must include calculation of risk factors, forecast of the number of incidents for each time variant and forecast costs of each traffic accident for transport-economic studies.

4.3.4.4 *Directive 2008/96/EC Application*

Fout! Verwijzingsbron niet gevonden., below, acts as a summarising view for Slovenia’s application of Directive 2008/96/EC with information derived from Transport & Mobility Leuven (2014).

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Table 26 – Slovenia – Application of Directive 2008/96/EC (Transport and Mobility Leuven, 2014)

Implementation	
Practical transposition into funding countries legislation	Integration with pre-existing standards/ guidelines
Road Safety Impact Assessments (RSIAs)	
Presence of the procedure in country's legislation before/ after the Directive	No/ Yes
Applicable to non-TEN-T roads	No
Degree of coverage	TEN-T
Road type	All TEN-T
Party responsibilities	NRA
Road Safety Audits (RSAs)	
Presence of the procedure in country's legislation before/ after the Directive	No/ Yes
Applicable to non-TEN-T roads	No
Degree of coverage	TEN-T
Road type	All TEN-T
Party responsibilities	NRA

Table 26 – Slovenia – Application of Directive 2008/96/EC (Transport and Mobility Leuven, 2014) (continued)

Network Safety Management (NSM)	
Presence of the procedure in countries legislation before/ after the Directive	No/ Yes
Applicable to non-TEN-T roads	No
Frequency of application of procedure	Every 5 Years
Road type	All TEN-T
Party responsibilities	NRA
Road Safety Inspections (RSIs)	
Presence of the procedure in country's legislation before/ after the Directive	Yes/ Yes
Applicable to non-TEN-T roads	No
Degree of coverage	TEN-T
Frequency of application of procedure	Every 5 Years
Road type	All TEN-T
Party responsibilities	NRA
Training	
Training for auditors	Yes – RSA
Procedures requiring certified auditors	RSAs
Impacts	
Impacts on road planning/ design/ maintenance	No Information
Impacts on road equipment and component selection quality	No
Impact on road user communication	Yes

Table 26 – Slovenia – Application of Directive 2008/96/EC (Transport and Mobility Leuven, 2014) (continued)

Problems & Drawbacks	
Lack of coherent regulatory framework	Yes
Acceptance issues	No
Complexity issues	Yes
Funding issues	No

4.3.5 Sweden

4.3.5.1 *Road Restraint Systems*

The need for RRS in Sweden is described in documents for roads, bridges, and tunnels. There are different document levels; some with “requirements” which define performance requirements and dimensions for road elements and “recommendations” which provide guidance. The following documents were used in this compilation of RRS requirements in Sweden:

- “Krav för Vägars och gators utformning – Requirements for road and street design” (Swedish Transport Administration, 2015a.)
- “Råd för Vägars och gators utformning – Recommendations for road and street design” (Swedish Transport Administration, 2015b)

RRS are installed on Swedish roads when the safety zone required for the road cannot be kept obstacle free. Side slopes steeper than 1:4 also require barriers. The size of the safety zone is specified by the road type and speed. Rural roads that are not separated also use ADT to dimension the safety zone. The safety zone size can be modified depending on the horizontal curvature and the vertical drop of the slope. The general safety zone dimensions are presented in **Fout! Verwijzingsbron niet gevonden.**.

Table 27 – Safety Zone Width (Swedish Transport Administration, 2015a)

Road Type	**Safety Zone Width (m)**
Motorway (120km/h)	12
Motorway (110km/h)	11
Separated Road (110km/h) AADT > 8000 AADT < 8000	 10 9
Rural Road (100km/h)	9
Rural Road (80km/h) AADT > 8000 4000 > AADT < 8000	8

All safety barriers must conform to EN 1317. The general requirement for roadside and median barriers is N2. Bridges must be equipped with H2 barriers. Barrier capacity must be increased if there are high risk objects near the road such as drinking water reservoirs, chemical industry, rail lines, and other situations deemed critical for society.

The working width of the safety barrier must be smaller than the distance to any permanent objects that are being shielded.

The minimum length of barrier installations in Sweden (excluding terminals) are defined by the reference speeds for the road unless they are shorter than the minimum length specified by the manufacturer. Both normal and high capacity barrier lengths are defined are follows;

- 120km/h – 120m,
- 110km/h – 110m,
- 100km/h – 100m,
- 80km/h – 80m and
- 60km/h or less – 60m.

The free space behind a barrier must be 10m if the barrier is placed on a tight curve. Deflecting concrete barriers must have a level surface behind the barrier.

Terminals are generally required to be energy absorbing if they are placed near traffic, and shall be tested to ENV 1317-4 with the following requirements:

- Turned down barrier ends are permitted if they are flared from the roadway.
- Performance class P4 is required for speeds of 100km/h and greater, and
- Performance class P3 is required for speeds of 80km/h and less.

Crash cushions are used to protect specific objects, and their speed class shall be in accordance with a reference speed of:

- ≥100km/h – 110km/h,
- 80km/h – 100km/h,
- ≤80km/h – 80km/h.

Crash cushions are to be redirective with deformations not allowing the vehicle to interfere with the obstacle. Vehicle deformation class Z2 specified in EN 1317-3 is required unless special permission is given by the road authority.

4.3.5.2 *Road Safety Audits*

Directive 2008/96 / EC of the European Parliament and road safety Council was introduced in Sweden by the Road Safety Act (2010: 1362), Road Safety Regulation (2010: 1367) and implementing regulations issued by the Transport Agency (TSFS 2010: 183.) For each road project, the Transport Agency shall designate a traffic safety examiner to undertake a road safety audit at each stage of the project, and create inspection reports. The purpose of this procedure is to ensure that road safety audits are carried out at the right stage of the project and that the results are handled correctly.

The RSA exercise includes road projects that are part of the TEN-T road network. The exercise does not cover road tunnels covered by the Road Safety Act (2006: 418). The exercise does not cover maintenance work.

The stages of a road project are:

1. Initial planning stage
2. Detailed design
3. Immediately before the road is put into use

4. Before the road opens for traffic.

The purpose at each stage is to resolve any safety issues that have been identified by the audit team. The project manager shall ensure that audit issues are handled within each step of the review. Review issues that are not resolved shall be justified.

Once the report is complete Traffic Safety Inspector carries out the final review report, including attachment with the Swedish Transport Agency Statement and motives, the report is then sent to the Transport Agency and project manager for the project.

4.3.5.3 *Road Safety Inspections*

Road safety inspections are covered by the Road Safety Act 2010:1362 (Ministry of Industry RS T, 2010) which includes the following:

Section 8 of the Act "Safety Inspections" states that the road keeper shall conduct regular road safety inspections, map the road safety standards and establish a plan of action for measures to be taken to increase road safety.

Section 9 of the Act "Safety" states that the road carrier shall systematically and continuously take the necessary measures to prevent serious personal injury as a result of the use of the roads. Measures to remedy the immediate risk of such damage should be taken first. The obligation applies to the extent that it may be considered reasonable. In this regard, the benefit of protective measures in comparison to the costs of such measures, as well as the question of the risk of damage, may be reduced by other measures, in particular.

4.3.5.4 *Directive 2008/96/EC Application*

Fout! Verwijzingsbron niet gevonden., below, acts as a summarising view for Sweden's application of Directive 2008/96/EC with information derived from Transport & Mobility Leuven (2014).

Table 28 – Sweden – Application of Directive 2008/96/EC (Transport and Mobility Leuven, 2014)

Implementation	
Practical transposition into funding countries legislation	Replacement of pre-existing standards/ guidelines
Road Safety Impact Assessments (RSIAs)	
Presence of the procedure in country's legislation before/ after the Directive	No/ Yes
Applicable to non-TEN-T roads	No
Degree of coverage	TEN-T (100%)
Road type	All TEN-T
Party responsibilities	Swedish Transport Administration
Road Safety Audits (RSAs)	
Presence of the procedure in country's legislation before/ after the Directive	No/ Yes
Applicable to non-TEN-T roads	No
Degree of coverage	TEN-T (100%)
Road type	All TEN-T
Party responsibilities	Swedish Transport Administration

Table 28 - Sweden – Application of Directive 2008/96/EC (Transport and Mobility Leuven, 2014) (continued)

Network Safety Management (NSM)	
Presence of the procedure in countries legislation before/ after the Directive	No/ Yes
Applicable to non-TEN-T roads	No
Frequency of application of procedure	Annually
Road type	All TEN-T
Party responsibilities	Swedish Transport Administration
Road Safety Inspections (RSIs)	
Presence of the procedure in country's legislation before/ after the Directive	No/ Yes
Applicable to non-TEN-T roads	No
Degree of coverage	TEN-T (100%)
Frequency of application of procedure	Annually
Road type	All TEN-T
Party responsibilities	Swedish Transport Administration
Training	
Training for auditors	Yes – RSA
Procedures requiring certified auditors	RSAs
Impacts	
Impacts on road planning/ design/ maintenance	No Information
Impacts on road equipment and component selection quality	No
Impact on road user communication	No

Table 28 - Sweden – Application of Directive 2008/96/EC (Transport and Mobility Leuven, 2014) (continued)

Problems & Drawbacks	
Lack of coherent regulatory framework	No
Acceptance issues	No
Complexity issues	No
Funding issues	No

4.3.6 United Kingdom

4.3.6.1 *Road Restraint Systems*

The current RRS standard in the UK for motorways and trunk roads consists of two parts:

- (DMRB Volume 2, section 2, Part 8, TD19/06) 'Requirement for Road Restraint Systems', (Department for Transport, 2006) which is a written standard, and
- 'Road Restraint Risk Assessment Process (RRRAP)' (Department for Transport, 2016), which is a Microsoft Excel based risk assessment tool.

TD19/06 is the written standard and includes mandatory requirements and general guidance for the provision of RRS. It explains the general risk assessment and mitigation approach. RRRAP is the risk assessment tool and enables the designer to calculate the level of risk resulting from each hazard on a site without a RRS or with RRS of different lengths and performance classes.

TD19/06 classifies risk into three categories using the principles of 'as low as reasonably practicable (ALARP)', as it is represented in **Fout! Verwijzingsbron niet gevonden.**. As the risk gets higher it becomes less tolerable and after a certain point becomes unacceptable. The TD 19/06 approach is to lower any risk within the unacceptable and tolerable region to a broadly acceptable level within the ALARP principles.

The Road Restraints Risk Assessment Process (RRRAP) is a Microsoft Excel based tool which uses many different parameters from a site to calculate the level of risk without a roadside barrier and if necessary with barriers of certain containment levels.

RRRAP calculates risk by multiplying the Likelihood of an errant vehicle hitting a hazard with the resulting Consequences, and expresses it in equivalent fatalities per 100 million vehicle km.

Figure 23 - Calculation of Risk (La Torre et al, 2014)

The containment level requirements for safety barriers in UK are:

Permanent Deformable and Rigid Safety Barriers:

- On roads with a speed limit of 50 mph or more:
  - Normal Containment Level = N2
  - Higher Containment Level = H1 or H2
  - Very High Containment Level = H4a

- On roads with a speed limit of less than 50 mph:
  - Normal Containment Level = N1

On motorways or roads constructed to motorway standard with a two-way AADT greater or equal to 25,000 veh/day, where a RRS is required, the safety barrier must be of rigid concrete construction with a containment level of H1 or greater. This is required to:

- Minimise cross-over incidents;
- Reduce the need for safety barriers to be repaired or maintained;
- Minimise the costs and congestion arising from temporary traffic management; and
- Reduce the risk to maintenance workers.

The use of an H1 rigid concrete safety barrier may not be practicable for lengths of 500 m or less. Therefore, where the provision of a rigid concrete safety barrier would, in total, be 500 m or less, Normal Containment Level N2 safety barrier may be used.

The Containment Levels required for vehicle parapets are:

- On roads with a speed limit of 50 mph or more:
  - Normal Containment Level = N2
  - Higher Containment Level = H2
  - Very High Containment Level = H4a

- On roads with a speed limit of less than 50 mph:
  - Normal Containment Level = N1
  - Normal Containment Level = N2
  - Higher Containment Level = H2
  - Very High Containment Level = H4a

The impact severity level for safety barriers and vehicle parapets must not normally exceed Class B as stipulated in BS EN 1317-2.

The Working Width Class for each vehicle parapet installation must be the same as, or numerically less than, that specified by the Design Organisation.

The Working Width Class for vehicle parapets must not be numerically greater than:

I. Normal Containment Levels (N1 & N2) - W4
II. Higher Containment Levels (H1 to H3) - W4
III. Very High Containment Level (H4a) - W5

The Performance Class requirements for terminals are as follows.

- On roads with a speed limit of 50 mph or more:

    - For terminals that face oncoming traffic, e.g. those at both ends of a RRS on a two-way single carriageway road, the minimum performance class must be P4. Ramped end terminals must not be used;
    - For terminals that do not face oncoming traffic, e.g. departure ends on dual carriageways or on a one-way road, the minimum performance class must be P1.
- On roads with a speed limit of less than 50 mph:
    - Terminals must have a minimum Performance Class of P1 or greater.

Where a transition is used to connect a Very High Containment vehicle parapet (H4a) to a Normal Containment (N1) vehicle parapet, the end section of the Normal Containment (N1) vehicle parapet must be strengthened to Normal Containment Level (N2).

The Performance Class requirements for crash cushions are presented in Tables 29 and 30:

Table 29 – Crash Cushions Requirements for speeds >50mph (Department for Transport, 2006)

Type	Performance Level	Acceptance					
Redirective (R)	110	TC 1.1.100	TC 1.3.100	TC 2.1.100	TC 3.3.110	TC 4.3.110	TC 5.3.110
Non-redirective (NR)	110	TC 1.1.100	TC 1.3.100	TC 2.1.100	TC 3.3.110	-	-

Table 30 – Crash Cushions Requirements for speeds ≤50mph (Department for Transport, 2006)

Type	Performance Level	Acceptance					
Redirective (R)	100 {80 (HA)}	TC 1.1.100	TC 1.2.100	TC 2.1.100	TC 3.2.100	TC 4.2.100	TC 5.2.100
Non-redirective (NR)	100 {80 (HA)}	TC 1.1.100	TC 1.2.100	TC 2.1.100	TC 3.2.100	-	-

At a potential crash cushion site, an evaluation based on the Risk assessment process must first be undertaken by the Design Organisation of the cost benefit of provision together with possible options for reducing the number, or severity of accidents, by other highway design measures.

4.3.6.2 *Road Safety Audits*

The RSA guidelines utilised in the UK are HD 19/15 Road Safety Audits (Department for Transport, 2015). The objective of this Standard is to ensure that the road safety implications of all Highway Improvement Schemes are fully considered for all users of the motorway and trunk road network. HD 19/15 sets out the procedures required to implement RSA on Highway Improvement Schemes on trunk roads including motorways. It defines the relevant schemes and stages in the design and construction process at which RSA shall be undertaken and sets out the requirements for post-implementation collision monitoring.

RSA shall be undertaken on Highway Improvement Schemes as follows:

Stage 1 – Preliminary Design;

Stage 2 – Detailed Design;

Stage 3 – Substantially complete and preferably before the scheme is opened to road users;

Stage 4 – 12 months and 36 months following scheme opening

Stage 1 RSAs shall be undertaken at the completion of preliminary design, (for example at the Order Publication Report Stage) before publication of draft Orders and for developer-led Highway Improvement Schemes, before planning consent is applied for.

Stage 2 RSAs shall be undertaken at the completion of the detailed design stage. At this stage, the Road Safety Audit team is concerned with the more detailed aspects of the Highway Improvement Scheme. The Road Safety Audit team will be able to consider geometry (such as the layout of junctions and highway cross sections), street furniture (such as the position of traffic signs and road restraint systems), carriageway markings, street lighting provision and other issues.

Stage 3 RSAs should be undertaken when the Highway Improvement Scheme is substantially complete and preferably before the works are opened to road users. This is to minimise potential risk to road users and the difficulty that would be experienced by Road Safety Audit teams in traversing the site when open to traffic.

Stage 4 RSAs should be undertaken when a Highway Improvement Scheme is opened to road users. Monitoring in the form of Stage 4 Road Safety Audits must be carried out on the number of personal injury collisions that occur, so that any road safety problems can be identified and remedial action taken as soon as possible. Stage 4 Road Safety Audit collision monitoring reports shall be prepared using 12 months and 36 months of personal injury collision data from the time the Highway Improvement Scheme became operational and shall be submitted to the Overseeing Organisation.

HD 19/15 states that it is the Project Sponsor’s responsibility to ensure that all problems raised by the Road Safety Audit team are given due consideration. To assist with this, the Design Team must prepare a Road Safety Audit Response Report to the Road Safety Audit Report at the Stage 1, Combined 1 & 2, Stage 2 and Stage 3 Road Safety Audits.

4.3.6.3 *Road Safety Inspections*

Information relating to RSI in the United Kingdom is based on the Road Inspection Manual (Department for Transport, 2017), issued initially in 2004. The objectives of the manual were to define hierarchies of carriageways, footways and cycle tracks for inspections, to recommend the procedures and the minimum frequencies for the inspections used to determine routine maintenance tasks, and to encourage consistency in the standards for the inspections. RSI fall within the remit of Highways Authorities maintenance offices. The maintenance tasks mentioned above should include according to the manual “the maintenance operations or works necessary for maintaining and restoring the road network to serviceable and safe conditions”. UK RSI is therefore part of the routine maintenance, and from that ensues the concentration on short term measures and improvements. The manual does not cover long-term measures, for example replacement of parts of the road which exceed the service life.

Along with carriageways the manual also covers footways and cycle tracks. All three of these elements are part of the road network. A road network hierarchy was developed to allow for better allocation of resources. The footways are divided into

- “Footways within Pedestrianisation Schemes” and
- “Footways outside Pedestrianisation Schemes”.

Concerning carriageways, the following categories exist:

- “Expressway”,
- “Trunk Road (Urban)”;
- “Trunk Road (Rural)”;
- “Primary Distributor”;
- “District Distributor”;
- “Local Distributor”;
- “Rural Road” and
- “Feeder Road”.

No categories exist for cycle tracks. In addition to the categorization of roads there is also a categorization of road defects. According to the manual two categories exist: Category (i) and Category (ii).

Road defects in category (i) require prompt attention as they represent an immediate or imminent hazard or there is a risk of short term structural deterioration. All other defects are included in category (ii). While the defects in category (i) should be corrected or made safe as soon as reasonably practicable, the correction of the defects in category (ii) should be included in the planned schedules of works. During the inspections report forms and checklists should be used. The completion of the report forms should be undertaken, when possible, at the time of the inspection.

The inspections are divided into two types:

- “Safety Inspections” and
- “Detailed Inspections”.

During the Safety Inspections (SI) “all defects likely to create danger or serious inconvenience to users of the network” have to be identified. Remedial measures to correct such defects should take place within 24 hours. When scheduling the SI, the maintenance officers should also consider other factors such as incident and inspection history. For every carriageway category, minimum frequencies for SI are recommended. The Rural Trunk Roads should be inspected every 7 days and Rural Roads every 3 months.

According to the manual the following defects constitute an immediate or imminent hazard and should therefore normally be identified and reported during the inspection:

- Potholes and other local defects, including missing paving blocks, missing/broken
- ironware, gully grating and cover;
- Excessive standing water and water discharging onto or from within, and/or flowing across the roads;
- Missing safety fences;
- Unguarded road openings;
- Damaged street furniture protruding into carriageway or footway/cycle track; and
- Fallen boulders, landslip debris or any other hazardous obstructions on carriageways, footways or cycle tracks, particularly on Expressways and high-speed roads.

Detailed Inspections (DI) are designed according to the Road Inspection Manual (RIM) “to record only those types of defects likely to require routine maintenance”.

The focus of the DI is carriageways, footways and cycle tracks. In conjunction with the carriageway inspection the following items should be inspected:

- Covers, Grating, Frames and Boxes
- Fences and Barriers
- Grassed Areas
- Road Studs and
- Road Marking
- Traffic Signs

During the carriageway inspection, the occurrence of the following defects are noted (in case of flexible pavement): cracking, corrugation, depression, rutting, shoving, surface deterioration, ravelling, potholes and hazardous obstructions. In case of rigid pavements, the important defects are: cracking, joint stepping, rocking, loss of sealant, spalling, surface defects, and hazardous obstructions. During the inspection of footways and cycle tracks the defects which must be identified are: defective surface, missing or loose blocks, defective kerbs, and hazardous obstructions.

The inspection of covers, gratings, frames and boxes is to focus on damaged, misplaced, loosened or missing items. Fences and barriers are to be inspected, along with the additional aspects such as ponding / flooding. During the inspection of grassed areas, the visibility at junctions, roundabouts and bends should be examined to see if it is affected by vegetation. The inspection of road studs concentrates on identifying missing or damaged road studs. Concerning the inspection of road markings, it should be noted if the road marking is faded. The inspection of traffic signs concentrates on observing the colour, serviceability and general conditions of traffic signs.

The minimum frequencies for carrying out these inspections vary by the different types of inspections and extend from every 6 to every 24 months. For the predefined defects, defect codes were developed. These codes are filled in the report form during the inspection. The SI can be conducted together with the DI, so there is no need to carry these two types of inspections separately.

4.3.6.4 *Implementation of Road Infrastructure Safety Management Directive*

A review of existing guidance and standards used in the design and management of the UK national roads was undertaken. The review found that "*In accordance with the UK's obligation to transpose EU Directives, careful consideration was given to whether transposition needed to be by way of regulation. An assessment of the requirements of the Directive revealed that almost all the obligations under the Directive were already being carried out by the UK's strategic road authorities. Consequently, the Directive was transposed by means of the administrative measures, guidance and domestic Law that constitutes the activities under the Directive and not by regulation*" (Guidelines for Competent Authorities on the Application of the Directive, Department of Transport, 2011). **Fout! Verwijzingsbron niet gevonden.** highlights the changes implemented by the UK agency responsible for the incorporation of the Directive into their current standards.

