Carlo Polidori, Xavier Cocu, An Volckaert, Tobias Teichner,
Kerstin Lemke, Peter Saleh, Petr Pokorny

Safety prevention manual for secondary roads

For the international training of Road Safety Inspectors and Auditors.

Complying with the European Directive 2008/96/CE

June 2012

PROJECT COORDINATOR

Adewole Adesiyun, FEHRL

EDITORS

Carlo Polidori, FEHRL subcontractor
Xavier Cocu, BRRC (Belgium)
An Volckaert, BRRC (Belgium)
Tobias Teichner, BASt (Germany)
Kerstin Lemke, BASt (Germany)
Peter Saleh, AIT (Austria)
Petr Pokorny, CDV (Czech Republic)

CONTRIBUTORS

Christian Stefan, AIT (Austria)
Marietta Spiliopoulou, Region of Central Macedonia (Greece)
Andreas Hegewald, BASt (Germany)

PROJECT PARTNERS

PILOT4SAFETY is supported by funding from the DG MOVE of the European Commission under grant agreement: MOVE/SUB/2010/D3/300-1/SI2.560087/PILOT4SAFETY

Table of Contents

1 Scope and Objectives of this Handbook....8
1.1 Introduction....8
1.2 Definition of Road Safety Procedures....9
1.2.1 Definition of Road Safety Audit (RSA)....9
1.2.2 Consolidated definition of RSA as adopted by PILOT4SAFETY....9
1.2.3 Definition of Road Safety Inspection (RSI)....10
1.2.4 Consolidated definition of RSI as adopted by PILOT4SAFETY....11
1.2.5 Black Spot Management, Network Safety Management....11
1.3 Definition of Secondary Roads....12
1.4 References....13
2 Principles of Road Safety Engineering....14
2.1 Accident Analysis and Statistics....14
2.1.1 Number and Severity of Accidents, Period under Review....14
2.1.2 Accident Costs....14
2.1.3 Accident Densities....16
2.1.4 Accident Rates....16
2.2 Geometric Parameters Affecting Road Safety....19
2.2.1 Geometric Parameters and Velocity....19
2.2.1.1 Definition and Indicators of Driving Behaviour....19
2.2.2 Geometric Parameters and Accidents....23
2.2.2.1 Horizontal Alignment....23
2.2.2.2 Vertical Alignment....26
2.2.2.3 Lane width....27
2.2.2.4 Shoulder width....28
2.2.2.5 Sight Distance....29
2.3 Other Factors affecting Road Safety....30
2.3.1 Road surface conditions....30
2.3.1.1 Friction....30
2.3.1.2 Evenness....37
2.3.2 Roadside Design....39
2.3.2.1 Slope flattening....41
2.3.3 Forgiving Roadsides....43
2.3.3.1 Definition of roadside....44
2.3.3.2 Forgiving vs. self-explaining....45

2.3.4 Road markings ... 45
2.3.5 Road lighting ... 46
2.3.6 Traffic volume and traffic composition ... 47
2.3.7 Junctions, intersections and driveways ... 47
2.3.7.1 Driveways or access points ... 47
2.3.7.2 At-grade intersections ... 50
2.3.7.3 Lighting of junctions/intersections ... 63
2.4 References ... 64
3 Vulnerable Road Users ... 69
3.1 Cyclists and Pedestrians ... 70
3.1.1 Cyclists ... 70
3.1.2 Road Sections ... 70
3.1.3 Intersections ... 74
3.1.4 Pedestrians ... 75
3.2 Risk factors regarding Powered Two Wheelers (PTW) ... 76
3.2.1 Type of area ... 76
3.2.2 Road geometry and roadside installations ... 77
3.2.3 Lighting and Visibility ... 81
3.2.4 Type of collision ... 81
3.2.5 Junction Type ... 82
3.2.6 Pavement surface conditions ... 82
3.2.7 Most relevant risk factors ... 85
3.2.8 References ... 86
4 Road Safety Audit (RSA) ... 90
4.1 General ... 90
4.1.1 Area of Application ... 90
4.1.2 Objective and definition of the RSA ... 90
4.1.3 Costs and Benefits of RSA ... 91
4.2 RSA phases ... 92
4.3 Audit process ... 93
4.4 Audit implementation ... 95
4.4.1 Required documents ... 95
4.4.2 Procedure ... 96
4.4.3 Audit report ... 97
4.5 Auditors ... 97
4.5.1 Requirements for the auditors ... 97
4.5.2 Position of the auditors ... 97
4.5.3 Audit team ... 98
4.6 Liability ... 98
4.7 References ... 98
5 Road Safety Inspections (RSI) ... 100
5.1 Why do we need RSIs? ... 100