Table 31 – Current UK Changes – Guidelines for Competent Authorities on the Application of the Directive, (Department for Transport, 2011).

Changes to Comply with RISM
Road Safety Audit training curriculum and Road Safety Auditor Certificate of Competence – this is published in IAN 152/111 which in time will be replaced by a revision to HD19 (DMRB Volume 5.2). Details of the arrangements for the issuing of certificates are published in IAN 152/11 which in time will be replaced by a revision to HD19 (DMRB Volume 5.2.). IAN 152/11 also explains how the Road Safety Auditor Certificate of Competence sits alongside the existing process for appointing an appropriate road safety audit team. Service Providers that employ road safety auditors should plan ahead to ensure that they can offer continuity of services.
Site visits for the investigation of accident hotspots – although currently it would be unusual for the process of preparing remedial schemes to omit site visits, the Directive now makes this mandatory. One member of the team that visits the prospective remedial site must be a suitably qualified road safety engineer. In England, the Safety Operational Folder has been updated to reflect these changes.
Reporting of accident costs along routes – the current arrangements for reporting accidents in a variety of ways are to be supplemented by the inclusion of route accident costs using individual accident monetary valuations already published annually in "Reported Road Casualties Great Britain", based on actual severity valuations of accidents. Service Providers and highway authority route managers should view such information alongside other information when determining priorities for investment. The information will be provided in the Regional Road Safety Reports that will support the Reported Road Casualties on the Highways Agency Network Report produced annually.3 The documents where these costs are reported are accessed by the HA website
Informing the public of "high accident concentration sections" – the current arrangements given in the Traffic Signs Manual for using warning signs, where appropriate, will continue. Signs that indicate unspecified hazards or inform roads users of the numbers of casualties/accidents at a location will not be erected. The publication of accident maps on public websites is the preferred method of compliance. These will be reported in www.roadcasualtiesonline.co.uk and will include a section for the TEN-T network.

4.3.6.5 *Directive 2008/96/EC Application*

Fout! Verwijzingsbron niet gevonden., below, acts as a summarising view for the UK's application of Directive 2008/96/EC with information derived from Transport & Mobility Leuven (2014).

Table 32 – United Kingdom – Application of Directive 2008/96/EC (Transport and Mobility Leuven, 2014)

Implementation	
Practical transposition into funding countries legislation	Integration with pre-existing standards/ guidelines
Road Safety Impact Assessments (RSIAs)	
Presence of the procedure in country's legislation before/ after the Directive	Yes/ Yes
Applicable to non-TEN-T roads	Yes
Degree of coverage	TEN-T (100%) and non-TEN-T
Road type	All TEN-T and Strategic roads on non-TEN-T
Party responsibilities	Local Highways Authorities
Road Safety Audits (RSAs)	
Presence of the procedure in country's legislation before/ after the Directive	Yes/ Yes
Applicable to non-TEN-T roads	Yes
Degree of coverage	TEN-T (100%) and non-TEN-T
Road type	All TEN-T and Strategic roads on non-TEN-T
Party responsibilities	Local Highways Authorities

Table 32 – United Kingdom – Application of Directive 2008/96/EC (Transport and Mobility Leuven, 2014) (continued)

Network Safety Management (NSM)	
Presence of the procedure in countries legislation before/ after the Directive	Yes/ Yes
Applicable to non-TEN-T roads	Yes
Frequency of application of procedure	Annually
Road type	All TEN-T and Strategic roads on non-TEN-T
Party responsibilities	Local Highways Authorities
Road Safety Inspections (RSIs)	
Presence of the procedure in country's legislation before/ after the Directive	Yes/ Yes
Applicable to non-TEN-T roads	Yes
Degree of coverage	TEN-T (100%) and non-TEN-T
Frequency of application of procedure	Every 3 Years
Road type	All TEN-T and Strategic roads on non-TEN-T
Party responsibilities	Local Highways Authorities
Training	
Training for auditors	Yes – RSA
Procedures requiring certified auditors	RSA, NSM
Impacts	
Impacts on road planning/ design/ maintenance	No Information
Impacts on road equipment and component selection quality	No
Impact on road user communication	Yes

Table 32 – United Kingdom – Application of Directive 2008/96/EC (Transport and Mobility Leuven, 2014) (continued)

Problems & Drawbacks	
Lack of coherent regulatory framework	No
Acceptance issues	No
Complexity issues	No
Funding issues	No

4.4 RISM and Country Experiences

4.4.1 Analysis of Funding Country Approaches

The objective of this section is to determine the effectiveness of the introduction of EU Directive 2008/96/EC/ RISM procedures with specific regards to the six funding countries (Belgium (Flanders), Ireland, Netherlands, Slovenia, Sweden and United Kingdom) along with highlighting funding country approaches. Information was compiled through a number of resources including interviews and literature reviews. The main literature document reviewed was Transport and Mobility Leuven's "Study on the effectiveness and on the improvement of the EU legislative framework on road infrastructure safety management (A. Sitran et al, 2016) and the Ex-Post Evaluation" (Transport and Mobility Leuven, 2014).

With the introduction of 2008/96/EC many countries were required to introduce procedures in line with the requirements of the Directive. **Fout! Verwijzingsbron niet gevonden.**, below, highlights the procedural presence within the funding countries before and after the directive.

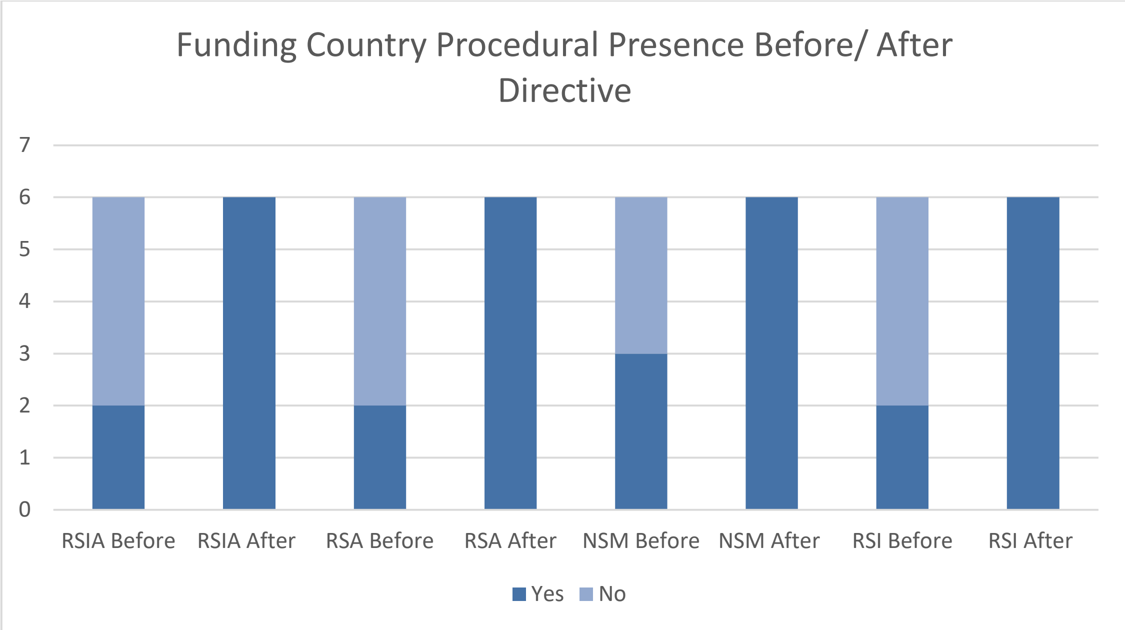

Figure 24 – Funding Country Procedural Presence Before/ After Directive

Fout! Verwijzingsbron niet gevonden. shows that prior to the introduction of the Directive no more than 50% of funding countries employed any one of the different procedures in question. It also shows that following the introduction of the Directive all funding countries implemented the main procedures.

The funding countries either replaced existing legislation or implemented the requirements of the Directive to ensure that the procedures were written into the particular guidelines/ standards. As can be seen in **Fout! Verwijzingsbron niet gevonden.**, out of the six funding countries, four (United Kingdom, Belgium (Flanders), Sweden, and Slovenia) replaced their existing standards while two countries (Ireland and Netherlands) integrated changes to allow their guidelines/ standards to comply with the Directive.

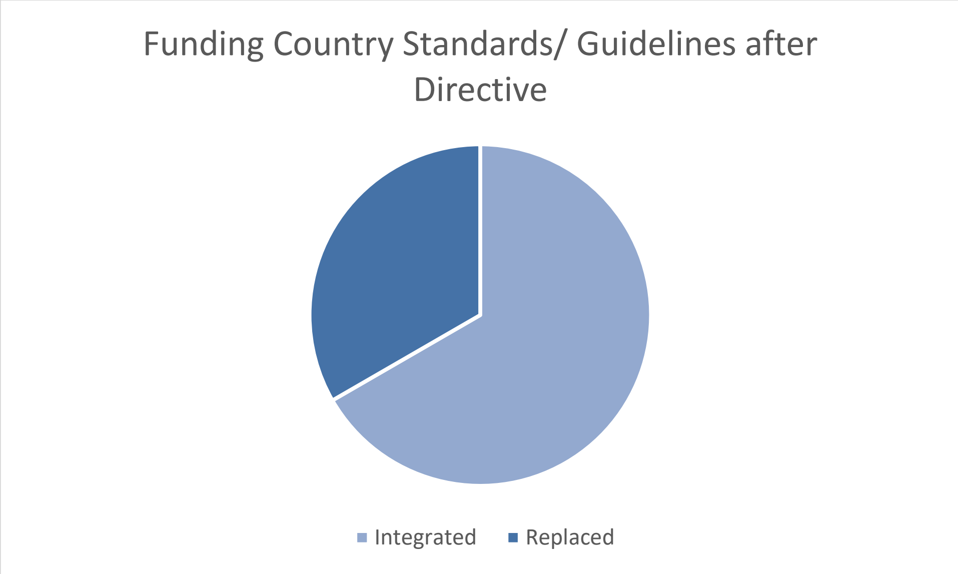

Figure 25 – Funding Country Standards/ Guidelines after Directive

The RISM Directive applies to TEN-T roads only, however, Ireland and United Kingdom have extended the requirements to also apply to their non-TEN-T roads. Netherlands has extended the requirements to apply to 90% of their roads (TEN-T and non-TEN-T). Belgium (Flanders), Sweden and Slovenia have not extended the requirements of the Directive to apply to non-TEN-T roads as per **Fout! Verwijzingsbron niet gevonden.**.

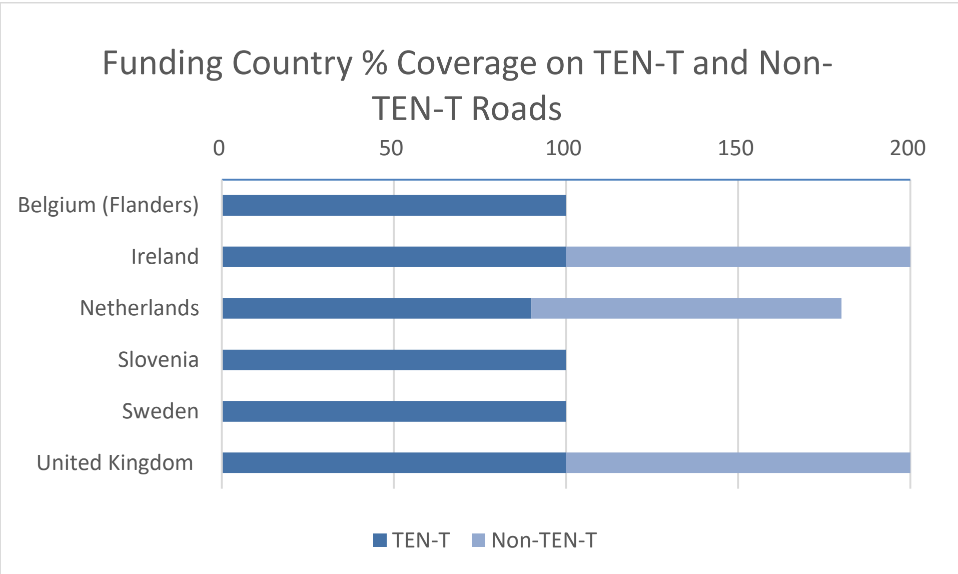

Figure 26 - Funding Country % Coverage on TEN-T and non-TEN-T Roads

According to EPE (2014) Belgium (Flanders), Ireland and Sweden expressed no difficulties with the implementation of the Directive. Netherlands expressed acceptance issues (lack of acceptance among policy makers/authorities or an improper or insufficient understanding of the new requirements) of the Directive. Slovenia expressed difficulties with a lack of coherent regulatory framework (spreading the use of the RISM procedure) and some complexity (of the infrastructure project) issues as well as impacts on road user communication (informing road users of high concentrated accident black spots through ITS, signposting, VMS etc.). United Kingdom expressed no difficulties although did note on an impact with road user communication.

4.4.2 Proposal to amend the RISM Directive

A proposal for a Directive of the European Parliament and of the Council amending Directive 2008/96/EC on Road Infrastructure Safety Management was published in May of 2018 (COM/2018/274 final - 2018/0129 (COD).

The Commission is proposing a road safety framework for 2020-2030 that is better adapted to the known challenges and to the changes in mobility resulting from societal trends and technological developments. The proposed framework follows the Safe System approach. This approach is based on the principle that human beings can and will continue to make mistakes and that it is a shared responsibility of actors at all levels to ensure that road crashes do not lead to serious or fatal injuries. According to the Safe System approach, the safety of all parts of the system must be improved — roads and roadsides, (which are of particular interest to this research project), speeds, vehicles and road use so that if one part fails, other parts will still protect those involved.

Road infrastructure will continue to be very much part of the new approach. Well-designed and properly maintained roads can reduce the probability of road traffic accidents, while ‘forgiving’ roads (roads laid out in an intelligent way to ensure that driving errors do not immediately have serious consequences) can reduce the severity of accidents that do happen.

4.5 Conclusion

Belgium (Flanders), Ireland, Netherlands, Slovenia and Sweden include requirements in their safety barrier design standards relating to the area at the side of the road which should be kept free of hazards that could increase the severity of a collision in the event of a run off road incident.

The general principle across the five countries is the same however the dimensions of the hazard free zone vary from country to country as can be seen in **Fout! Verwijzingsbron niet gevonden.**. Slovenia do not have a *“required clear zone defined in any official documents (law or sub law) due to expenses and configuration of the terrain in Slovenia”* (Tollazzi 2018). It can be seen from **Fout! Verwijzingsbron niet gevonden.** that there is a 40% difference between the lowest required clear zone at 120kph (8.6m, Belgium (Flanders)) compared to the highest required clear zone at 120kph of 13m in the Netherlands.

Table 33 - Clear Zone Dimensions at 120kph

Country	Clear Zone Dimension at 120kph
Belgium (Flanders)	8.6m
Ireland	10m
Netherlands	13m
Slovenia	-
Sweden	12m

In the United Kingdom, a risk based approach is required which uses many different parameters from a site to calculate the level of risk without a roadside barrier and if necessary with barriers of certain containment levels. As such a hazard free zone, as per the other funding countries, is not specifically defined within the design standard.

Tables 12, 19, 22, 26, 28 and 32 summarise the application of Directive 2008/96/EC in each of the funding countries.

In terms of the impacts of RISM on road planning/ design/ maintenance across the funding countries no information was available in all countries except for Ireland where minimal information was available. The specific impacts, in an Irish context, relate to the items included in Table 19 which outline measures implemented as a result of a review of road safety audits undertaken by, or on behalf, of TII. This review lead to the development of:

- a training course relating to RRS design, installation and maintenance;
- the adoption of the forgiving roadside approach at planning stage of road schemes;
- the revision of the RRS design standard to remove a fence type that was previously deemed not to be a collision hazard within the clear zone but following collision investigation was found to have been a factor in serious injury and fatal collisions.

In terms of the impact of RISM on road equipment and component selection quality there was no impact determined.

In terms of the impact of RISM on road user communication, as per Article 5 of the Directive, the responses varied from “No” (Belgium (Flanders) and Sweden, “Not Directly” (Ireland and Netherlands) and “Yes” (Slovenia and UK).

Fout! Verwijzingsbron niet gevonden. below summaries the application of the RISM Directive to Non-TEN-T roads within each of the funding countries. It can be seen that there is a 50/50 split with Ireland, Netherlands and the United Kingdom applying the requirements of the Directive to their Non-TEN-T roads and Belgium (Flanders), Slovenia and Sweden not applying the requirements.

Table 34 – RISM Directive Applicable to Non-TEN-T Roads

	Applicable to Non-TEN-T			
Country (Region)	**RSIA**	**RSA**	**RSI**	**NSM**
Belgium (Flanders)	✘	✘	✘	✘
Ireland	✓	✓	✓	✓
Netherlands	✓	✓	✓	✓
Slovenia	✘	✘	✘	✘
Sweden	✘	✘	✘	✘
United Kingdom	✓	✓	✓	✓

In preparing the impact assessment for the proposal to amend the RISM Directive (see section 4.4.3), the Commission carried out a number of stakeholder consultations. Of particular relevance to this research project was a near unanimous response that:

"(…) improvements are needed to the maintenance and repair of existing roads, upgrading the safety features of existing roads and improving the protection of vulnerable road users."

Also of particular relevance, as previously mentioned in Section 4.2 is:

"(…)extending the scope of the Directive beyond the trans-European transport network (TEN-T) to cover motorways and primary roads outside the network as well as all roads outside urban areas that are built using EU funds in whole or in part."

It can be seen from the above that the proposed amendment seeks to extend the reach of the RISM Directive to include Non-TEN-T roads in an attempt to improve safety for all road users on all rural roads within the EU.

5 Assessment of road side maintenance guidelines, practices and road worker safety

This chapter discusses the standards and guidelines that relate specifically to road side maintenance and operations to establish whether maintenance of road side furniture and equipment are related directly to road safety or whether these are inferred (i.e. preventive versus reactive).

5.1 Legislation

At both European and Member State level, a range of legislation and guidance exists that is relevant to the issue of safety in the context of working on or near roads either directly or indirectly. At the European level, a number of Directives have been developed that have implications for this area in terms of provisions for standards and procedures.

Directive 2008/96/EC on Road Infrastructure Safety Management introduced a comprehensive system of road infrastructure safety management. It addresses projects for the construction of new road infrastructure or substantial modifications to the existing network which affects the traffic flow within the Trans-European Network for Transport (TEN-T). The Directive requires Member States to adopt guidelines on temporary safety measures applying to roadworks.

The following four points cite the regulations relating to the application of safety inspections as included in Article 6 of the Directive (European Parliament and the Council of the European Union, 2008):

1. *Member States shall ensure that safety inspections are undertaken in respect of the roads in operation in order to identify the road safety related features and prevent accidents.*

2. *Safety inspections shall comprise periodic inspections of the road network and surveys on the possible impact of roadworks on the safety of the traffic flow.*

3. *Member States shall ensure that periodic inspections are undertaken by the competent entity. Such inspections shall be sufficiently frequent to safeguard adequate safety levels for the road infrastructure in question.*

4. *Without prejudice to the guidelines adopted pursuant to Article 8, Member States shall adopt guidelines on temporary safety measures applying to roadworks. They shall also implement an appropriate inspection scheme to ensure that those guidelines are properly applied.*

Directive 92/57/EEC (European Parliament and Council, 1989a) relating to 'Temporary or mobile construction sites' sets out minimum safety and health requirements for temporary or mobile construction sites (i.e. any construction site at which building or civil engineering works are carried out) and intends to prevent risks by establishing a chain of responsibility linking all the parties involved. While Annex I of the Directive does not explicitly state that it applies to road works, several of the mentioned activities are a part of road construction. In Belgium, for example, the Royal Decree transposing this directive includes temporary road works when more than one contractor is involved (which is almost always the case). In the UK, construction work is defined to include road works.

Safety Framework Directive 89/391/EEC (European Parliament and Council, 1989b) underlines the onus on employers to protect their employees and states that they should evaluate the risks to the health and safety of their workers and take measures necessary for the safety and health protection of workers. This requires a risk assessment based approach to safety management.

The Personal Protective Equipment Directive 1989/686 applies to any device or appliance designed to be worn or held by an individual for protection against one or more health and safety hazards (as defined in the Directive).

5.2 Road Side Operations

5.2.1 Work Zones

The level of risk at a work zone depends on the type of works to be carried out, the duration of the works, the location of the works, the classification of the road and the volumes of traffic. Road types vary and require different approaches in terms of safety provision. The type of road work will also have a bearing on safety measures to be implemented as the works can be long, medium, short term or mobile.

The type of work zone in terms of function, area and duration can vary significantly as can the type of work being undertaken and the environment in which the work zone is located. As a result, these variables determine the type and nature of the potential risk and on the processes, that can minimise this risk. Work zone types also present different driving conditions to road users which can have implications for safety and are an essential consideration when planning and operating the work zone.

Work zone types generally fall into one of the following categories (European Transport Safety Council, 2011):

- Long-term stationary work that occurs in a single location with duration of more than three days.
- Medium-term stationary work occurs in a single location for more than one daylight period (up to three days) or night-time work lasting more than one hour.
- Short-term stationary work that lasts for more than one hour, but is completed within a single daylight period.
- Mobile work that moves intermittently or continuously.

5.2.2 Road Safety

The various road types and work zone types interact to produce dynamic environments which are made increasingly complex with the introduction of workers, road users and changing weather and local environment. This serves to highlight the fact that in many ways each road work scenario is unique – it will have unique characteristics working together with the potential to create risk and means that a “one size fits all” approach to providing for safety is not appropriate.

From a road safety viewpoint, the risks involved with work zones can include risk of collisions between general road users (vehicles, cyclists, pedestrians) and road restraint systems, equipment, vehicles or personnel associated with the work zone as well as collisions involving only road users due to the change to the normal traffic flow introduced by the work zone (i.e. side swipe incidents due to sudden lane changes, rear-end crashes due to sudden breaking).

5.2.3 Planning

During the work planning phase, fundamental decisions about the work zone are made which dictate levels of safety either directly or indirectly. When determining the timing, form and type of road works, a balance should be achieved between the following (European Transport Safety Council, 2011):

- Safety of road users and workers.
- Traffic flow and road user inconvenience.
- Efficient work zone scheduling and economical traffic operation.
- Environmental impact and other quality requirements.

5.2.4 Safety Appraisal

A safety appraisal is a systematic and critical examination of the workplace for the purpose of identifying hazards, assessing the risk and recommending controls to reduce the risk, where appropriate. Safety appraisals and risk assessment should be carried out prior to all proposed works in or adjacent to roads. The level of detail involved should reflect the complexity of the work proposed and the local environment and should cover both issues relating specifically to employees as well as all other road users: pedestrians, cyclists, public transport, HGV’s and cars as different hazards risks and subsequently mitigation measures may emerge (European Transport Safety Council, 2011).

5.2.5 Employee Safety

Inherent in the planning procedure relating to road works is the need to redress the balance between traffic management and employee safety. The risks for workers are not always recognised. Occupational health and safety must be integrated into the overall road works planning and execution process. There are five key principles that should be implemented to protect road workers (ARROWS,1998):

1. Avoid exposure of workers to traffic.
2. Make workers visible to road users, both by ensuring adequate visibility for drivers and by providing suitable clothing for road workers.
3. Provide physical protection of workers from traffic. Even in short-term work zones, buffer zones should be foreseen as a minimum.
4. Protect workers from collisions involving works vehicles. The movements of works vehicles should be adequately perceived by workers.

5. Avoid excessive work hours. European and national legal requirements regarding work hours must be observed. Fatigue can contribute to increased risk for road workers.

5.2.6 Traffic Management

Traffic Management is central to the planning phase and plays a vital role in providing safe and efficient road user flow and worker safety within and adjacent to work zones.

5.2.7 Road Works Safety Auditing

Road safety audits during road works are required to ensure that both road users, including non-motorised users, and construction workers are afforded a safe environment. A desktop audit of all construction phases of traffic management plans (TMP) is undertaken followed by a site visit during the implementation of the TMP. Additional site visits may be required dependant on the duration of the works and complexity of the traffic management being implemented. **Fout! Verwijzingsbron niet gevonden.** shows the inspection frequency at road works in Ireland as per TII Publication CC-STY-04002, Temporary Safety Measures Inspection.

Table 35 – Inspection Frequency at Road Works (Transport Infrastructure Ireland, 2017g)

<table>
<tr><th>Duration of Road Works</th><th>Type of Road Works</th><th>Frequency of Inspection</th></tr>
<tr><td rowspan="8">In excess of 12 hours (Static road works requiring full time temporary safety measures)</td><td>Major Road Works</td><td rowspan="8">Greater than 1 year / 1 every 3 months

6 months to 1 year / Two required

1 month to 6 months / One required

Greater than 12 hours but less than 1 month / One required</td></tr>
<tr><td>Minor Improvement Schemes e.g. realignment, widening, junction improvements</td></tr>
<tr><td>Road Safety Improvement schemes</td></tr>
<tr><td>Utility Installation e.g. laying water mains</td></tr>
<tr><td>Upgrade works e.g. filter drain renewal works</td></tr>
<tr><td>Resurfacing works</td></tr>
<tr><td>Pavement Overlay/Inlay Schemes and Resurfacing works</td></tr>
<tr><td>Bridge rehabilitation works such as parapet replacement and deck renewal</td></tr>
<tr><td rowspan="14">Up to 12 hours (short duration maintenance works requiring part time temporary safety measures)</td><td>Grass/Hedge Cutting</td><td rowspan="14">Exceeding 6 months in duration /
Six Inspections per annum

3 months to 6 months in duration / Four Inspections

Less than 3 months in duration / Single Inspection</td></tr>
<tr><td>Litter picking</td></tr>
<tr><td>Sign Cleaning</td></tr>
<tr><td>Traffic Calming Maintenance Works</td></tr>
<tr><td>Vegetation removal/weed control</td></tr>
<tr><td>Delineation schemes i.e. Line Marking/Painting and line removal</td></tr>
<tr><td>Stud inserts/removal/cats eye replacement</td></tr>
<tr><td>Seasonal Maintenance Works e.g. Winter Maintenance (de- icing/gritting roads)</td></tr>
<tr><td>Road sweeping</td></tr>
<tr><td>Gully cleaning</td></tr>
<tr><td>Minor Sign Installation Works</td></tr>
<tr><td>ITS Maintenance</td></tr>
<tr><td>Non-emergency Maintenance and Repair Operations including e.g. maintenance of utilities and street furniture</td></tr>
<tr><td>Emergency Maintenance and Repair Operations e.g. due to storm damage such as:
- Drain/ditch clearing works to relieve flooding
- Statutory undertaker repairs i.e. repairing power lines, utility faults</td></tr>
</table>

5.2.8 Installation and Removal

Training for personnel must include the installation and removal of a work zone. Workers need to be informed about the organisation and operation of the site, including all safety aspects, as well as about the emergency plan in the event of an incident occurring. The physical design of work zones aims to provide smooth transitions between the normal roadway and the work area, as well as the provision of adequate space (buffer area) for separating the travelled way from the road works. This also needs to be considered when removing the work zone.

5.3 Road Side Maintenance

Maintenance of roads is undertaken to ensure the safety of road users and to sustain the serviceability and appearance of the road. Road maintenance involves remedying defects that occur from time to time (corrective maintenance) and providing treatments which will slow the rate of deterioration (preventative maintenance).

An overview of current practices in each funding country was gathered by analysing design standards, previous CEDR research projects (RISER, ASAP, BROWsER (See Chapter 2.1)), the PIARC Asset Management Manual and sourcing information from road authority representatives. A summary is provided at the end of the chapter to highlight the specific maintenance practices associated with the countries in question.

The current maintenance and operations practice within each country was assessed by identifying the answers to the following set of questions:

- How often should inspections occur?
- How often should repair works occur (plus response times)?
- What are the criteria of component replacement?
- Who reports the need for maintenance?
- What are the maintenance procedures after a road incident?
- Where is the information recorded and stored?
- Are there training systems for those responsible for maintenance?
- Is there guidance and/or standards for traffic management operations at the road side?
- Are there road side safety measures that are implemented at roadworks?

These questions allowed for further understanding of the current practices being utilised within each funding country and allowed a summary to be derived from the collated data. Tables 36 to 41 highlight the summarising answers to the above questions and are broken down by country. Information specifically related to road side maintenance is shaded grey.

Table 36 - Belgium (Flanders): Current Practice regarding road maintenance, practices and road worker safety

Item	**Information**	**Source**
Inspection Frequency	Road Inspectors are on the road on a daily basis.	Wegenenverkeer, 2018
Repair Frequency	If the safety of the road user is jeopardised, immediate action is taken. If the safety is not immediately jeopardised but follow ups are required, various repairs are bundled into one assignment for a contractor. During the winter, it is almost always temporary repairs, since thorough repairs are only possible at positive temperatures and dry weather. After each winter, the damage is inventoried and the damaged roads and cycle paths are thoroughly repaired as quickly as possible.	Wegenenverkeer, 2018
Component Replacement Criteria		
Who Reports Maintenance Needs?	Belgium has a dedicated reporting website allowing road users to report any problems to the Flemish road authority.	Wegenenverkeer, 2018
Post Incident Procedure		
Where is Information Recorded and Stored	Information is stored and recorded on a dedicated website, where users can also report issues. www.melpuntwegen.be Road safety data is electronically collected and centralised by the police force. After validation procedures, data is transferred to the National Statistics Office (NSO). The NSO carries out some corrections and adds the fatalities occurring within 30 days to the database.	Wegenenverkeer, 2018 ITF Road Safety Annual Report, 2017

Table 36 - Belgium (Flanders): Current Practice regarding road maintenance, practices and road worker safety (continued)

Item	Information	Source
Training Systems in Place for those Responsible for Maintenance	The Flemish Region of Belgium attended the First Pilot4Safety Road Safety Inspection Training that was held in 2011. This allowed for the identification and categorising of maintenance issues while carrying out RSI's. The following parties are involved in designing and implementing training and education: The teacher is responsible for RSE The police: local municipal or urban police (with their own education centre) or the federal police with the "department education and prevention", among which the mobile traffic parks for fundamental education for each province and teachers for the secondary grade Representatives of associations (cyclers association, etc.) Flemish Traffic Foundation (Flaams Stichting Verkeerskunde)	
Guidance and standards for traffic management operations * Information specifically related to road side maintenance is shaded grey.	1. Standard tender specifications: "Standaardbestek 250" (Chapter X. 3 on road works signing) is used as a reference document when preparing the road work contract documents; 2. Schemes for signing of the more typical road works layouts (appendix to the Standaardbestek 250) are used as a guide to build the signing plans; 3. Regional Service orders ("dienstorders") complementing the standard tender specifications.	Lawton, B. et al 2014

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Conference of European Directors of Roads

Table 36 - Belgium (Flanders): Current Practice regarding road maintenance, practices and road worker safety (continued)

Item	Information	Source
Safety measures implemented on roadworks	• Advance Signage • Safety Zones	Agentschap Wegen en Verkeer, 2000.

Table 37 - Ireland: Current Practice regarding road side maintenance, practices and road worker safety

Item	Information	Source
Inspection Frequency	Safety Inspections, safety patrols and daily inspections of the network by a combination of TII procured contractors, PPP Operators and local authorities.	Transport Infrastructure Ireland, 2018
Repair Frequency	Routine and Cyclic maintenance of defined assets, including repairs of Category 1 & 2 Defects.	Transport Infrastructure Ireland, 2018
Component Replacement Criteria	Pavement Management System under Development (dTIMS) Guidance on RRS Maintenance under Development	Transport Infrastructure Ireland, 2018
Who Reports Maintenance Needs?	TII procured contractors, PPP Operators and local authority staff. Members of the public can report maintenance issues through a dedicated hotline and (or) email address.	Transport Infrastructure Ireland, 2018
Post Incident Procedure	Emergency services have primary responsibility at incidents Incident Response Plan MTCC central to communications and coordination Undertake joint exercises Provide Initial Response, Support Response and Standard Diversions	Transport Infrastructure Ireland, 2018

Table 37 - Ireland: Current Practice regarding road side maintenance, practices and road worker safety (continued)

Item	Information	Source
Where is Information Recorded and Stored	The data on road condition is combined with information derived during site visits by road inspectors in order to identify the priorities for maintenance funding. The information is circulated to road authorities to allow maintenance programmes to be planned in advance.	Transport Infrastructure Ireland, 2018
Training Systems in Place for those Responsible for Maintenance	RRS Design Course. Commenced in 2016. Aiming for the course to be Mandatory Requirement.	Transport Infrastructure Ireland, 2018
Guidance and standards for traffic management operations * Information specifically related to road side maintenance is shaded grey.	1. Traffic Signs Manual, Chapter 8, Temporary Traffic Measures and Signs for Roadworks 2. Guidance for the control and management of Traffic at Road Works	Department of Transport, 2010
Safety measures implemented on roadworks	• Advance Signage • Safety Zones • Impact Protection Vehicles • Barriers • Speed Control	Department of Transport, 2010

Table 38 - Netherlands: Current Practice regarding road side maintenance, practices and road worker safety (Gunnar Lannér et al, 2006)

Item	Information	Source
Inspection Frequency	Inspections of the road are done every day. If damage or irregularities are found extra inspections will be carried out. Action will be taken according to the expert judgement. Every 2-3 months a large technical inspection is completed.	Rijkwaterstaat, Responsible Unit for Amsterdam, 2006
Repair Frequency	Depending on expert judgement. Normally maintenance is undertaken together with maintenance of road to avoid delay times of traffic.	Rijkwaterstaat, Responsible Unit for Amsterdam, 2006
Component Replacement Criteria	For barriers, there are standards on how much corrosion can occur before renovating or changing a guardrail Utilisation of a damage prediction model as a preventative measure	Hanboek bermbeveillgingsvoorzieningen, 1989
Who Reports Maintenance Needs?	It is the responsibility of the “Road Owner” in the specific area. The inspections done by the fieldworkers will report their findings or take immediate action themselves. If big maintenance or replacement of the barrier is required it should be combined with maintenance at the road.	

Table 38 - Netherlands: Current Practice regarding road side maintenance, practices and road worker safety (Gunnar Lannér et al, 2006) (continued)

Item	**Information**	**Source**
Post Incident Procedure	Police Contact the Road Owner. The inspectors go on the spot and decide the importance. If immediate repair is necessary then the road builder has to be available in 1 hour. If there is no immediate danger a plan is made to repair the damage.	Rijkwaterstaat, Responsible Unit for Amsterdam, 2006
Where is Information Recorded and Stored	The Road Owner makes their own Registration	Rijkwaterstaat, Responsible Unit for Amsterdam, 2006
Training Systems in Place for those Responsible for Maintenance	2 Day Training for inspection specific items and quality system training are available. Inspections are only done by persons who have taken the course.	Rijkwaterstaat, Responsible Unit for Amsterdam, Construction Department, 2006
Guidance and standards for traffic management operations * Information specifically related to road side maintenance is shaded grey.	1. Crow, Beleid en proces veilig werken aan wegen (Policy and process work safely on roads)	
Safety measures implemented on roadworks	• Advance Signage • Safety Zones • Impact Protection Vehicles • Barriers • Speed Control	Crow, Beleid en proces veilig werken aan wegen (Policy and process work safely on roads), 2014

Table 39 - Slovenia: Current Practice regarding road side maintenance, practices and road worker safety

Item	Information	Source
Inspection Frequency	No specific guidelines for road site maintenance and operations	Bene, P., 2018
Repair Frequency	No specific guidelines for road site maintenance and operations	Bene, P., 2018
Component Replacement Criteria	No specific guidelines for road site maintenance and operations	Bene, P., 2018
Who Reports Maintenance Needs?	No specific guidelines for road site maintenance and operations	Bene, P., 2018
Post Incident Procedure	No specific guidelines for road site maintenance and operations	Bene, P., 2018
Where is Information Recorded and Stored	No specific guidelines for road site maintenance and operations	Bene, P., 2018
Training Systems in Place for those Responsible for Maintenance	No specific guidelines for road site maintenance and operations	Bene, P., 2018
Guidance and standards for traffic management operations * Information specifically related to road side maintenance is shaded grey.	1. Rules on road closures (Pravilnik o zaporah na cestah) 2. 5732. Law on Roads (ZCes-1), page 16849. (Z A K O N O CESTAH (ZCes-1)) 3. Regulation on ensuring safety and health at work on temporary and mobile construction sites (Uredba o zagotavljanju varnosti in zdravja pri delu na začasnih in premičnih gradbiščih)	
Safety measures implemented on roadworks	• Safety Zones • Speed Control • Barriers • Use of approved equipment • Impact Protection Vehicles • Advance warning Signs	Rules on road closures (Pravilnik o zaporah na cestah), 2016

Table 40 - Sweden: Current Practice regarding road side maintenance, practices and road worker safety (Gunnar Lannér et al, 2006)

Item	**Information**	**Source**
Inspection Frequency	Safety Inspection Intervals for Different Road Categories: Category 1 3 x Weekly Category 2 2 x Weekly Category 3 7 Days Category 4 14 Days Category 5 14 Days Wire Barriers 3 Years	Swedish National Administration's (SNRA) Description for Maintenance Management, 2006 Funktions- och standardbeskrivning, 2006
Repair Frequency	For a Hazardous Situation: 1 Hour - Midweek 3 Hours - Weekends Non-Hazardous Damage: Category 1-3 10 Days Category 4-5 20 Days	Swedish National Administration's (SNRA) Description for Maintenance Management, 2006 Funktions- och standardbeskrivning, 2006
Component Replacement Criteria	Beams, Posts, Anchors and Fasteners should not have Visible Cracks or Stress Raisers	Swedish National Administration's (SNRA) Description for Maintenance Management, 2006 Funktions- och standardbeskrivning, 2006
Who Reports Maintenance Needs?	Road Inspectors, Police, Fire Brigade, General Public	RISeR document Deliverable 7: Current Maintenance Practices, 2006

Table 40 - Sweden: Current Practice regarding road side maintenance, practices and road worker safety (Gunnar Lannér et al, 2006) (continued)

Item	**Information**	**Source**
Post Incident Procedure	Emergency call centre (LAC) alerts police and rescue personal, they report if there is any damage done. If so, LAC contact SNRA or the maintenance contractor and they send out a road inspector (RI). The RI determines the damage and possible repairs. If this affects the traffic, it is reported to the traffic information central (TIC). If the incident was severe SNRA have their own commission of inquiry.	Personal Interview conducted for the purpose of RISeR Document Deliverable 7: Current Maintenance Practices, 2006
Where is Information Recorded and Stored?	No database or other detailed registration system is in place. The maintenance measures are documented in invoices from the contractor to the SNRA.	Personal Interview conducted for the purpose of RISeR Document Deliverable 7: Current Maintenance Practices, 2006
Training Systems in Place for those Responsible for Maintenance	The road sectors education centre (VUC) run courses for clerks of work, inspectors, technicians, engineers and road workers.	Swedish National Road Administration (SNRA), 2006
Guidance and standards for traffic management operations * Information specifically related to road side maintenance is shaded grey.	1. TRVK Apv, Swedish national technical requirements for working on the road (TRVR Apv, Trafikverkets tekniska råd för Arbete på väg)	
Safety measures implemented on roadworks	• Speed Control • Traffic calming measures • Barriers • Safety Zone • Advance warning signs	TRVK Apv, Swedish national technical requirements for working on the road (TRVR Apv, Trafikverkets tekniska råd för Arbete på väg), 2006

Table 41 - United Kingdom: Current Practice regarding road side maintenance, practices and road worker safety (Gunnar Lannér et al, 2006)

Item	Findings	Source
Inspection Frequency	Trunk Roads Category I – Weekly & Safety Patrols Category II – Weekly Category III – Monthly Non-Trunk Roads Primary Route – Monthly Categories 2, 3a & 3b – Monthly Categories 4a, 4b & Unclassified – 3-monthly Detailed Inspections: Timber & Steel Components – More than 10 years old - 2 yearly, Less than 10 years old - 5 yearly Concrete Components – More than 15 years old – 2 yearly, Less than 15 years old 5 yearly Highways Structures General Inspection - Every 2 Years Principle Inspection - Every 6 Years	BS 7669-3, 1994 Code of Practice for Maintenance Management, 2005 Trunk Road Maintenance Manual (Volume 2), 2006 BD 63/94, 1994
Repair Frequency	Category 1 - 24 Hours Category 2 - As per Maintenance Programme, Also: R1 - Within 24 Hours R2 - Within 5 Days R3 - Within 4 Weeks R4 - Next Avail. Programme Safety Barrier Repairs within 7 Days	Code of Practice for Maintenance Management, 2005 Incident Management Study, 2002
Component Replacement Criteria	Scope - Beams, Posts, Anchors and Fasteners. Procedures for Replacement of Tensioned and Untensioned Fence Beams and Tensioned Fence Posts.	BS 7669-3, 1994

Item	Findings	Source
Who Reports Maintenance Needs?	The Maintaining Agent (MA), who informs the Term Maintenance Contractor (TMC) of the Repair Needs.	Highways Agency; Incident Management Study as per RISeR D7, 2006

Table 41 - United Kingdom: Current Practice regarding road side maintenance, practices and road worker safety (Gunnar Lannér et al, 2006)

Item	Findings	Source
Post Incident Procedure	Police Contact MA. The MA contacts TMC who then Attend Accident Scene and either Temp or Perm Repair Damage. Permanent Repairs must be completed in Seven Days.	Highways Agency; Incident Management Study as per RISeR D7, 2006
Where is Information Recorded and Stored?	Fences: At Head Office within 24 Hours, Retained for 6 Years Highway Structures: At MA and Regional Office	BS 7669-3, 1994 BD 62/94, 2006
Training Systems in Place for those Responsible for Maintenance	LANTRA deliver courses on: General Fencing Environmental Barriers (structural) Manufacture of Parapets Permanent Vehicle Restraint Systems incorporating NHSS2B & NHSS5B Static Temporary Traffic Management on Motorways and other Dual Carriageways Mobile Lane Closure Traffic Management on Motorways and other Dual Carriageways Temporary Traffic Management on Rural and Urban Roads	LANTRA, 2018
Guidance and standards for traffic management operations	1. Traffic Signs Manual, Chapter 8, Traffic Safety Measures and Signs for Road Works and Temporary Situations, Part 1 Design	

Item	Findings	Source
* Information specifically related to road side maintenance is shaded grey.	2. Traffic Signs Manual, Chapter 8, Traffic Safety Measures and Signs for Road Works and Temporary Situation, Part 2 Operations	
Safety measures implemented on roadworks	• Advance Signage • Safety Zones • Impact Protection Vehicles • Barriers • Speed Control	Traffic Signs Manual, Chapter 8, Traffic Safety Measures and Signs for Road Works and Temporary Situations, Part 1 Design, 2006

5.4 Results

An overview summary of the operational practices identified in the above sections is provided below.