5.2 Benefits and costs of RSIs ... 101
5.3 When should RSI be carried out? ... 102
5.3.1 RSI and accident data ... 103
5.3.2 Driving reasons to start RSI ... 103
5.3.3 Frequency of inspection ... 104
5.3.4 Inspection and maintenance ... 104
5.4 Partners in the RSI process: their roles and responsibilities ... 105
5.5 Liability issues ... 106
5.6 The inspection process ... 107
5.6.1 Overview/Introduction ... 107
5.6.2 Guidelines for RSI ... 107
5.6.2.1 Inspection conditions ... 107
5.6.2.2 Approach from the perspective of all road users ... 108
5.6.2.3 Independent and multidisciplinary approach ... 109
5.6.2.4 Fundamental safety elements ... 110
5.6.3 Phased approach ... 110
5.6.3.1 Preparatory work in the office (= step 1) ... 111
5.6.3.2 Field study (= Step 2) ... 113
5.6.3.3 RSI findings and inspection report (= Step 3) ... 114
5.6.3.4 Completion of the RSI (= Step 3) – Recommendations and final meeting 118
5.6.3.5 RSI Action plan and Follow up (= Step 4) ... 119
5.7 Typical safety deficiencies – Some concepts ... 121
5.8 References ... 122
APPENDIX 1: Check lists for RSA and RSI - as proposed by the PIARC Technical Committee Road Safety ... 123
APPENDIX 2: RSA Report Template ... 151
APPENDIX 3: RSI Report Template ... 157
APPENDIX 4: Audit Response Template ... 162
APPENDIX 5: Guidelines for the national/local versions of this Manual ... 167
APPENDIX 6: Directive 2008/96/CE on road infrastructure safety management ... 168

Abbreviations

Abbreviation	**Meaning**
AADT	Average Annual Daily Traffic
AC	Accident Costs
ACD	Accident Cost Densities
ACR	Accident Cost Rate
AD	Accident Densities
ADT	Average Daily Traffic
AMF	Accident Modification Factor
AR	Accident Rate
BSM	Black Spot Management
CCR	Curvature Change Rate
ICRS	Inter-ministerial Committee for Road Safety
IHSDM	Interactive Highway Safety Design Model
IRI	International Roughness Index
NSM	Network Safety Management
OECD	Organisation for Economic Co-operation and Development
PSR	Present Serviceability Rating
PTW	Powered Two-Wheelers
RHR	Road Hazard Rating
RSI	Relative Severity Index
RSIA or RIA	Road Safety Impact Assessment
RSA	Road Safety Audit
RSI	Road Safety Inspection
RSM	Road Safety Management
SCRIM	Side force Coefficient Road Inventory Machine
SD	Severe material Damage-only accident
SI	Severe personal Injury accident

TERN	Trans-European Road Network
VRU	Vulnerable Road Users
VRS	Vehicle Restraint Systems