5.4.1 Frequency of Inspections

The frequency of inspections generally depends on the age and type of road. In order to make a comparison between funding countries, the highest level/category of road has been selected with the result that inspection frequencies range from daily to weekly in all countries except Slovenia where a defined inspection regime does not currently exist.

5.4.2 Frequency of Repair

The frequency of repair is dependent on factors including level of repairs required, the impact of not carrying out repairs, safety issues associated with the remedial issue and potential delays due to the remedial issue. If safety is jeopardised immediate repairs are implemented to allow the road to return to a satisfactory level of safety.

Belgium (Flanders) state that repairs made in winter are almost always temporary repairs due to the harsh winter weather.

5.4.3 Criteria for Component Replacement

Countries including Ireland, UK and Sweden base component replacement criteria on visual inspections and evidence of corrosion, cracks etc. Other countries, including Netherlands have additional replacement criteria based on recycling and (or) environmental conditions.

5.4.4 Individual Responsible for Reporting Maintenance Issues

Belgium, Ireland, Netherlands & Sweden utilise road inspectors to provide information to the relevant maintenance teams, local authorities or roads authorities of any required repairs. Sweden also identify the local emergency services as an informer of required maintenance as a result of a road traffic incident. In Ireland, Sweden and Belgium, a mechanism is also in place which enables the public to report maintenance issues on the public roads. In the United Kingdom, the responsibility of reporting maintenance issues is that of the maintaining agent who then inform the maintenance contractor of the need of repair. The public can submit maintenance issues through websites and (or) a telephone hotline.

5.4.5 Procedure After a Road Traffic Incident

In the case of all funding countries the police will inform the road owners of the incident. The road owners will then send out the relevant parties to inspect the damage resulting from the incident. Repair time, for all countries, depends on the severity of the damage along with the effect the incident has on the traffic delay/ safety level of the road.

5.4.6 Maintenance Data Storage

In the UK and Ireland, a formal data archiving system is in place for the storage of data. Sweden has a local level storage system that doubles as an invoicing system for repair pricing. Belgium utilises a dedicated website for reporting maintenance needs while also storing the data at the same time. Slovenia does not currently have a system in place for data collection nor storage.

5.4.7 Training of Maintenance Personnel

Different levels of training are provided to maintenance staff in each of the funding countries. Road Inspectors also receive training through workshops and courses. The UK and Sweden have courses for supervisors, clerks of work, inspectors and engineers. In Ireland, maintenance personnel undertaking works on the national road network must have completed and successfully passed training relating to signing, lighting and guarding. The Netherlands has a 2-day quality system training for their inspectors which is compulsory to be a road inspector. In Belgium, training is provided and penned by different parties including the police, the RSE and representatives from different associations such as cyclists, pedestrians and the Flemish Traffic Foundation (Vlaams Stichting Verkeerskunde).

5.4.8 Guidance on temporary traffic management operations

From a review of documents and standards of each funding country, it appears that all countries have a standard or guidance document specifically related to temporary traffic management operations. In some countries cases (Belgium (Flanders), Ireland, Netherlands and UK) it was found that countries have both a design and implementation standard.

For Ireland, Netherlands, Slovenia, Sweden and UK they apply safety measures to protect road users and road workers such as speed control, traffic calming measures, barriers, safety zone and warning signs. Belgium (Flanders) apply advance signage and safety zones to protect road users.

5.5 Conclusions

Legislation relating to temporary safety measures applying to roadworks, health and safety for temporary construction sites, employer responsibility relating to employee safety and personal protective equipment have been implemented across the EU between 1989 and 2008 and have been adopted by all countries.

Road side operations and maintenance procedures across the six funding countries appear to be of a similar format with country specific differences in terms of the frequency of inspections. Requirements relating to the provision of work zones, planning, road safety, safety appraisals, employee safety and traffic management are broadly similar. Road safety auditing of temporary works areas also appear to be consistent with the requirements of the Irish Roads Authority included as an example.

It can be concluded that the UK has the most comprehensive maintenance standards and guidelines when compared to the other five funding countries. Detailed condition surveys of existing roadside infrastructure are required at varying intervals. Ireland is in the process of completing a pavement management system and RRS maintenance guidance. Sweden has standards and guidelines for inspection work and repair works. The Netherlands was identified as having standards and guidelines for inspections only.

Slovenia utilise standards and guidelines for traffic management operations. The other five funding countries also utilise standards and guidelines for the traffic management operations at a relatively high level of detail.

Belgium (Flanders), Ireland, Sweden and the UK have processes in place which require immediate attention for a defect identified as requiring prompt attention, because they represent an immediate or imminent hazard, or because there is a risk of short-term deterioration. In the Netherlands, the action required following the identification of such a defect is determined by the attending inspection professional who use their expert judgement. Slovenia has no standards or guidelines relating to road side maintenance. The determination of defects which require immediate attention can be deemed a preventive approach if the issue has been identified prior to an incident occurring. However, the determination of defects which require immediate attention can also be deemed reactive as a result of an incident that has occurred. All other defects which are of a non-urgent nature and may be included in planned programmes of work, according to overall maintenance priorities.

6 Problem definition and scale of problem

Almost 28,000 persons were killed in ROR crashes in the six funding countries plus Germany and Portugal within the decade 2006-2015. This number represents almost one third of all road accident fatalities in those countries (30%).

Figure 27 shows the developments in the number of fatalities in the eight countries under analysis from 2006 to 2015. The number of people killed in ROR crashes diminished 6.8% annually in that period, which is slightly more than the yearly average reduction in the total number of fatalities (6.5%).

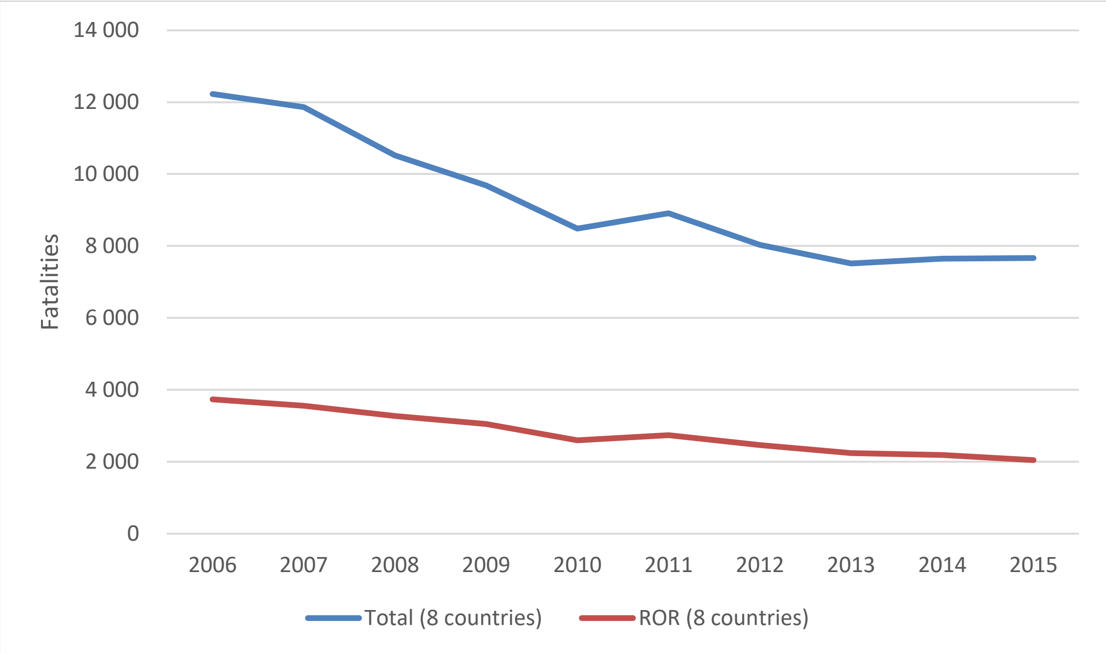


Figure 27 – Total number of fatalities and ROR fatalities in the six funding countries plus Germany and Portugal 2006-2015 (CARE database)

Table 42 provides an overview of the developments in single vehicle accident fatalities during the decade 2006-2015 in the six funding countries plus Germany and Portugal. Within the decade, the most significant reduction in single vehicle fatalities occurred in the United Kingdom (55%) and Slovenia (48%), whilst in the Netherlands an increase was recorded (16%).

Table 42 – Number of ROR crash fatalities by country, 2006-2015 (CARE database)

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Annual variation
Belgium	470	464	420	421	355	351	320	309	269	270	-6.1%
Germany	1 638	1 566	1 390	1 372	1 119	1 267	1 102	987	995	958	-6.3%
Ireland	-	-	-	-	-	-	-	-	-	-	-
Netherlands	158	154	244	226	176	167	180	148	151	184	+1.4%
Portugal	383	381	365	229	368	334	301	233	245	209	-5.6%
Slovenia	56	65	43	36	31	30	39	30	21	29	-9.2%
Sweden	157	169	153	149	101	107	97	98	85	-	-7.0%
United Kingdom	874	754	655	619	444	483	422	433	423	395	-9.9%
Total	**3 736**	**3 553**	**3 270**	**3 052**	**2 594**	**2 739**	**2 461**	**2 238**	**2 189**	**2 045**	**-6.8%**

Table 43 provides the percentage of fatalities that occurred in ROR crashes in the six funding countries plus Germany and Portugal for the decade 2006-2015. In 2015, this was 27% of all road fatalities in the mentioned countries.

Table 43 – ROR crash fatalities as a percentage of all road fatalities by country, 2006-2015 (CARE database)

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Belgium	44%	43%	44%	45%	42%	41%	42%	43%	37%	37%
Germany	32%	32%	31%	33%	31%	32%	31%	30%	29%	28%
Ireland	-	-	-	-	-	-	-	-	-	-
Netherlands	22%	22%	36%	35%	33%	31%	32%	31%	32%	35%
Portugal	40%	39%	41%	27%	39%	37%	42%	37%	38%	35%
Slovenia	21%	22%	20%	21%	22%	21%	30%	24%	19%	24%
Sweden	35%	36%	39%	42%	38%	34%	34%	38%	31%	-
United Kingdom	27%	25%	25%	26%	23%	25%	23%	24%	23%	22%
Total	**31%**	**30%**	**31%**	**32%**	**31%**	**31%**	**31%**	**30%**	**29%**	**27%**

In 2015, ROR crash fatalities averaged almost one third of the total number of road fatalities; a wide country variation was registered, the lowest value being 22% (UK) and the highest 37% (Belgium).

6.1 Crash prediction models

Crash prediction models (CPMs) are developed by statistically assessing how a range of candidate measured explanatory variables explains the observed variation in the number of crashes, generally using advanced regression techniques (Elvik, 2010). CPMs express the predicted crash frequency of a road element as a function of explanatory variables, which may be continuous or discrete (factors). These variables describe exposure to crash risk and other characteristics related to cross section, road design and other road and traffic attributes (Ambros et al., 2018).

CPMs play a major role in highway safety analysis. These models can be used for various purposes, such as predicting the number of road crashes or establishing relationships between these crashes and different covariates. In the PROGReSS project, CPMs may analyse and highlight potential road side safety issues, and help to identify possible safety improvements.

In this WP, the Dutch provincial road network was selected as the study area. The study area consisted of, approximately, 7200 km of roads divided into 100 m segments, from all provincial roads in the Netherlands.

To investigate the effects of road geometric, environmental, and traffic characteristics on ROR crash frequency, required data were collected from two sources: International Road Assessment Programme (iRAP) Road Protection Score (RPS) data, and crash data. The first database includes a list of road geometric and environmental characteristics such as curvature, land use, shoulder width, number of lanes, distance to the nearest object to the edge line, etc. The second database consists of crash data on the considered segments between 2007 and 2016.

Merging these two databases provided the study with a data set containing 10 years of crashes along with site-specific road and traffic characteristics for the considered road segments.

However, it was not possible to calibrate ROR CPMs using these Dutch data, because traffic volume (AADT) was not a significant covariate and a single AADT value was provided for the whole 10-year analysis period. It is worthwhile to note that when the set of candidate explanatory variables for CPMs include traffic volumes, this variable is usually identified as the most important explaining factor for the observed systematic variation in the number of crashes. Variation in traffic volume typically explains 60% to 80% of the systematic variation in the number of crashes (Elvik, 2010).

Bias due to aggregation, averaging or incompleteness of traffic volume data is a potential confounding factor that is likely to be present in many CPMs. In particular, AADT as a measure of traffic volume may be biased both because it is an average, it is an aggregate (combining the various vehicle categories that make up traffic) and it is very often incomplete (Elvik, 2010). In addition, location uncertainties do exist, as traffic volumes typically measured at one location are assumed to apply to an entire section, and often to multiple sections (Ambros et al., 2018).

Crash data are known for various biases, such as underreporting, location errors, severity misclassification or inaccurate identification of contributory factors (Ambros et al., 2018).

Additionally, the Dutch data set is affected by changes in the crash data registration policy adopted by the police in the Netherlands in 2009. Starting in this year, the police did not register road crashes, except when they involved a severe transgression. This reduced the number of registered crashes substantially.

As a result of these issues, it was not possible to calibrate ROR CPMs using the data available. New model fitting will be attempted, if more data is made available within the PROGReSS timeframe.

6.2 Topic analysis of Irish RSI using latent Dirichlet allocation

As already mentioned in Section 4, RSI is a road safety management procedure that was introduced in Ireland by TII to comply with the European Directive 2008/96/EC on Road Infrastructure Safety Management.

The RSI process is described in TII Design Manual for Roads and Bridges under TII AM-STY-06044 Road Safety Inspection (Transport Infrastructure Ireland, 2014).

An individual RSI report is prepared by each RSI team for each inspected route. The report includes a brief description of each safety issue. The RSI team carries out an informal risk assessment of each identified hazard, which is provided in the report. The final report is submitted to TII (Transport Infrastructure Ireland, 2017).

In Ireland, RSI are being carried out on all national roads. For this study, 54 RSI were analysed, gathered over a period of six years (2012 - 2017).

The large number of issues described in the RSI, and the detailed description of each issue, yields a large-scale dataset, which supports identifying patterns of co-occurring conditions and interventions' patterns.

Safety in RoR crashes can be improved by identifying crash conditions that tend to co-occur in the context of RoR crashes, followed by evidence-based road side safety interventions. In this chapter, the aim is to identify co-occurrence patterns of attributes related to the ROR crashes, as well as the interventions' patterns associated with these crashes, as described in the RSI reports.

A significant portion of unstructured content collected by an organization is in textual format, from e-mail communications and reports to web pages and social media content. Text Mining aims to extract information from textual data and using it for research or business purposes (Canito et al., 2018).

Specifically, a data driven approach was adopted to identify many-to-many associations among a broad group of conditions associated with RoR crashes and road side safety interventions.

In this chapter, we use the following terms defined by Blei et al (2003):

- A *word* is the basic unit of discrete data, defined to be an item from a vocabulary;
- A *document* is a sequence of *N words*;
- A *corpus* is a collection of *M documents*.

Considering the technical requirements of text analysis, this research applies *latent Dirichlet allocation* (LDA) (Blei et al., 2003), a particularly popular method for fitting a topic[3] model, to analyse the topics of RSI, divided into two groups: problems found and proposed solutions. The LDA algorithm is a three-level hierarchical Bayesian modelling process, which groups a set of items into topics defined by words or terms, where each of the terms identified characterizes a topic (Blei et al, 2003).

Underlying the "bag-of-words" assumption, LDA represents a document as a mixture of latent topics in which a topic has a multinomial distribution over words. Every document will have its own mixing proportion of topics, and each topic has its own word distribution (Wang et al. 2018).

[3] Blei et al. (2003) refer to the latent multinomial variables in the LDA model as topics, so as to exploit text-oriented intuitions, but make no epistemological claims regarding these latent variables beyond their utility in representing probability distributions on sets of words.

Based on an unsupervised Bayesian learning algorithm, LDA can capture the latent topics that represent the opinions of the inspection teams from unstructured and large written reports. Each topic can be regarded as a specific feature of the issue or road that inspection team members expressed in their reports.

LDA was applied to two datasets collected from the reports, one comprising the issues raised, and the other the proposed solutions. In both cases, the obtained informative, distinct and tight topics aligned well with known co-occurrences among conditions cited in the literature.

The method's ability to generate meaningful topics from both datasets, where one comprises more common conditions (issues raised) and the other safety interventions (proposed solutions), demonstrates its effectiveness in reliably exposing co-occurring attributes.

Notably, the results uncover a few indirect associations among conditions that have hitherto gone unreported, suggesting that topic modelling over RSI can expose yet unnoticed associations.

To perform the text mining procedure, the statistical open-source tool R was adopted. Namely, the "tm" (Feinerer et al., 2008) and "topicmodel" packages (Grün and Hornik, 2011) were chosen. The former provides text mining functions, while the latter implements the LDA algorithm.

6.2.1 Data

The main element of a RSI is the identification of the road safety issues and associated risks (Transport Infrastructure Ireland, 2014). Each RSI includes attributes such as identification number, whether the issues occurs on the mainline or side road, detailed description of the safety issues, primary collision type, a broad solution to eliminate or mitigate each safety issue, and a detailed description of an initial solution to eliminate or mitigate the safety issues. Each RSI includes an appendix (Appendix A) with a summary spreadsheet of all issues (Transport Infrastructure Ireland, 2017).

As mentioned earlier, 54 RSI were analysed, gathered over a period of six years (2012 - 2017). Table 44 shows a summary description of the routes where RSI were carried out

Table 44 – Summary description of Irish routes

Route No.	Route Length (km)						National Primary	National Secondary
	Total	Urban	Rural	Motorway	Single Carriageway	Dual Carriageway		
N2	133	15	118	14	101	18	•	
N3	70	7	63	0	59	11	•	
N4	114	110	4	0	114	0	•	
N5	131	7	124	0	131	0	•	
N10	17	0	17	0	17	0	•	
N11	41	4	37	0	41	0	•	

Route No.	Route Length (km)						National Primary	National Secondary
	Total	Urban	Rural	Motorway	Single Carriageway	Dual Carriageway		
N12	7	0	7	0	7	0	•	
N13	44	3	41	0	39	5	•	
N15	110	4	106	0	110	0	•	
N17	123	4	119	0	123	0	•	
N20	96	29	67	10	67	29	•	
N21	85	13	72	0	77	8	•	
N22	116	18	98	0	107	9	•	
N23	8	2	6	0	8	0	•	
N24	118	28	78	0	106	12	•	
N25	188	31	156	0	156	33	•	
N26	30	24	5	0	30	0	•	
N27	6	4	2	0	3	3	•	
N28	12	0	12	0	10	2	•	
N29	4	1	3	0	4	0	•	
N30	33	3	30	0	33	0	•	
N33	8	0	8	0	8	0	•	
N51	53	0	53	0	51	3		•
N52	178	12	166	0	178	0		•
N53	18	0	18	0	18	0		•
N54	36	0	36	0	36	0		•
N55	79	8	71	0	79	0		•
N56	11	10	1	0	11	0		•
N59	298	19	279	0	298	0		•
N60	92	0	92	0	92	0		•
N61	75	3	72	0	75	0		•
N62	99	80	19	0	99	1		•
N63	88	13	75	0	88	0		•
N65	53	3	50	0	53	0		•
N66	28	1	27	0	28	0		•
N67	130	6	124	0	130	0		•
N68	41	9	32	0	41	0		•
N69	98	7	91	0	98	0		•
N70	143	24	119	0	143	0		•
N71	188	28	160	0	185	3		•
N72	170	11	159	0	170	0		•
N73	34	3	31	0	34	0		•
N74	20	0	20	0	20	0		•

Route No.	Route Length (km)						National Primary	National Secondary
	Total	Urban	Rural	Motorway	Single Carriageway	Dual Carriageway		
N75	8	0	8	0	8	0		•
N76	47	0	47	0	47	0		•
N77	49	5	44	0	49	0		•
N78	51	14	37	0	51	0		•
N80	115	23	92	0	115	0		•
N81	76	27	49	0	73	3		•
N83	46	2	44	0	46	0		•
N84	74	5	69	0	74	0		•
N85	32	2	30	0	29	3		•
N86	49	3	46	0	49	0		•
N87	28	0	28	0	28	0		•
Total	**4000**	**626**	**3361**	**24**	**3846**	**141**		

The focus was solely on the spreadsheets containing a summary of the identified safety problems and the corresponding proposed mitigating interventions (Appendix A of the reports). Second, the content of the inspection teams' reports, including the description of safety issues and proposed solutions were tracked, and two record sets – document-term matrices were constructed.

To create a document-term matrix that can be processed via topic modelling several data organization and pre-processing choices were made. The document-term matrix serves as input to the LDA topic modelling to obtain the most relevant topics (Blei et al., 2003).

Text pre-processing in this study includes word text tokenization, converting words to lower-case, removing punctuation characters and numbers, and removing stop words.

Stemming (reducing inflected words to their base or root form) was not considered in pre-processing since it sometimes combines terms that would best be considered distinct, and variations of the same word will usually end up in the same topic.

Figure 28 and Figure 29 show descriptions of the twenty most frequent words appearing in each record set, in decreasing order of occurrence frequency. Each bar represents the number of occurrences of each word in the respective record set.

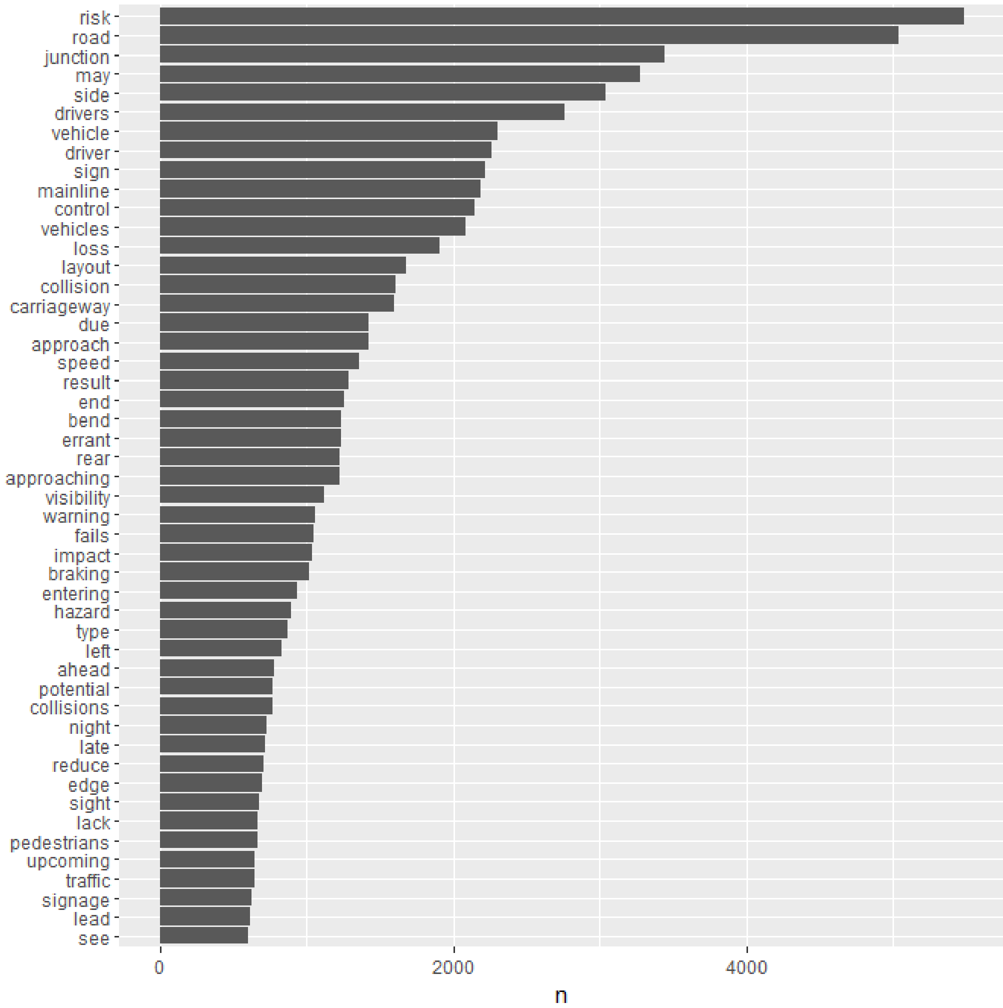


Figure 28 – Number of occurrences of the twenty most frequent words in the problems record set.

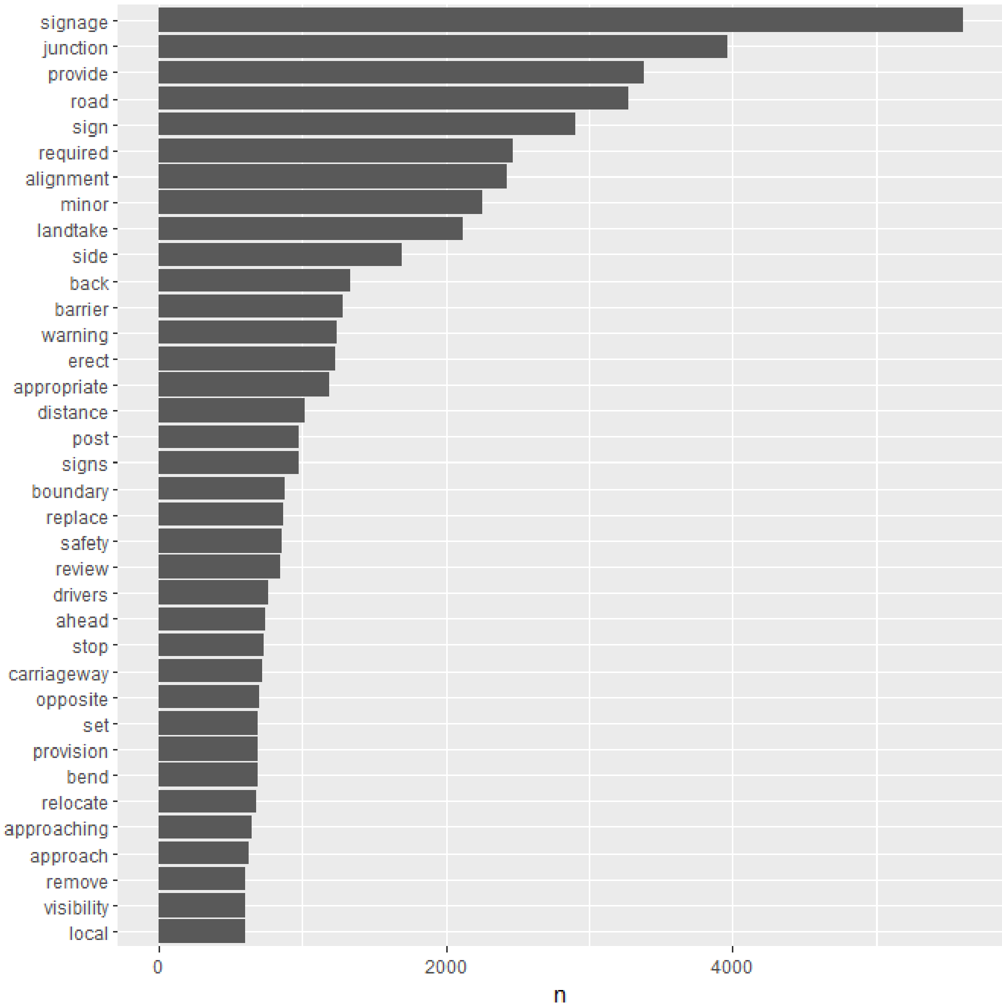


Figure 29 – Number of occurrences of the twenty most frequent words in the solutions record set.

6.2.2 Relationships between words: bigrams and correlations

The relationships between two words were analysed by counting how often word X is followed by word Y. By automatically extracting and using phrases, especially two-word phrases (hereafter bigrams) it is possible to improve the identification of the road safety issues and interventions described in the RSI reports.

Figure 30 and Figure 31 present a combination of connected nodes for both the problems and the solutions record sets, where it is possible to visualize some details of the text structure. The relationships here are directional (marked with an arrow).

In Figure 30 one can see that *words* such as “road”, “vehicle”, “sign”, and “roadside” form common centres of nodes. The *word* “roadside” is preceded by “unforgiving” and followed by “hazard”. We also see pairs and triplets that form common short phrases related to road side issues ("safety barrier", "bridge parapet" or "errant vehicle enters/striking"). Figure 30 also shows the more general character of RSI, highlighting visibility and sight distance problems associated with road, vehicle and the bigram "drivers-inappropriately".

Figure 31 shows that the solutions record sets is particularly focused around *words* such as "sign", "signs" and "signage". In terms of road side interventions, the phrases "safety barrier board" and "roadside boundary wall" stands out. Similar to the previous figure, Figure 31 also highlights the broader set of remedial actions in RSI (e.g., vulnerable road users and layout review).

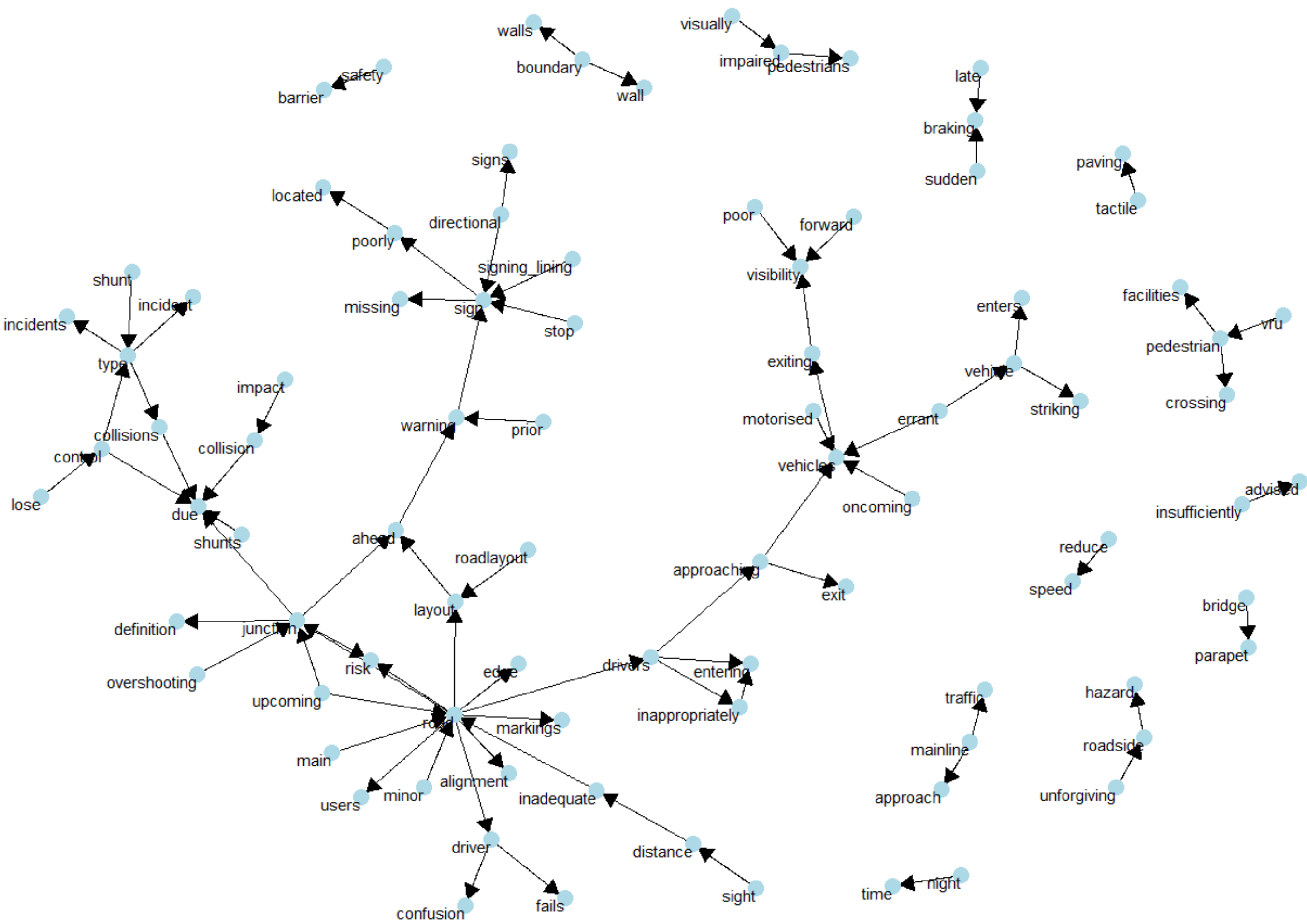


Figure 30 – Directed graph of common bigrams in the problems record set.

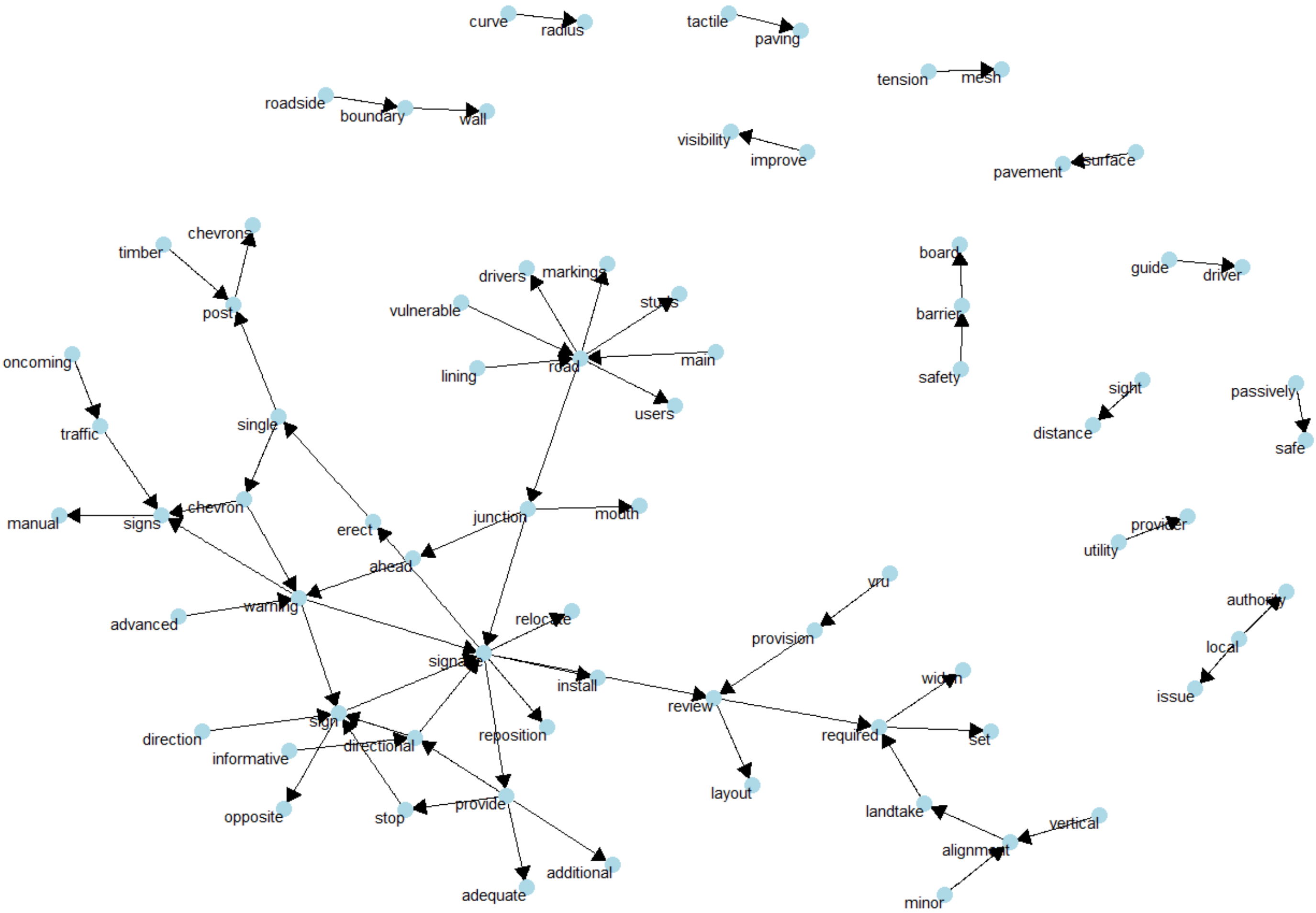


Figure 31 – Directed graph of common bigrams in the solutions record set.

In Figure 32 and Figure 33, the correlations are depicted among words for the problems and solutions record sets, respectively. Correlation indicates how often these words appear together in the same document (defined as a sequence of N words) relative to how often they appear separately. Note that unlike the bigram analysis, the relationships here are symmetrical, rather than directional. It can also be seen that while pairings of words that dominated bigram pairings are common, such as “unforgiving/roadside” or “barrier/safety”, pairings of words that appear close to each other are also present, such as “clear” and “zone”, “working” and “barrier”, “utility” and “pole”, or “forgiving” and “fence”. The *word* “kerb” also appears correlated with several words (e.g. “provision”, “dropped” and “paving”).

It is worth mentioning that aquaplaning stands out as an issue in non-motorway RSI. Some correlations show the broader scope of RSI (e.g. “sight”, “distance” and mainline”, in Figure 32; and “drainage”, “setting” and “need”, in Figure 33). “Vulnerable road users” and “surfacing” are at the core of two important correlated solutions record set depicted in Figure 33.

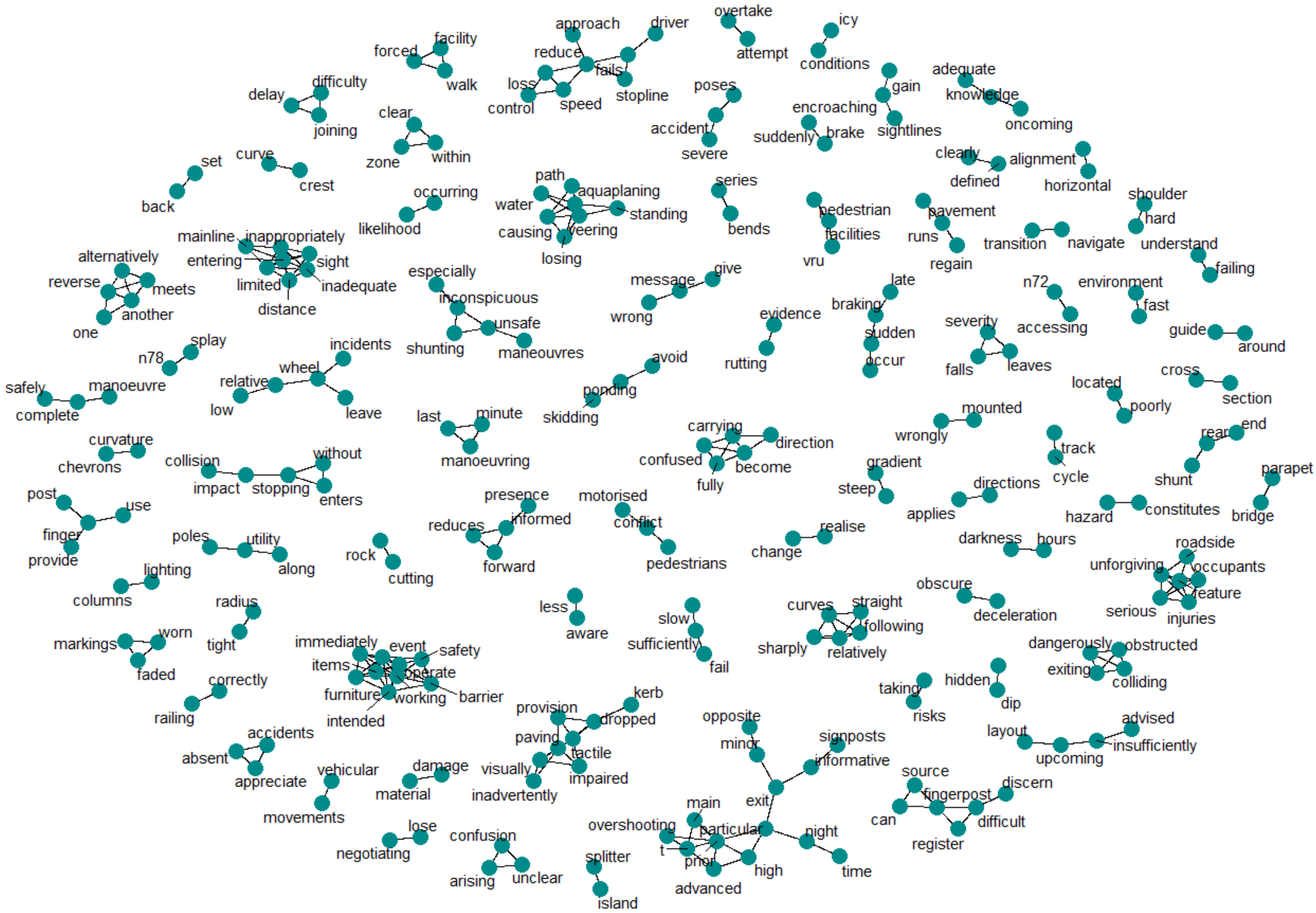


Figure 32 – Pairs of words in the problems record set that show at least a 0.50 correlation of appearing within the same *document*

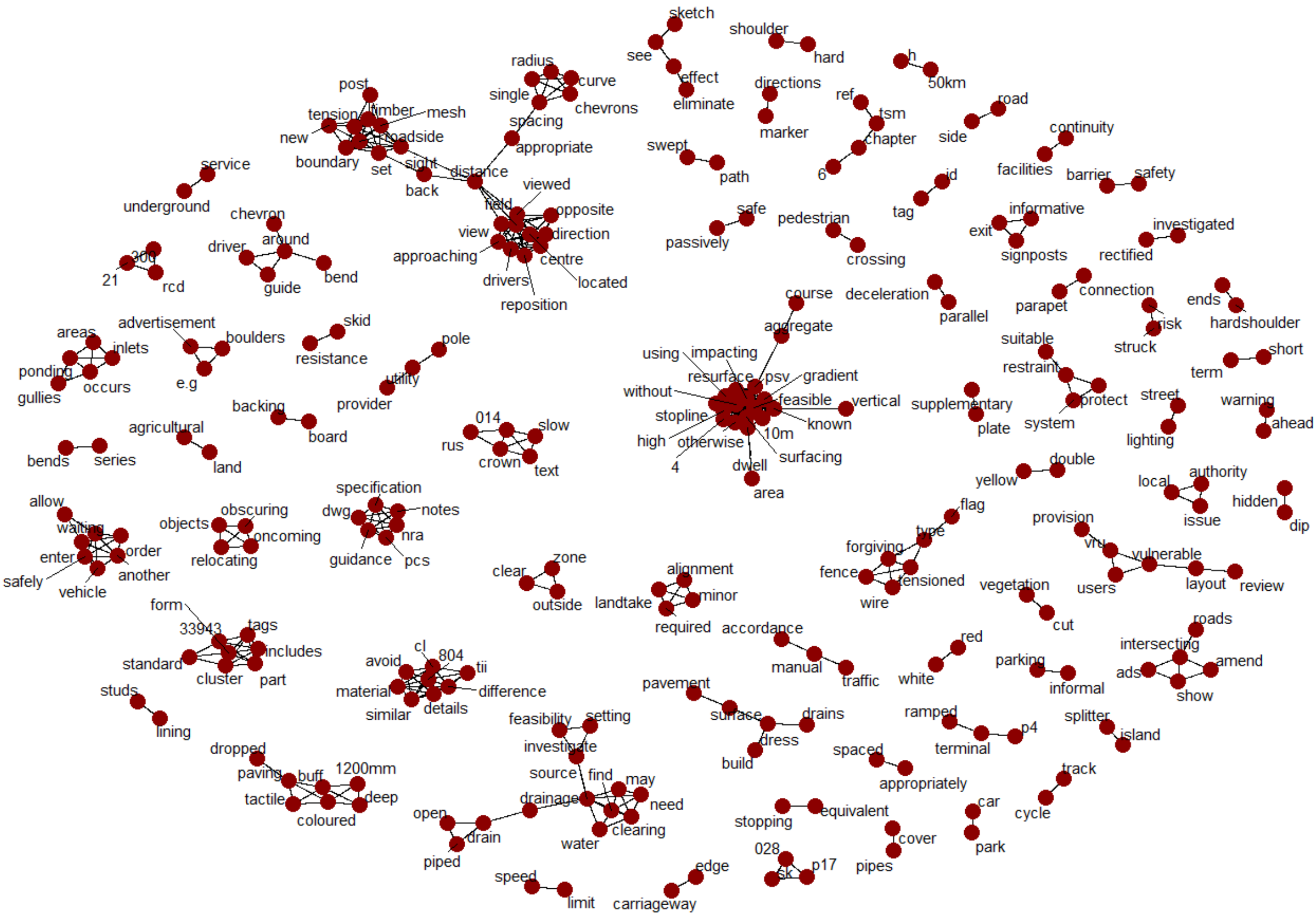


Figure 33 – Pairs of words in the solutions record set that show at least a 0.50 correlation of appearing within the same *document*

Finally, in Figure 34 and in Figure 35, the words most correlated with “barrier”, “pole”, “roadside”, and “zone” are presented for the problems and solutions record sets, respectively.