List of Figures

Figure 1: Road Safety Inspection as part of Road Safety Management - source BRRC 10
Figure 2: Overview of RSA and RSI compared to black spot management............................... 12
Figure 3: E67 Via Baltica: a secondary road, according to the definition 13
Figure 4: Comparison of (average) accident rate and critical accident rate (Source: PIARC Road Safety Manual, 2003, page 112)... 17
Figure 5: Curve radius and velocity (several international approaches)...................................22
Figure 6: Super elevation in development Road Safety manual (PIARC, 2003) 21
Figure 7: Speed differences and accidents of consecutive curves (LIPPOLD 1997) 22
Figure 8: Accident cost rate and radius of single curve, HAMMERSCHMIDT (2006) 24
Figure 9: Accident cost rate and CCR (HAMMERSCHMIDT 2006) 25
Figure 10: Ratio of consecutive curves, LIPPOLD (1997)... 26
Figure 11: Friction Force and its Properties 30
Figure 12: Texture Wavelength (m) Influence on Surface Characteristics................................ 31
Figure 13: Non-Linear Relationship between Wet-Pavement Crashes and Friction.................. 34
Figure 14: Percentage of Wet-Pavement Accidents and Friction 35
Figure 15: Crash Rates as a Function of Friction 36
Figure 16: Definitions of the Roadside Hazard Ratings used with the Accident Prediction Algorithm.. 41
Figure 17: Chance of single vehicle accidents on different slopes compared to a slope 1:7...... 42
Figure 18: Roadway cross section with examples for roadsides with clear zones..................... 44
Figure 19: Accidents per Mvkm for different access point densities... 49
Figure 20: Accidents per Mvkm for different access point densities... 50
Figure 21: Skew angles for different intersection forms.. 51
Figure 22: Skew angles for different intersection forms... 54
Figure 23: 9 conflict points of a 3-leg intersection and 6 conflict points of a 3-leg roundabout 58
Figure 24: 32 conflict points of a 4-leg intersection (Standard intersection) and 8 conflict points of a 4-leg roundabout 59
Figure 25: 18 conflict points of a staggered intersection (2 closely spaced T-intersections) 59
Figure 26: 18 conflict points of a 4-leg intersection with two jug handles 59
Figure 27: Deaths on rural roads by road user groups (2007-2009 average), source: ETSC, 2010 69
Figure 28: The option diagram for road sections outside built-up areas (CROW, 2007)............ 70
Figure 29: Secondary road with high volumes of motorised traffic and cyclists. Road marking and signing to highlight the presence of cyclists. (South Moravia region, CZ) 71
Figure 30: Unsuitable shoulder and warning sign with ”share the road” reminder (photo by Allen McGregor) 72
Figure 31: Advisory cycle lane on rural road in Holland.. 73
Figure 32: Cycle path along the rural road connects the adjacent village with town Prostejov in central Moravia region (CZ). It is used mainly for commuting traffic. 73
Figure 33: Cycle path connecting two villages in central Moravia region (CZ) is used instead of busy rural road 73