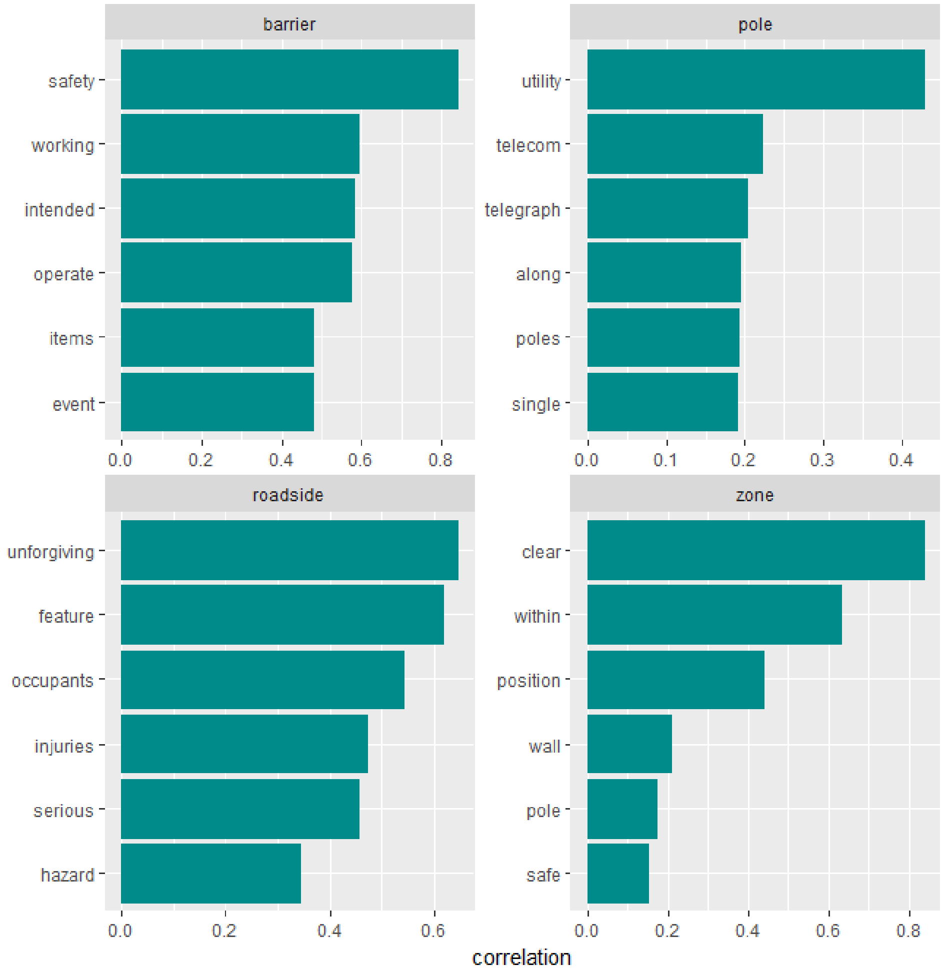


Figure 34 – Words most associated with “barrier”, “pole”, “roadside” and “zone” in the problems record set.

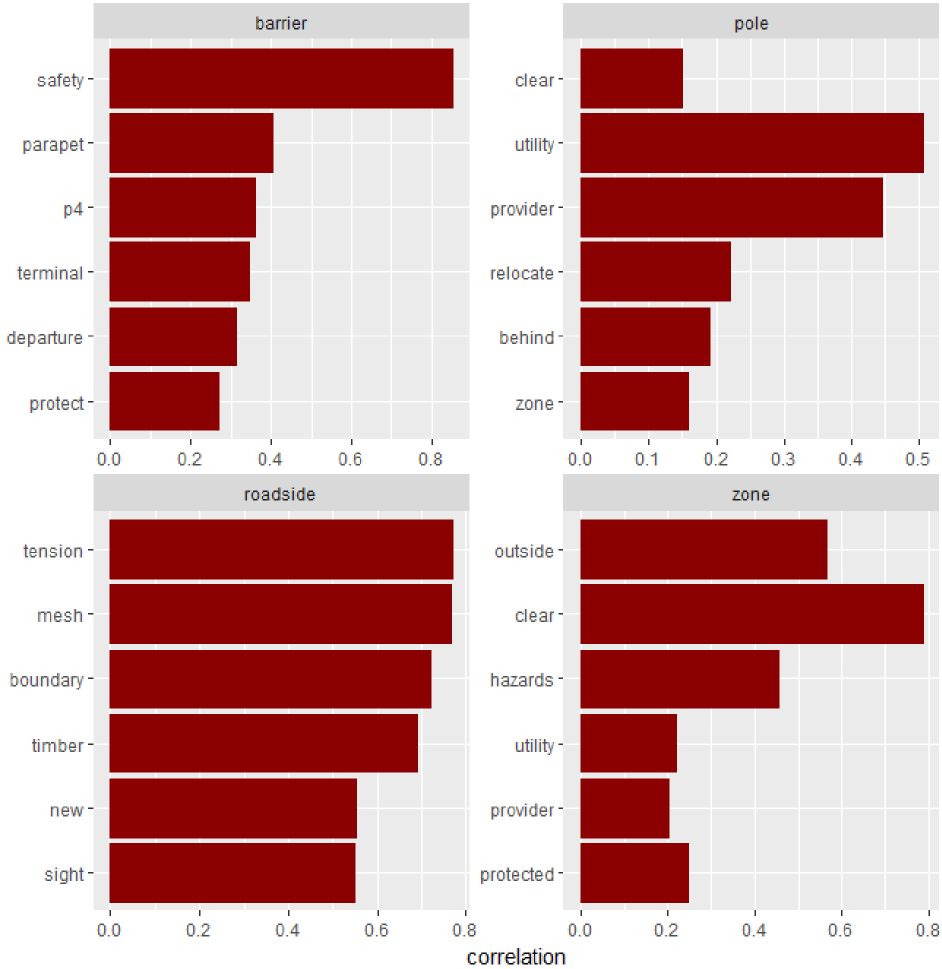


Figure 35 – Words most associated with “barrier”, “pole”, “roadside” and “zone” in the solutions record set.

6.2.3 Topic modelling

Topic modeling is a method for unsupervised classification of *documents*, by modelling each document as a mixture of topics and each topic as a mixture of words.

LDA was employed to model problems and solutions *documents* as though they were generated by sampling from a mixture of *K* topics, where a topic is a multinomial distribution over all words in our vocabulary (Blei et al, 2003).

The generative process for each problems or solutions file consists of the following steps, taken from Bhattacharya et al. (2018):

First, a multinomial distribution over *V* words for the t^{th} topic, denoted Φ_t ($1 \leq t \leq K$), is obtained by sampling from a Dirichlet distribution with parameter α; Φ_t represents the conditional probability of a word to occur in the t^{th} topic. Next, for each document, F_i, a multinomial distribution over *K* topics, denoted θ_i, is sampled from a Dirichlet distribution with parameter β; θ_i represents the conditional probability of the file to be associated with each of the K topics. Subsequently, for each word-position, j, in the document, F_i: (1) A topic is drawn by sampling from θ_i; the selected topic at position j in F_i, is denoted $z_j^i \in \{1,\ldots,K\}$; (2) Given the topic z_j^i a word c_j^i is drawn by sampling the topic-word distribution, $\theta_{z_j^i}$.

The model parameters are set iteratively for different values of K (in our study K ranges from two to 25), and the data log-likelihood is calculated for each value of K. To determine the optimal number of topics, we identify the K value that maximizes the data log-likelihood, which is defined as: $\sum_{i=1}^{M} log \int \left\{\sum_z \left[\sum_{j=1}^{N_j} Pr\left(c_j^i|z_j^i,\theta_{z_j^i}\right) Pr\left(z_j^i|\theta_i\right)\right]\right\} Pr(\theta_i|\beta)d\theta_i$ (1)

where M denotes the number of documents in the corpus and N_i denotes the total number of words in the i^{th} file. See Grün and Hornik (2011) for details.

The exact parameter inference of the LDA model is intractable, and thus, approximate estimation methods are needed. An approximate algorithm named Gibbs sampling (Griffiths and Steyvers, 2004) is widely used for parameter estimation in topic models due to its simplicity under Dirichlet priors (Wang et al., 2018).

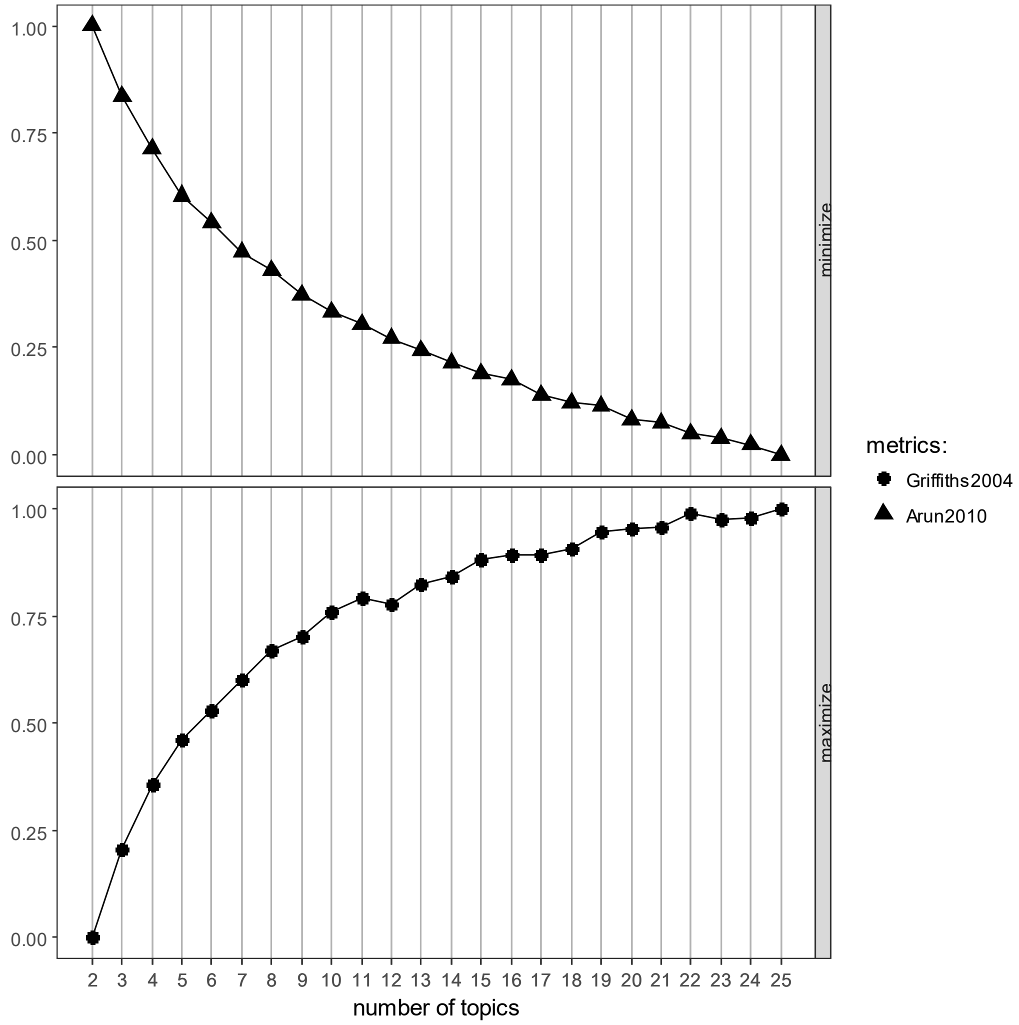
The R “topicmodel” package (Grün and Hornik, 2011) uses Gibbs sampling. Estimation of the LDA model using Gibbs sampling requires specification of values for the parameters of the prior distributions. Griffiths and Steyvers (2004) suggest a initial value of 50/M for α and 0.1 for *β.* The parameter values used for the parameter *β* (0.1) and for the initial value of the parameter *α* (50/M) were suggested by Griffiths and Steyvers (2004).

While LDA uses Bayesian inference to generatively estimate the posterior model distribution based only on the words shown in the texts, it requires one parameter (*K*: number of latent topics to identify) to begin with its iteration process.

Researchers have recommended various approaches to establish the optimal *K* (Arun et al., 2010; Cao et al., 2009; Deveaud et al., 2014; Griffiths and Steyvers, 2004; Zhao et al., 2015). These approaches provide a good range of possible *K* values that are mathematically plausible. The R package “ldatuning” (Nikita, 2016) was used for this purpose, which simultaneously runs two different approaches:

a. KL-divergence minimization method of Arun et al. (2010),
b. and expectation maximization method of Griffiths and Steyvers (2004).

The LDA implementation was applied to both problems and solutions *corpora*, where each of the resulting topics is a distribution over words. Different numbers of topics, *K*, were considered, ranging from two to 25. To avoid the use of poor initial estimates as part of the Gibbs sampling process, 4,000 samples were discarded in the burn-in period – the initial stage of the sampling process in which the Gibbs samples are poor estimates of the posterior (Bhattacharya et al., 2018). Following the burn-in period, 2000 iterations were performed, taking every 500th iteration for further use. This procedure is done to avoid correlations between samples. Each experiment was repeated five times employing different initial seeds, and calculated an average log-likelihood value. The initial seeds were saved so that the results can be reproduced.



As shown in

Figure **36** and Figure 37, the KL-divergence minimization method (top charts) and the expectation maximization method (bottom charts) agree that the ideal number of topics for our sample dataset is 25. Consequently, two LDA models are estimated by setting the *K* value equal to 25.

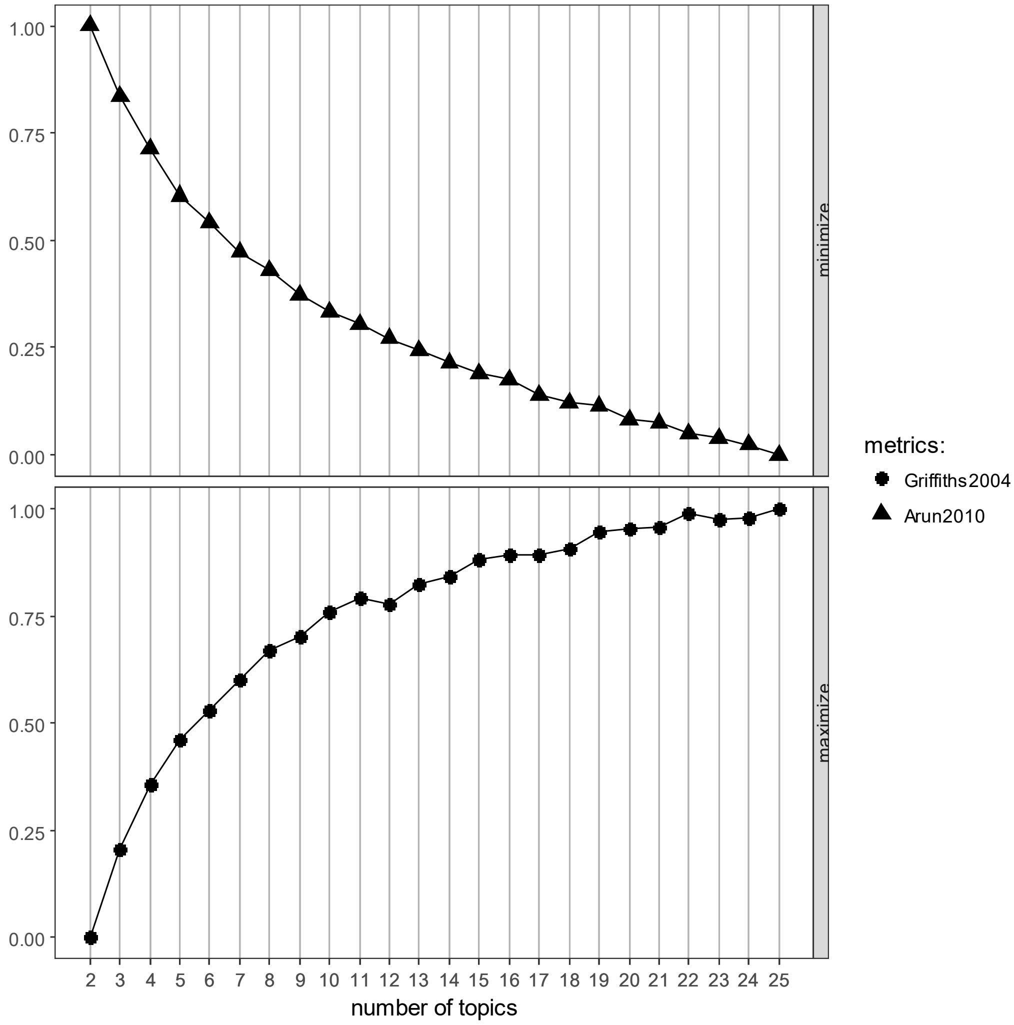


Figure 36 – Determining the number of latent topics (*K*) for the problems record set.

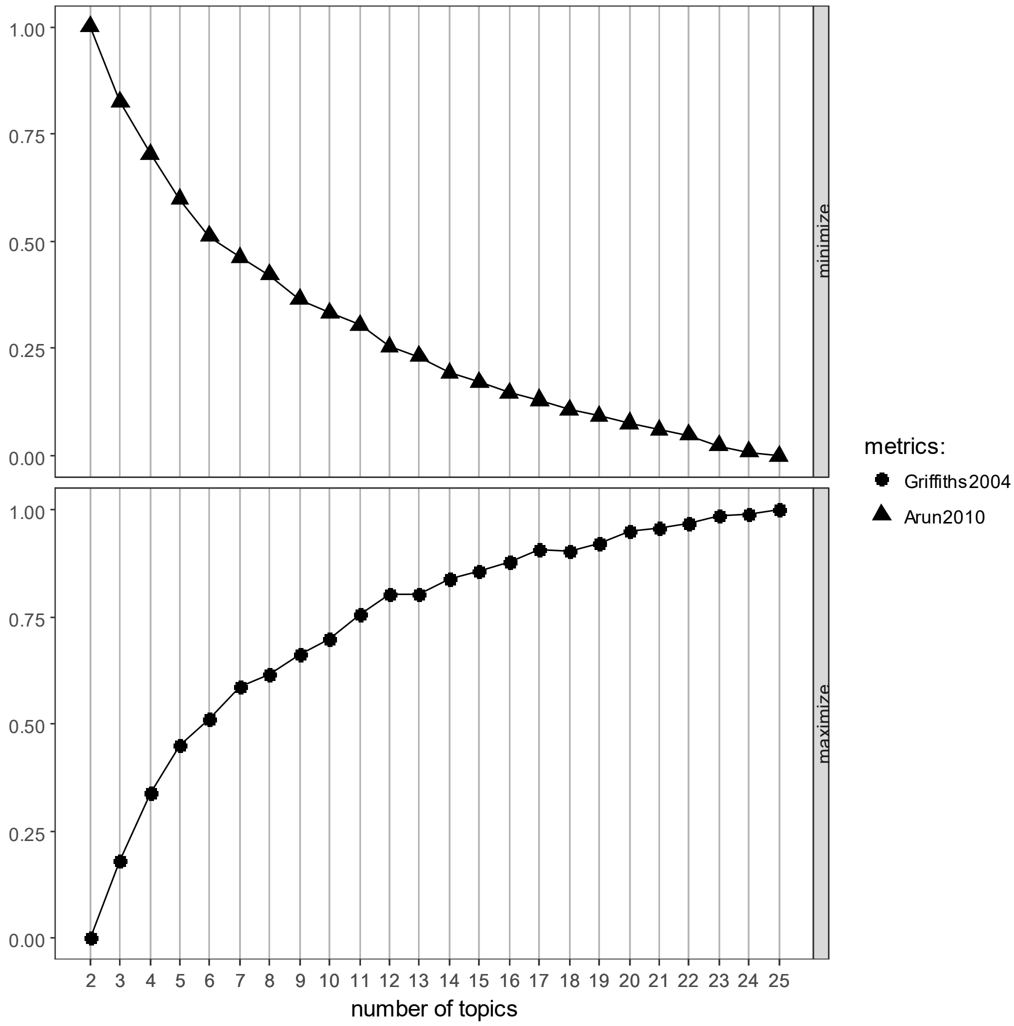


Figure 37 – Determining the number of latent topics (*K*) for the solutions record set.