Figure 34: Cycle route turns from very busy secondary road to the left to cycle path without any measure (South Moravia region, CZ) ... 74
Figure 35: Warning signs on very busy main secondary road in front of its crossing with minor road with busy cycle traffic – a black spot (South Moravia region, CZ) ... 75
Figure 36: Semi-rural roundabout with separated two-way cycle paths (near city of Otrokovice, CZ) ... 75
Figure 37: Planning and design process ... 93
Figure 38: Participants in RSA ... 93
Figure 39: Procedure of safety audit ... 94
Figure 40: Accident contributing factors -Treat & al (1979) ... 100
Figure 41: Cost-effectiveness of the most promising road safety infrastructure investments – CEDR (2008) ... 102
Figure 42: Partners in the RSI process; their role and responsibilities - source BRRC ... 106
Figure 43: RSI must consider representative road conditions - source BRRC ... 108
Figure 44: Optical illusion – combination of horizontal and vertical curves – PIARC (2003) ... 109
Figure 45: Detailed situation map, here with location of the photos showing some deficiencies - source BRRC ... 112
Figure 46: An odometer used to locate the deficiencies - source BRRC ... 112
Figure 47: Inspection car with flashing lights and warning triangle (left) – Inspectors with reflecting safety vest (right) - source BRRC ... 113
Figure 48: RSI report - general information about the inspected road section and the inspection team members (example from SETRA, 2008) ... 115
Figure 49: RSI report - (basic) identification and illustration of deficiencies - source BRRC ... 116
Figure 50: above: risk matrix from a Norwegian inspection report; below: example from a Portuguese inspection report, Ratings: possible harm: 3 = slight; 2 = serious; 1 = very serious; probability of harmful event: IV = rare; III = occasional; II = frequent; I = very frequent (extracts from Cardoso & al., 2005). ... 117
Figure 51: Part of an inspection report with recommendations – source BRRC ... 118
Figure 52: Illustration of recommendations on short to long term ... 119
Figure 53: Actions planed after a road safety inspection in France (from SETRA, 2008) ... 121
Figure 54: Example of title page ... 152
Figure 55: Example of Introduction page ... 153
Figure 56: Example of Specific project details page ... 154
Figure 57: Example of Items resulting from the audit page ... 155
Figure 58: Example of Audit team statement page ... 156
Figure 59: Example of problems location map from Italy ... 158
Figure 60: Example of title page ... 158
Figure 61: Example of Introduction page ... 159
Figure 62: Example of Specific project details page ... 160
Figure 63: Example of Items resulting from the inspection page (Spain) ... 160
Figure 64: Example of Items resulting from the inspection page (Denmark) ... 161

List of Tables

Table 1: Mean cost per accident MCA(c) in €/A for evaluation of the current accident situation as a function of accident category (c) and road category for different European countries 15
Table 2: Influence of Texture on Some Variables 32
Table 3: Typical Skid Resistance Values in Finland 32
Table 4: U.K.'s Investigative Skid Resistance Values 33
Table 5: Gradation Used for Internally Draining Asphalt Mixes..... 35
Table 6: Crash Rates for Different Friction Intervals 35
Table 7: Crash Rates at Different Roadway Conditions 36
Table 8: Variability of PSR 38
Table 9: Recommended widths for obstacle free zones according to Road Safety handbook... 42
Table 10: AMFs for Installation of Left-turn Lanes on the Major Legs of Intersections 52
Table 11: AMFs for Installation of Right-turn Lanes on the Major Legs of Intersections 53
Table 12: Mean accident reductions in various countries 55
Table 13: Accident frequency at U.K. roundabouts by number of arms 1999 - 2003 55
Table 14: Accident frequency at roundabouts in different countries..... 56
Table 15: Comparative table of results commensurate with accident severity 57
Table 16: Results for Swedish accident model by Brüde and Larson..... 58
Table 17: Characteristic accident values for different intersection types (Schnüll et al. 1994) . 60
Table 18: Recommended intersection type for intersections between secondary roads and roads of other categories. 61
Table 19: B/C ratio of RSA 91
Table 20: Required audit documents 95
Table 21: Summary of effects on injury accidents to be expected as a result of road safety inspections – Elvik (2006) 101
Table 22: RSI and accident data following PILOT4SAFETY 103

1 Scope and Objectives of this Handbook

1.1 Introduction

The European Parliament and Council issued on 19/11/2008 the Directive 2008/96/CE on road infrastructure safety management, which foresees a series of safety checks, as well as the training and certification of road safety auditors.

The application field of the Directive is limited only to the TEN-T road network (covering only a part of EU highways), while the highest number of fatalities occurs on the so-called **"*secondary roads*[1]"**.

The PILOT4SAFETY project, co-financed by the European Commission (DG MOVE) aims to apply the Directive's approach on some selected secondary roads in the EU regions, in order to share good practices and define common agreed training curricula and tools for the qualification of road safety personnel.

PILOT4SAFETY is a pilot project, which only focuses on Road Safety Audits (RSA) and Road Safety Inspections (RSI) out of all the measures indicated by the Directive, as these two procedures greatly influence the road safety factors for infrastructure and at the same time are easily managed.

One of the tasks of the project is to develop tools for the auditing and inspections of secondary roads in a selected group of EU regions by implementing the deliverable of the FP6 RIPORD-ISEREST project: "Safety Handbook of secondary roads", as well as other relevant training materials from other sources.

The aim of this manual is to support the training of road safety auditors and road safety inspectors. This manual is composed of this introduction, a general road safety part which comes from several EU research projects and the two specific RSA and RSI sections.

<u>Its structure has been conceived to allow each individual regional or local road manager to add specific parts that comply with his/her local needs;</u> the present version has been updated to take into account the results of the 10 international RSAs and RSIs carried out during the project.

Two months after the start of the project, the European Commission issued the Communication COM(2010) 389 final "*Towards a European road Safety area: policy orientation on road safety 2011-2020*", where it is clearly stated in objective number 3 that "t*he Commission will promote the application of the relevant principles on infrastructure safety management to* ***secondary roads*** *of Member States, in particular through the exchange of best practices*".

The PILOT4SAFETY partners are proud to see the basic concepts of the project included in this Deliverable.

[1]Two lane paved roads outside the urban areas, as defined in the RIPCORD-ISEREST project

1.2 Definition of Road Safety Procedures

With its Directive No. 2008/96 on Road Infrastructure Safety Management published in October 2008, the European Union made a clear decision that RSAs and RSIs will be mandatory for the Trans-European Road Network (TERN) in the next years. In the mentioned Directive, RSA and RSI are components of a package composed of the following road safety procedures:

- Road safety impact assessment (RSIA or RIA) (article 3),
- RSAs for the design stages of roads (article 4),
- Safety ranking and management of the road network in operation (incl. management of high-risk road sections) (article 5)
- RSIs for existing roads (article 6).

As a basis for PILOT4SAFETY, a clear definition of the relevant procedures and a clear understanding of how these procedures complement each other within the overall road infrastructure safety management are necessary. In the following section, major emphasis will be given to RSI and RSA while RSIA (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) will not be considered. An explanation of “Black Spot Management” and “Network Safety Management” is given at the end of this section.

1.2.1 Definition of Road Safety Audit (RSA)

An RSA is a systematic and independent investigation of the safety deficits of construction projects. The objectives of RSAs are to design roads under construction, as well as carry out redevelopment and expansion works as safely as possible and minimise the risk of accidents. An RSA emphasises the issue of road safety in the entire planning, design and construction process. The RSA covers all stages from planning to early operation. Following on from the RSA, road safety must be balanced against all other factors in a comprehensive review. The outcome is a formal report which identifies any road safety deficiency and, if appropriate, makes recommendations aimed at removing or reducing the deficiency.

The systematic application of RSAs should therefore result in the satisfaction of the safety needs of all relevant road users (motorists, cyclists, pedestrians and other transport means) following new construction, redevelopment and expansion projects.

Article 2 of the Directive defines RSA as “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.”

1.2.2 Consolidated definition of RSA as adopted by PILOT4SAFETY

Within this project, the following definition is used:

A **Road Safety Audit** (RSA) describes a systematic and independent examination of a project designed to highlight potential security issues at the earliest possible stage of planning and construction, to reduce or eliminate these problems and limit the risk for different types of road users.

It has to be stated that RSA has a strong relationship and many similarities with RSI and it is interesting to provide a reminder here of their role in the global approach to road infrastructure safety management and how they are linked to the three other procedures of the Directive. This is the purpose of Figure 1.