6.2.4 Results

Table 45 and

Table 46 show the 25 extracted latent topics for the problems and solutions record sets (topics directly related to road side issues are shaded grey). Each topic contains all words in the corpus, albeit with different probabilities. The top 10 terms for each record set are listed in Table 45 and

Table 46.

Table 45 – Extracted Latent Topics with keywords (problems record set).

	Topic 1	Topic 2	Topic 3	Topic 4	Topic 5	Topic 6	Topic 7	Topic 8	Topic 9	Topic 10
1	hazard	vehicle	collision	road	barrier	sign	may	sign	through	pedestrians
2	edge	errant	side	layout	vehicle	junction	layout	may	road	pedestrian
3	carriageway	parapet	mainline	users	safety	warning	lack	result	side	conflict
4	constitutes	bridge	impact	inappropriate	pole	located	drivers	missing	traffic	crossing
5	Roadside-hazard	unprotected	without	resulting	along	ahead	definition	being	onto	between
6	cyclists	strike	where	type	poles	advance	upcoming	warning	potential	facilities
7	hard	striking	stopping	clearly	errant	poorly	which	ahead	layout	carriageway
8	over	increased	enters	potential	within	too	result	been	see	motorised
9	area	severity	vehicle	other	lighting	misleading	aware	provided	conflicts	impaired
10	verge	drop	risk	defined	has	visible	being	has	result	footway

	Topic 11	Topic 12	Topic 13	Topic 14	Topic 15	Topic 16	Topic 17	Topic 18	Topic 19	Topic 20
1	vehicles	due	may	road	loss	bend	risk	end	mainline	vehicles
2	left	junction	drivers	collisions	control	control	road	rear	entering	risk
3	exiting	drivers	signs	type	speed	loss	due	shunt	drivers	boundary
4	visibility	main	roundabout	signage	approach	risk	poor	from	visibility	wall
5	right	approaching	lead	failing	where	speed	control	risk	inadequate	roadside
6	lane	night	insufficient	leading	driver	chevrons	surface	directional	sight	collisions
7	from	particular	post	night	fails	lose	water	minor	distance	fence
8	turn	high	finger	chevron	reduce	does	ponding	braking	which	occupants
9	turning	exit	information	time	stopline	change	oncoming	shunts	result	injuries
10	junction	risk	which	both	risk	negotiating	avoid	exit	alignment	errant

	Topic 21	Topic 22	Topic 23	Topic 24	Topic 25
1	junction	road	driver	carriageway	risk
2	braking	stop	risk	could	side
3	turning	side	from	type	approaching
4	sudden	traffic	approach	head	collision
5	unsafe	markings	confusion	very	where
6	late	line	location	lead	driver
7	direction	overtaking	side	vehicle	vehicles

8	manoeuvres	steep	late	section	impact
9	difficult	gradient	braking	cross	see
10	shunting	centre	road	potential	fails

Table 46 – Extracted Latent Topics with keywords (solutions record set).

	Topic 1	Topic 2	Topic 3	Topic 4	Topic 5	Topic 6	Topic 7	Topic 8	Topic 9	Topic 10
1	junction	junction	sign	road	may	risk	driver	end	pedestrian	bend
2	warning	signs	located	layout	result	control	from	rear	pedestrians	control
3	sign	unsafe	stop	type	being	loss	risk	shunt	carriageway	speed
4	ahead	turning	signinglining	resulting	upcoming	where	approach	risk	crossing	risk
5	advance	directional	poorly	inappropriate	layout	over	side	due	facilities	loss
6	overshooting	direction	too	potential	which	approach	braking	turning	conflict	drivers
7	local	late	junction	may	lack	pavement	location	delay	lack	approaching
8	having	post	misleading	users	definition	strikes	confusion	collisions	may	poor
9	brake	difficult	obscured	clearly	missing	runs	late	from	footway	due
10	does	shunting	visible	defined	insufficiently	rock	road	braking	impaired	chevrons
	Topic 11	**Topic 12**	**Topic 13**	**Topic 14**	**Topic 15**	**Topic 16**	**Topic 17**	**Topic 18**	**Topic 19**	**Topic 20**
1	carriageway	road	side	wall	vehicles	mainline	collision	road	speed	could
2	hazard	due	approaching	boundary	visibility	entering	side	through	driver	lead
3	edge	main	risk	errant	exiting	drivers	mainline	side	approach	head
4	constitutes	exit	collision	roadside	left	sight	where	onto	fails	very
5	vehicle	night	impact	vehicle	alignment	inadequate	vehicle	see	reduce	width
6	poles	drivers	driver	within	from	distance	without	traffic	where	section
7	leave	particular	where	risk	crest	which	impact	potential	loss	struck
8	pole	high	see	occupants	forward	result	risk	conflicts	control	area
9	roadsidehaz ard	minor	fails	increased	right	visibility	stopping	layout	stopline	cross
10	along	risk	vehicles	injuries	mainline	limited	enters	possible	does	narrow
	Topic 21	**Topic 22**	**Topic 23**	**Topic 24**	**Topic 25**					
1	may	road	vehicle	vehicles	road					
2	drivers	poor	errant	between	collisions					
3	sudden	markings	barrier	left	type					
4	roundabout	both	parapet	conflict	failing					
5	overshoot	line	bridge	lane	signage					
6	occur	lighting	safety	traffic	leading					
7	braking	risk	strike	turn	chevron					

8	manoeuvres	water	severity	motorised	time
9	road	surface	striking	insufficient	ahead
10	unaware	directions	increased	cyclists	layout

Since the extracted topics, expressed as collections of *words*, are inherently latent, they often contain multi-dimensional meanings (semantics).

A parallel understanding can be drawn between topics in LDA and principal components in Principal Component Analysis (PCA). LDA turns a text document (represented by *word* frequencies) into a linear combination of *topics* (also represented by *word* frequencies). This linear combination of *topics* are similar to the eigenvectors in PCA. In PCA, a numerical signal of dimension N can be re-represented by a combination of K eigenvectors $K< N$. These dimensionality reductions lead to a loss of information (unless $K = N$), and the modeller has to seek the best compromise. In the case of LDA, given a set of documents (represented as a vector of *word* frequencies) and a number of K topics, the algorithm extracts the set of K topics that minimizes the reconstruction error of the original documents. Each topic is also a vector of *word* frequencies (Li et al., 2015).

This characteristic of LDA is useful to efficiently extract from RSI reports those documents and references which are specifically related to road side safety.

To provide a better understanding of the LDA's latent topics, Figure 38 presents some examples of the topic-specific words probabilities (β) for the 25 topics of the problems record set. For instance, the word "hazard" has a 13% probability of being generated from Topic 1, whereas "roadsidehazard" has 3% probability of being generated from the same topic. Figure 39 presents the topic-specific words probabilities (β) for the 25 topics of the solutions record set. Here we can see that the word "hazard" has a 11% probability of being generated from Topic 11, whereas "roadsidehazard" has 3% probability of being generated from the same topic.

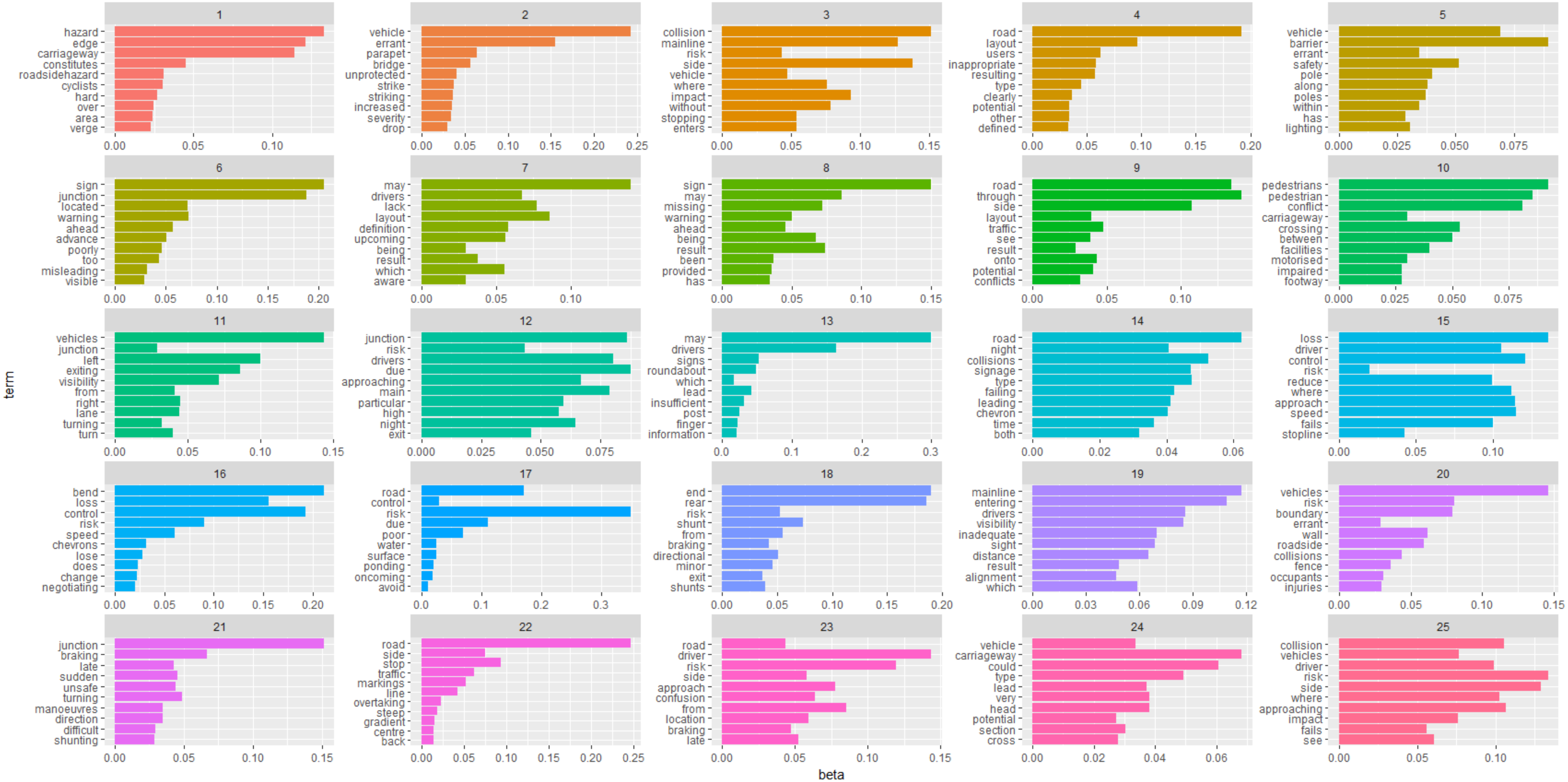


Figure 38 –Topic-specific word probabilities for the problems record set.

Figure 39 –Topic-specific word probabilities for the solutions record set.

As demonstrated by Table 45 and

Table 46, the extracted 25 topics obtained from both record sets match the typical issues and interventions in road safety reasonably well, suggesting that RSIs have been successfully covering most of the relevant state-of-the-practice road safety aspects.

There are four topics in Table 45 and Figure 38 directly related to road side issues:

- Topic 1, relates to roadside hazards and verges – edge of carriageway;
- Topic 2, corresponds with ROR crashes in bridges;
- Topic 5, associated with a specific roadside hazard (poles);
- Topic 20 shows patterns of fixed roadside hazards (walls and fences).

There are three topics in

Table 46 and Figure 39 directly related to road side interventions:

- Topic 11, mitigating the effects of edge road side hazards and poles;
- Topic 14, to address fixed road side hazards;
- Topic 23, related to road side issues in bridges.

It should be noted that some words relating to the ‘‘forgiving roadside’’ and ‘‘clear zone’’ concepts as well as the relevant European technical standards (EN1317 and EN 12767) are absent from these topics. That is, these words are not mentioned often enough to be extracted as a distinctive topic. The absence of the ‘‘clear zone’’ concept in these topics may reveal a lack of application of this concept in Irish roads, at least as a specific characteristic deserving to be explicitly mentioned in the reports.

It is also worthwhile to point out that the word “cyclists”, not typically related to road side safety, appears in Topic 1 of the problems record set. In fact, several statements in the problems record set relate cyclists to road side safety. Some examples are presented below:

- "Safety Barrier. Barrier layout. The pedestrian guardrails are located too close the carriageway edge resulting in insufficient lateral clearance and poses a hazard to cyclists."
- "VRU Pedestrian facilities. The location of the gantry signal pole may cause an obstruction to cyclists using this path."
- "Roadside hazard. Lighting Columns. The lamp column is very close to the edge of the pavement which may pose a hazard to vehicles, including cyclists, when meeting oncoming traffic at this location."
- "Roadside hazard. Sign Supports. The traffic lights ahead sign is located very close to the edge of the pavement. This poses a hazard to errant vehicles and cyclists."
- "Roadside hazard. Utility poles along carriageway. The telephone pole is located very close to the edge of the carriageway. Acts as a potential hazard to errant vehicles and cyclists."

- "Roadside hazard. Boundary walls. The retaining wall and pedestrian railings are located very close to the edge of the carriageway. This poses a hazard to errant vehicles and cyclists."
- "Utility poles along carriageway. The lighting column in the carriageway constitutes a hazard to vehicles including cyclists".

The examples shown indicate that vulnerable road users' safety issues are already considered in Irish RSI, even though they are still mostly associated with issues for vehicle occupants and drivers.

While LDA models estimates each topic as a combination of *words* (with probabilities of *β*), it also estimates each *document* as a combination of topics (with probabilities of *γ*).

To identify the frequency distribution of the topics in both *corpus* (problems and solutions record sets), a heuristic assumption[4] was introduced where each *document* should be categorized into one, and only one, topic group. That is, each *document* is categorized into one topic group that shows the highest *γ* value.

With this assumption, the relative frequencies of the topics are shown in Table 47. The shaded cells represent the road side safety topics identified in Table 45 and

Table 46 as most relevant for road side safety. From Table 47, it is clear that the frequency of topics related to road side safety is higher in the problems record set (topics 1, 2, 5 and 20 which correspond to 20.1%) than in the solutions record set (topics 11, 14 and 23 which correspond to 16.6%), meaning that problems are more easily identified and related to the road side area than interventions may be. This seems reasonable, as sometimes road side safety issues may be mitigated by interventions in the roadway itself (e.g. improving road surface characteristics and correcting geometric deficiencies). The relative frequencies per solutions topic are higher than per problems topic.

[4] A heuristic assumption is a counterfactual proposition about the nature of a system, used to investigate it in the hope of moving on to something better.

Table 47 – Relative frequencies of extracted topics for problems and solutions record sets.

Topic	Problems		Solutions	
	#	%	#	%
1	533	5,5%	341	3,6%
2	687	7,2%	401	4,2%
3	556	5,8%	463	4,8%
4	358	3,7%	275	2,9%
5	421	4,4%	326	3,4%
6	409	4,3%	229	2,4%
7	321	3,3%	223	2,3%
8	300	3,1%	453	4,7%
9	262	2,7%	507	5,3%
10	667	6,9%	341	3,6%
11	383	4,0%	567	5,9%
12	474	4,9%	519	5,4%
13	179	1,9%	446	4,6%
14	290	3,0%	401	4,2%
15	635	6,6%	354	3,7%
16	355	3,7%	387	4,0%
17	127	1,3%	374	3,9%
18	411	4,3%	241	2,5%
19	443	4,6%	639	6,7%
20	287	3,0%	332	3,5%
21	431	4,5%	298	3,1%
22	270	2,8%	285	3,0%
23	191	2,0%	625	6,5%
24	252	2,6%	363	3,8%
25	364	3,8%	215	2,2%

Total	9606	100,0%	9605	100,0%

7 Conclusions

As described in the preceding chapters, the technical review of existing standards and guidelines developed in this work package 1 allowed to consolidate an overall view on international practices as regards the design and management of rural road sides, which will be the basis for carrying out work on following work packages. A summary of the qualitative findings is presented in Table 48.

Table 48 – Summary of findings

Task	Contents	Results
Task 1.1 (Chapter 2)	• Summarise the results of several roadside safety projects • Collect the most relevant studies related to the application of guidelines and standards in the improvement of roadside safety. The review focused on studies that explore and highlight the relationship between safety and compliance to standards and guidelines.	• 10 road side safety projects and 137 studies were analysed. • There are not any projects that have looked thoroughly into the application of guidelines and standards on road side safety. • 13 studies selected. • None of the studies related to the application of European guidelines and standards on road side safety. • Only 3 related to the application of other guidelines and standards. • All other studies (10) are focused on neighbouring roadside safety issues rather than directly on the application of guidelines and standards. • The effect of the application of guidelines and standards on roadside safety has not been sufficiently studied or reported in scientific journals in Europe or the rest of the world.

Task	Contents	Results
Task 1.2 (Chapter 3)	• Identify any quantified relationships between roadside design elements (which are featured in the road side design guidelines of the six funding countries) and the real world crashes. • Evaluate the relevance of the road side design guidelines and standards • Provide input to an eventual revision by making the relationships with safety explicit. • In-depth literature review A matrix was developed to illustrate all identified relationships between the different road side design elements with road safety in general and crashes in particular.	• The literature review focused on identifying roadside design elements and parameters, of which the effect on accident frequency and severity has been quantified. • All quantified relationships identified through the literature review were collated in a matrix • Within the matrix, roadside design elements and related parameters were grouped into three categories, with regards to their relation to the risk model from a roadside safety perspective • These roadside elements are related to: Clear/Safety zones; Hazards reduction; Side slopes; Shoulders; Drainage structures; Passively safe poles and Roadside and Median barriers • 150 road side safety features were identified to contribute to road safety by the frequency and/or severity of crashes in this literature review.
Task 1.3 (Chapter 4)	• Summarise a review of existing design standards and guidelines related to road side design and management. • Analyse the relevant CEN standards, the Directive 2008/96/EC, and the related guidelines for the six funding countries.	• Impact of RISM on road equipment and component selection quality – no impact was determined • Proposed to extend the reach of the RISM Directive to include Non-TEN-T roads in an attempt to improve safety for all road users on all rural roads within the EU • Belgium (Flanders), Ireland, Netherlands, Slovenia and Sweden include requirements in their RRS standards relating to the area at the side of the road which should be kept free of hazards. UK is the only funding country which does not specify clear/obstacle free zones in their standards.

Task	Contents	Results
Task 1.4 (Chapter 5)	• Discussion of the standards and guidelines that relate specifically to road side maintenance and operations • Evaluate if maintenance of road side furniture and equipment are directly related to road safety or whether these are inferred (preventive versus reactive)	• UK has the most comprehensive maintenance standards and guidelines when compared to the other five funding countries • Temporary safety measures applying to roadworks, health and safety for temporary construction sites, employer responsibility relating to employee safety and personal protective equipment have been implemented across the EU between 1989 & 2008 and have been adopted by all countries • Road side operations and maintenance procedures appear to be of a similar format with country specific differences in terms of the frequency of inspections
Task 1.5 (Chapter 6)	• Benchmark roadside safety performance in the six funding countries plus Germany and Portugal based on crash data analysis. • Identification of patterns of attributes related to the ROR crashes in RSI reports • Identification of proposed RSI intervention' patterns associated with ROR crashes.	• Almost 28,000 persons were killed in ROR crashes in the six funding countries plus Germany and Portugal within the decade 2006-2015. • It was not possible to calibrate ROR CPMs using the data available. • New model fitting will be attempted, if more data is made available within the PROGReSS timeframe. • Latent Dirichlet allocation (LDA) was applied to identify the importance given to road side issues in RSI performed in Ireland. • Important key words relating to the ''forgiving roadside'' and ''clear zone'' concepts as well as the relevant European technical standards (EN1317 and EN 12767) are absent from the extracted latent topics. • The frequency of topics related to road side safety is higher in the problems record set than in the solutions record set, meaning that problems are more easily identified and related to the road side area than interventions may be.

The results from road side safety projects were described, and the impacts of guidelines and standards on road side safety were assessed through literature search.

It is clear that there are not that many projects nor studies that have actually looked thoroughly into the application of guidelines and standards on road side safety. None of the studies analysed investigated the relationship between the actual application of European guidelines and standards and roadside safety, and only two studies focused on that relationship based on international guidelines, within the scope of road safety audits.

The findings of the literature review were also described and assessed and the potential relationships between roadside design elements and parameters and the effect on accident frequency and severity were quantified. A number of road side safety features were identified to contribute to road safety and their effects on accident frequency and severity have been quantified.