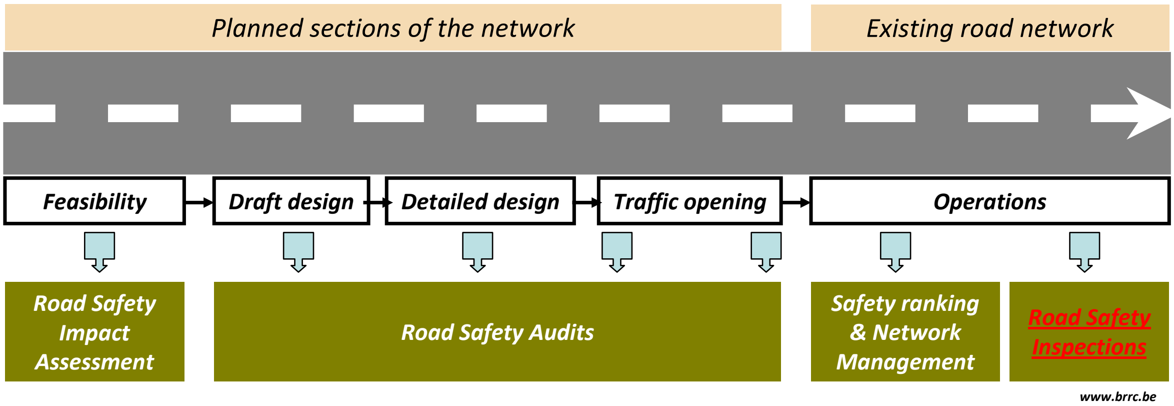


Figure 1: Road Safety Inspection as part of Road Safety Management - source BRRC

1.2.3 Definition of Road Safety Inspection (RSI)

Following the Directive (*Article 2 "Definition"*), 'safety inspection' is a dedicated periodical verification of the characteristics and defects that require maintenance work for reasons of safety.

In its *Article 6* entitled *"Safety inspections",* the Directive also stipulates that:

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 of periodic inspections on the road network and surveys on the possible impact of road works on the safety of the traffic flow;
3. Member States shall ensure that periodic inspections are undertaken by a competent entity. Such inspections should be frequent enough to safeguard adequate safety levels for the road infrastructure in question.

The words underlined above explain the most important elements of an RSI and how it should be carried out. To a certain extent, a Directive is a result of a benchmarking process during which different practices and opinions (in short, the state-of-the-art at a certain time) are discussed together. Of course, such a process sometimes results in a compromise.

To have a comprehensive definition of RSI, it is important to widen the perspective as well as refer to other relevant bibliographical sources.

According to Allan (2006), an RSI is an on-site systematic review of an existing road or section of road to identify hazardous conditions, faults, deficiencies that may lead to serious accidents.

At the European level, the RiPCORD-iSEREST project tried to identify best practices for RSI and formulate recommendations. In this framework, a definition has been proposed by Cardoso & al. (2005) based on a common understanding (among countries surveyed and expert opinions) of RSI. RSI has been defined as:

- A preventive tool;
- Consisting of a regular, systematic, on-site inspection of existing roads, covering the whole road network;
- Carried out by trained safety expert teams;
- Resulting in a formal report on detected road hazards and safety issues;
- Requiring a formal response by the relevant road authority.

Following a survey on safety effects and best practices carried out amongst four European countries, Elvik (2006) proposed some guidelines for best practice with respect to RSI, i.e.:

- The elements to be included in RSIs should be known to be risk factors for accidents or injuries;
- Inspections should be standardised and designed to ensure that all elements included are covered and are assessed in an objective manner;
- Inspections should report their findings and propose safety measures by means of standardised reports;
- Inspectors should be formally qualified for their job;
- There should be a follow-up inspection after some time.

1.2.4 Consolidated definition of RSI as adopted by PILOT4SAFETY

The previous references illustrates that common practice for RSI is not yet standardised and various interpretations exist for how to conduct such an inspection. There is also no common definition. Yet the previous section has shown that there is a kind of common understanding of what an RSI should be.

A comprehensive definition of RSI has therefore been drafted (based on the different elements underlined in the two previous chapters) by the PILOT4SAFETY partners and adopted for this project.

A **Road Safety Inspection** (RSI) is a preventive safety management tool implemented by road authorities/operators as part of a global Road Safety Management. An RSI is a systematic field survey organised sufficiently frequently on all existing roads or sections of a road to secure adequate safety levels. It is carried out by trained road safety experts to identify hazardous conditions and deficiencies that may lead to serious accidents. RSI results in a formal report on detected road hazards and safety issues.

This definition is the result of an analysis of relevant references and, in this way, reflects the author's common understanding of the RSI procedure. However, the definition also raises some very important questions concerning current practices at the European level, such as:

1. Inspection frequency;
2. Use, or lack of use, of accident data within the RSI process;
3. Independence of the inspection team;
4. Reporting layouts and contents; more particularly, does it need to recommend some corrective safety measure?

These questions will be addressed in chapter 5 dedicated to RSI.

1.2.5 Black Spot Management, Network Safety Management

Once fully operational, the safety level of an existing road may be improved through other types of procedures: Black Spot Management (BSM) and Network Safety Management (NSM).

BSM and NSM aim at the identification, analysis and treatment of black spots and hazardous road sections, respectively. Black spots/hazardous sections are defined as any location/section that gets a higher number of expected accidents than other similar locations/sections as a result of local and section-based accident and injury factors. NSM differs from BSM by focusing on longer road sections of normally 2 to 10 km.

For many years, BSM and NSM have become important safety tools. Yet they also exhibit some limitations as explained in Cocu & al, (2011):

- They rely on accident statistics which are not always recent and not necessarily fully reliable (registration rate, accident localisation);
- Eliminating a black spot sometimes moves the area of increased accidents further up or down the road (mitigation of accidents);
- Black spot analysis basically concerns locations with a higher expected number of accidents; once these particular spots have been treated and the total number of accident decreased, this approach will become insufficient due to the "accident dilution" all along the network;
- Only a "small" number of accidents are concentrated on black spots; e.g. in Wallonia (Belgium), high and medium risk areas concern only 15% of accidents with injuries on regional roads.

These points demonstrate that mitigating procedures such as BSM and NSM are not the only steps necessary to achieve a drastic reduction in accidents and traffic fatalities. As stated in the Directive, pro-active safety measures applied largely on the road network are necessary, such as RSIs.