The relationship between the design and management of road side elements and factors with road safety in general and crashes in particular was reviewed focusing on the standards and guidelines for road side design and management of the six funding countries plus the relevant CEN standards. Belgium (Flanders), Ireland, Netherlands, Slovenia and Sweden include requirements in their safety barrier design standards relating to the area at the side of the road which should be kept free of hazards that could increase the severity of a collision in the event of a run off road incident. The general principle across the five countries is the same even though the dimensions of the hazard free zone may vary from country to country. In the United Kingdom, a risk based approach is required, which uses many different site specific parameters from a site to calculate the level of risk without a roadside barrier and if necessary with barriers of specified containment levels. As such, a hazard free zone is not specifically defined within the design standard. This is also the approach used in the other funding countries. In terms of the impact of RISM on road equipment and component selection quality there is no register of impact assessment results.

Also, road side operations and maintenance procedures across the six funding countries appear to be of a similar format with most important country specific differences limited to the frequency of inspections. Requirements relating to the provision of work zones, planning, road safety, work place safety appraisals, employee safety and traffic management are broadly similar. It can be concluded that the UK has the most comprehensive set of maintenance standards and guidelines when compared with the other five funding countries. Detailed condition surveys of existing roadside infrastructure are required at varying intervals. Belgium (Flanders), Ireland, Sweden and the UK have procedures in place which require immediate attention for a defect identified as requiring prompt attention, because they represent an immediate or imminent hazard, or because there is a risk of short-term deterioration. In the Netherlands, the action required following the identification of such a defect is determined by the attending inspection professionals who are expected to use their expert judgement. Slovenia has no standards or guidelines relating to road side maintenance. Detailed analysis of road side crash statistics and mathematical modelling was not possible, at this stage, due to lack of appropriate crash data.

A benchmark of the roadside safety performance in the six funding countries plus Germany and Portugal, based on crash data analysis, was provided.

Finally, a data driven approach was adopted to identify the importance given to road side issues in RSI performed in Ireland, the sole country that provided those reports. The reports were analysed using data mining methods, to identify many-to-many associations among a broad group of conditions associated with RoR crashes and road side safety interventions. For that purpose, *latent Dirichlet allocation* (LDA) was applied) to analyse the topics of Irish Road Safety Inspection (RSI) reports, divided into two groups: problems found and proposed solutions.

Important key words relating to the ‘‘forgiving roadside’’ and ‘‘clear zone’’ concepts as well as the relevant European technical standards (EN1317 and EN 12767) are absent from the extracted latent topics. That is, these words are not mentioned often enough to be extracted as a distinctive topic. The absence of the ‘‘clear zone’’ term and those topics may reveal a lack of application of this concept in Irish roads, at least as a specific characteristic deserving to be explicitly mentioned in the reports.

It is also worthwhile to point out that the word “cyclists”, not typically related to road side safety, appears in one of the topics of the problems record set. In fact, several statements in the problems record set relate cyclists to road side safety. Vulnerable road users’ safety issues are already considered in Irish RSI, even though they are still mostly associated with issues specific to vehicle occupants and drivers.

The frequency of topics related to road side safety is higher in the problems record set than in the solutions record set, meaning that problems are more easily identified and related to the road side area than interventions may be. This seems reasonable, as sometimes road side safety issues may be mitigated by interventions in the roadway itself (e.g. improving road surface characteristics and correcting geometric deficiencies).

In terms of work plan, PROGReSS comprises a total of seven work packages, five work packages dealing with the essential content of the project, one work package dealing with dissemination and a project management work package to ensure project progress and provide liaison between the CEDR management team and the project team.

Work package 1 conducted a technical review of existing standards and guidelines in each of the contributing countries and consolidated knowledge on the design and management of rural road sides internationally. These results will be used in Work package 3, to identify the effective, promising and innovative practices used by different road authorities. Work package 3 will consolidate the results of Work package 1 in the preparation of a complete assessment of roadside safety management and the development of a roadside safety evaluation tool.

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Appendix A: Abstracts of literature search

Authors:	Bambach, M.R., Grzebieta, R.H., Olivier, J., McIntosh, A.S.
Title:	Fatality risk for motorcyclists in fixed object collisions
Abstract:	Motorcyclists contribute significantly to road trauma around the world through the high incidence of serious injuries and fatalities. Around one fourth of motorcyclist fatalities may be attributed to collisions with fixed objects. A greater understanding of factors associated with fatalities occurring from fixed object collisions will enable safer roadway infrastructure design for motorcyclists. In this article, a multiple variable logistic regression model is developed to determine such factors, from a nationally representative weighted sample of around 30,000 single-vehicle fixed object motorcycle collisions which occurred in the United States over the 10-year period between 2000 and 2009. Additionally, a single variable logistic regression model is developed for motorcyclist fatality risk from fixed object collisions as a function of travel speed. This model may be a useful predictive tool for implementing motorcyclist safety strategies.
Relevance:	L

Authors:	Grzebieta, R., Bambach, M., McIntosh, A.
Title:	Motorcyclist impacts into roadside barriers

Abstract:	This paper reports on a study that reviewed the European Standard EN 1317-8 for motorists crashing into barriers and the relevance to Australian motorcycle fatalities. The data collection and analysis of 78 Australian motorcyclist-into-barrier fatalities described here were used to justify the review. In Australia each year approximately 15 motorcyclists die from striking a road safety barrier. A retrospective analysis of the fatalities during 2001 to 2006 (n 5 78) was carried out. Consistent with European findings, approximately half the motorcyclists were in the upright posture when they struck the barrier, whereas half slid into the barrier. The mean precrash speed was 100.8 km/h, and the mean impact angle was 15.4 . The areas of the body that were injured were similar across different barrier types (concrete, wire rope, and W-beam) and crash postures. The thorax area had the highest incidence of injury and maximum injury in fatal motorcycle crashes into barriers; the head area had the second-highest incidence of injury. Moreover, thorax and pelvis injuries had a greater association with sliding crashes than with those in the upright posture. The existing European Standard EN 1317-8 addresses only the sliding mechanism, uses a head injury criterion, and does not specify any thorax injury criterion. It was proposed that a thorax injury criterion and an additional test should be introduced with the rider in the upright position when striking the barrier and then sliding along the top of the barrier.
Relevance:	L

Authors:	Jalayer, M., Zhou, H.
Title:	Evaluating the safety risk of roadside features for rural two-lane roads using reliability analysis.
Abstract:	The severity of roadway departure crashes mainly depends on the roadside features, including the sideslope, fixed-object density, offset from fixed objects, and shoulder width. Common engineering countermeasures to improve roadside safety

	include: cross section improvements, hazard removal or modification, and delineation. It is not always feasible to maintain an object-free and smooth roadside clear zone as recommended in design guidelines. Currently, clear zone width and sideslope are used to determine roadside hazard ratings (RHRs) to quantify the roadside safety of rural two-lane roadways on a seven-point pictorial scale. Since these two variables are continuous and can be treated as random, probabilistic analysis can be applied as an alternative method to address existing uncertainties. Specifically, using reliability analysis, it is possible to quantify roadside safety levels by treating the clear zone width and sideslope as two continuous, rather than discrete, variables. The objective of this manuscript is to present a new approach for defining the reliability index for measuring roadside safety on rural two-lane roads. To evaluate the proposed approach, we gathered five years (2009-2013) of Illinois run-off-road (ROR) crash data and identified the roadside features (i.e., clear zone widths and sideslopes) of 4500 300 ft roadway segments. Based on the obtained results, we confirm that reliability indices can serve as indicators to gauge safety levels, such that the greater the reliability index value, the lower the ROR crash rate. © 2016 Elsevier Ltd. All rights reserved.
Relevance:	L

Authors:	La Torre, F., Erginbas, C., Thomson, R., Amato, G., Pengal, B., Stefan, C., Hemmings, G.
Title:	Selection of the Most Appropriate Roadside Vehicle Restraint System - The SAVeRS Project
Abstract:	Run Off Road (ROR) crashes are road accidents that often result in severe injuries or fatalities. To reduce the severity of ROR crashes, "forgiving roadsides" need to be designed and this includes identifying situations where there is a need for a Vehicle Restraint System (RRS) and what appropriate RRS should be selected for a specific location and traffic condition. Whilst there are standards covering testing, evaluation and classification of RRS within Europe (EN1317 parts 1 to 8), their

	selection, location and installation requirements are typically based upon national guidelines and standards, often produced by National Road Authorities (NRA) and/or overseeing organisations. Due to local conditions, these national guidelines vary across Europe. The European SAVeRS project, funded within the 2012 CEDR Transnational Research Programme "Safety", has developed a practical and readily understandable RRS guidance document and a user-friendly software tool which allow designers and road administrations to select the most appropriate solution in different road and traffic conditions. This paper describes the main outcomes of the project, the process to select the most appropriate roadside barrier, and the user friendly SAVeRS tool.
Relevance:	L

Authors:	Montella, A.
Title:	Selection of roadside safety barrier containment level according to European Union Standards
Abstract:	The new European Standards EN 1317-1/2 define the performance classes of road restraint systems and induce a growing interest for roadside safety. However, analytical procedures, like benefit-cost analysis, are not used in Europe for the selection of specific roadside safety features at specific locations or for the development of warrants, policies, and guidelines on a systemwide basis. A model for the selection of roadside safety barrier performance level according to European Union standards is presented. The new procedure is an encroachment-based benefit-cost analysis that takes into account the effective performance level of road safety barriers on the basis of a comparison between the real-world impact conditions and the impact conditions of the full-scale crash tests performed according to the European Committee for Standardization standards. The behavior of the safety barriers In relation to the impact conditions has been studied by performing nonlinear dynamic finite element analysis of collisions of heavy-goods vehicles against steel road safety barriers. As a result of the study, analytical relationships between a barrier's containment capacity and impact conditions have been obtained. The expressions obtained allow one to evaluate the number of vehicles successfully redirected from the safety barriers In relation to the type of road, to the geometrical features of the road, to the traffic volume and composition, and to the safety barrier containment level. The model allows one to calculate the benefits arising from the greater number of vehicles redirected from safety barriers with greater level of performance and to compare roadside alternatives.
Relevance:	L

Authors:	Osoba, M; Tubic, V; Mertner, J
Title:	First experience on road safety auditing in Serbia - is it cost-effective?
Abstract:	A project where extensive road safety auditing was carried the first time in Serbia is described. The Serbian road network is traditionally characterized by low level of safety due to the outdated road design, poor physical conditions of the existing roads and lack of maintenance over a long period. Although not completely operative yet, Road Safety Auditing (RSA) is an important component of the activities to improve the road network in the Feasibility Study of the Road Network between Belgrade and Montenegro. This is one of the most extensive RSA works that have been carried out in Serbia until now. More than 550 km of existing roads were assessed on site and additionally the corresponding road design projects were checked. The roads analysed are among the roads with highest accident rates in Serbia. The police have registered an average of 1350 accidents per year on the project roads. These accidents lead to an average of 60 fatalities and 670 injuries per year. When accident data are missing or inadequate as on the project road then road safety can be improved by assessing the existing road with regard to road safety. The visual inspection was carried out by driving and walking along the road registering potential dangerous elements related to the roads design, layout, surface condition, signs and markings. The measures considered to improve the road safety situation are based on 4 principles. First of all accidents should be avoided, secondly the road should be more forgiving, thirdly the road design should be according to the speed limits, fourthly to obtain good safety results it may often be necessary to go beyond the road standards, e.g. be stricter on curves, safety zones and junctions than the road standards suggest. This is because road standards are a compromise between traffic flow, road safety, environment and costs. The measures suggested on the project road include guard rails, improved junctions, speed reducing measures in towns and larger built up areas, facilities for pedestrians, pre-warning and local speed limits at sharp curves, reduced length of sections with 2+1 lanes (or climbing lanes), thus change direction at least every 4-5 km., locate bus stops, etc. correctly, provide adequate and consistent road markings and traffic signing, including speed limits. The costs of the suggested measures were assessed both if only road safety measures were applied on the road and also if the road safety measures were to be part of the road design of the entire road. The cost effectiveness could then be calculated to justify the focus on road safety. Assuming that all the suggested road safety measures are established on the project network as suggested then the safety effects are expected to be up to 35-37%. This will in total cost approx. 35 million Euro or 65,000 Euro per km. The cost benefit ratio is expected to exceed 8 and the internal rate of return (IRR) 42%. For the covering abstract see ITRD E137145.
Relevance:	L

Authors:	Pardillo-Mayora, J.M., Domínguez-Lira, C.A., Jurado-Piña, R.
Title:	Empirical calibration of a roadside hazardousness index for Spanish two-lane rural

	roads
Abstract:	Crash records and roadside data from Spanish two-lane rural roads were analyzed to study the effect of roadside configuration on safety. Four indicators were used to characterize the main roadside features that have an influence on the consequences of roadway departures: roadside slope, non-traversable obstacles distance from the roadway edge, safety barrier installation, and alignment. Based on the analysis of the effect of roadside configuration on the frequency and severity of run-off-road injury crashes, a categorical roadside hazardousness scale was defined. Cluster analysis was applied to group the combinations of the four indicators into categories with homogeneous effects on run-off-road injury crashes frequency and severity. As a result a 5-level Roadside Hazardousness Index (RH1) was defined. RHI can be used as reference to normalize the collection of roadside safety related information. The index can also be used as variable for inclusion of roadside condition information in multivariate crash prediction models.
Relevance:	L

Authors:	Roque, C., Jalayer, M.
Title:	Improving roadside design policies for safety enhancement using hazard-based duration modeling
Abstract:	Roadway departure (RwD) crashes, comprising run-off-road (ROR) and cross-

	median/centerline head-on collisions, are one of the most lethal crash types. Nationwide, from 2014 to 2016, annual RwD crashes accounted for 53% of all motor vehicle traffic fatalities. Several factors may cause a driver leave the travel lane, including an avoidance maneuver and inattention or fatigue. Roadway and roadside geometric design features (e.g., lane widths and clear zones) play a significant role in whether human error results in a crash. In this paper, we present a hazard-based duration model to investigate the distance traveled by an errant vehicle in a run-off-road crash, the stopping hazard rates, and associated risk factors. For this study, we obtained five years' (2010–2014) of crash data related to roadway departures (i.e., overturn and fixed-object crashes) from the Federal Highway Administration's Highway Safety Information System Database. The results indicate that over 50% of the observed vehicles traveled no more than 36 ft. in a ROR crash and 25% of the observed vehicles traveled at least 78 ft. We also found that seasonal, roadway, and crash variables, along with vehicle information and driver characteristics significantly contributed to the distances traveled by errant vehicles in ROR crashes. This paper presents methodological empirical evidence that the Cox proportional-hazards model is appropriate for investigating the distances traveled by errant vehicles in ROR crashes. In addition, it also provides valuable information for traffic design and management agencies to improve roadside design policies and implementing appropriately forgiving roadsides for errant vehicles.
Relevance:	M

Authors:	Tomasch, E., Sinz, W., Hoschopf, H., Gobald, M., Steffan, H., Nadler, B., Nadler, F., Strnad, B., Schneider, F.
Title:	Required length of guardrails before hazards
Abstract:	One way to protect against impacts during run-off-road accidents with infrastructure is the use of guardrails. However, real-world accidents indicate that vehicles can leave the road and end up behind the guardrail. These vehicles have no possibility of returning to the lane. Vehicles often end up behind the guardrail because the length of the guardrails installed before hazards is too short; this can lead to a collision with a shielded hazard. To identify the basic speed for determining the necessary length of guardrails, we analyzed the speed at which vehicles leave the roadway from the ZEDATU (Zentrale Datenbank Tödlicher Unfälle) real-world accidents database. The required length of guardrail was considered the length that reduces vehicle speed at a maximum theoretically possible deceleration of 0.3 g behind the barrier based on real-world road departure speed. To determine the desired length of a guardrail ahead of a hazard, we developed a relationship between guardrail length and the speed at which vehicles depart the roadway. If the initial elements are flared away from the carriageway, the required length will be reduced by up to an additional 30% The ZEDATU database analysis showed that extending the current length of guardrails to the evaluated required length would reduce the number of fatalities among occupants of vehicles striking bridge abutments by approximately eight percent.
Relevance:	L

Authors:	Wang, J., Hu, X., Dong, T., Yan, L.
Title:	Evaluation on low-grade highways roadside safety in mountainous area by projection pursuit model
Abstract:	In the recent years, the roadside safety accidents happen frequently in our national mountainous area, therefore, determining the roadside safety grades scientifically and reasonably is imperative for the prevention of more roadside accidents in the mountainous area. To qualitatively evaluate the roadside safety grade of the highways in the mountainous area, this paper adopts the Friedman-Tukey projection index to establish the projection pursuit model and introduces the multi-agent genetic algorithm to solve it. After that, the weights of factors influencing the roadside safety of the highways in the mountainous area can be acquired. Then, the Fisher optimal dissection method is applied to group the samples according to their projection values. Therefore, the number of grades and corresponding threshold values can be obtained. Finally, take highways in the mountainous area of Luanping County as an example, the reasonability and the validity of the established model were verified.
Relevance:	L

Authors:	Wang, Y.G., Chen, K.M., Ci, Y.S., Hu, L.W.
Title:	Safety performance audit for roadside and median barriers using freeway crash records: Case study in Jiangxi, China
Abstract:	Globally, the Road Safety Audit (RSA) concept has been recognized as an effective tool in examining the crash potential of in-service and future roadways in planning and design stages. As such, there is critical need for a practical tool that focuses on the safety of the existing, as-built, local road facilities. As requested by the World Bank, the RSA process has been developed for this purpose, giving specific recognition to the safety performance of roadside and median barriers for three existing, typical freeways in Jiangxi, China, and to the gathering of design experience for a new RGF project. On top of a routine road safety audit process, a total of 172 roadside crashes are collected, with 74 belonging to single vehicle Run-off-Road crashes, and crash records are analyzed to supplement the qualitative auditing suggestions. The structure and safety performance of the roadside and median barriers in the three freeways reviewed are evaluated and compared with their counterparts in the US barrier system. Several critical issues were identified and improvement suggestions were recommended, including less attention being paid to the roadside Clear Recovery Zone (CRZ), weak barrier structures, un-protected roadside obstacles (i.e. barrier ends, advertisement signs, drainage ditches, etc.), and poor connections or transitions of rails. Based on these observations, detailed pertinent countermeasures for each issue have been suggested in a roadside safety audit report for guiding roadside safety design in the RGF project.
Relevance:	M

Authors:	Xie, L.-F., Liao, X.-F., Wang, Z.-R.
Title:	Roadside safety audit for three expressway facilities in China
Abstract:	At the request of the World Bank, a roadside safety audit was conducted for three existing expressways in Jiangxi Province, China, with an aim to developing safer roadside safety designs for the World Bank funded Ruijin Ganzhou Expressway (RGE) project in Jiangxi Province. On top of a routine road safety audit process, traffic collision records for roadside safety crashes were analyzed to supplement the qualitative auditing suggestions. The performance of Chinese roadside barrier designs was also evaluated based on a comparison with their counterparts in the United States. Several critical issues were identified and countermeasures recommended. First of all, it was found that the current Chinese highway design standard is silent about the dimension specifications of roadside clear recovery zone (CRZ), which does not lend itself to safe roadside safety design. Second, it was realized that the existing roadside barriers are not strong enough to protect the heavy trucks from running off the road. In addition, some roadside obstacles are found to be unprotected or un-treated, such as barrier ends, and drainage ditches. Based on these observations, pertinent countermeasures for each issue were discussed in detail in this paper, and a roadside safety audit report was generated for the Jiangxi Provincial Communications Department to guide the RGE project roadside design.
Relevance:	M

Authors:	Zou, Y., Tarko, A.P., Chen, E., Romero, M.A.
Title:	Effectiveness of cable barriers, guardrails, and concrete barrier walls in reducing the risk of injury.
Abstract:	Roadway departure crashes tend to be severe, especially when the roadside exposes the occupants of errant vehicles to excessive injury hazards. As a cost-effective method when the clear zone width is insufficient, road barriers are often installed to prevent errant vehicles from colliding with dangerous obstacles or traversing steep slopes. This paper focuses on the safety performance of road barriers in Indiana in reducing the risk of injury. The objective of the study presented here is to compare the risk of injury among different hazardous events faced by an occupant in a single-vehicle crash. The studied hazardous events include rolling over, striking three types of barriers (guardrails, concrete barrier walls, and cable barriers) with different barrier offsets to the edge of the travelled way, and striking various roadside objects. A total of 2124 single-vehicle crashes (3257 occupants) that occurred between 2008 and 2012 on 517 pair-matched homogeneous barrier and non-barrier segments were analyzed. A binary logistic regression model with mixed effects was estimated for vehicle occupants. The segment pairing process and the use of random effects were able to handle the commonality within the same segment pair as well as the heterogeneity across segment pairs. The modeling results revealed that hitting a barrier is associated with lower risk of injury than a high-hazard event (hitting a pole, rollover, etc.). The odds of injury are reduced by 39% for median concrete barrier walls offset 15-18 ft from the travelled way, reduced by 65% for a guardrail face offset 5-55 ft, reduced by 85% for near-side median cable barriers (offset between 10 ft and 29 ft), and reduced by 78% with far-side median cable barriers (offset at least 30 ft). Comparing different types of barriers is useful where some types of barriers can be used alternatively. This study found that the odds of injury are 43% lower when striking a guardrail instead of a median concrete barrier offset 15-18 ft and 65% lower when striking a median concrete barrier offset 7-14 ft. The odds of injury when striking a near-side median cable barrier is 57% lower than the odds for a guardrail face. This reduction for a far side median cable barrier is 37%. Thus, a guardrail should be preferred over a concrete wall and a cable barrier should be preferred over a guardrail where the road and traffic conditions allow. In the light of the results, installing median cable barriers on both sides of the median to reduce their lateral offset is beneficial for safety. The study also found that the unexplained heterogeneity across vehicles is much larger than it was across matched segment pairs.
Relevance:	L