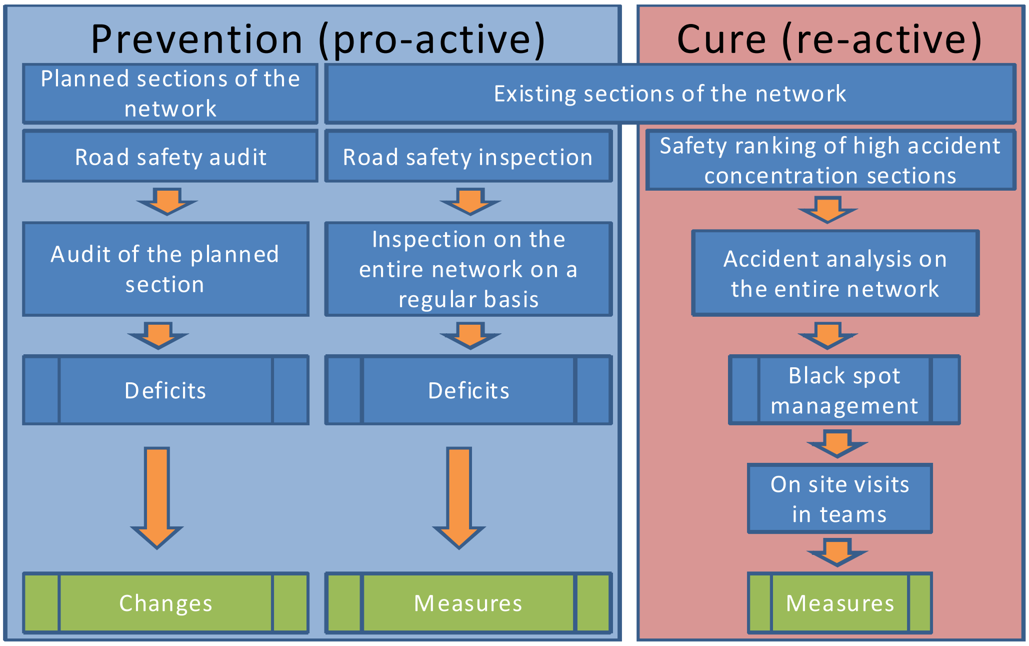


Figure 2: Overview of RSA and RSI compared to black spot management

Both RSA and RSI are pro-active procedures that aim to prevent accidents from occurring, while the management of high-risk road sites is a re-active procedure when accident numbers are already high (Figure 2).

1.3 Definition of Secondary Roads

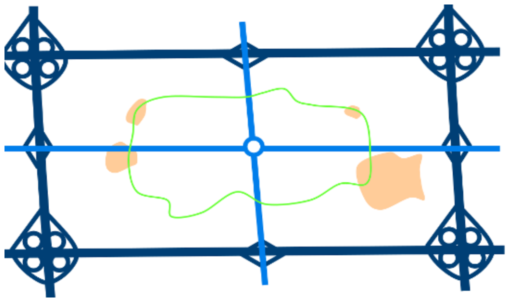
The Organisation for Economic Co-operation and Development (OECD) recognised that the understanding of rural road safety is hampered because "no formal accepted international definition exists to classify rural roads" (OECD, 1999).

OECD defines rural roads as roads that are "outside urban areas and that are not motorways or unpaved roads" (Hamilton, Kennedy, 2005). However, many different definitions can be found in different literature sources, and understanding of what is meant by "rural" is the key to understanding the risks associated with these kinds of roads.

For planning purposes, however, "rural" is used in opposition to "suburban" and "urban," which are more populous and can be defined by a combination of different criteria.

The need for a clear and standardised definition arises from the above consideration; this manual adopts the term "*secondary road*" for a road with the following **physical** characteristics:

1. **Single carriageway, two lanes**
2. **Paved road**
3. **Outside urban areas**



In several EU countries, the definition of secondary roads is mainly based on *functional characteristics* as in the scheme, where the different line colours and thicknesses indicate flow/connection roads, collection roads and access/residential roads.

However, since the safety measures are mainly related to the physical characteristics of the road infrastructure, <u>*this manual does not consider any functional distinction*</u>: main connection roads belonging to the TREN Network and complying with the given definition are also considered as secondary roads.

Figure 3: E67 Via Baltica: a secondary road, according to the definition

1.4 References

Kevin Hamilton and Janet Kennedy - Rural Road Safety: a literature review – Scottish Executive Social Research – 2005

2 Principles of Road Safety Engineering

2.1 Accident Analysis and Statistics

2.1.1 Number and Severity of Accidents, Period under Review

Due to the different legal basic conditions and reporting practices, extent and coverage of national accident databases differ widely within European countries. Furthermore, accident categorisations (accident types) also show many inconsistencies between the various countries. Therefore, international accident comparisons (e.g. IRTAD – www.irtad.net) usually concentrate on restricted accident populations such as fatalities. Best reported accident data are usually available for motorways and the national road network. Damage-only accidents are in most cases not part of national accident databases.

For a ranking of road sections to be treated by road administrations, the evaluation should be based on all available information in order to achieve statistically reliable results. Consequently, for the network under review, data of less severe accidents should also be included in the analysis if available.

Concerning the described methodology, the following accident categories can be distinguished:

- SI Severe personal injury accident (accidents with fatalities and seriously injured persons)
- MI Minor personal injury accident (accidents involving people suffering minor injuries)
- SD Severe material damage-only accident

Differing definitions of those accident categories do not affect the methodology, but have to be considered when adapting the parameters to the national situation.

Sufficiently large accident numbers must be available for analysing existing roads. If not, statistical tests should be conducted. The number of fatal accidents is often very low, especially on short sections with low traffic volumes, and the ranking would not provide statistically reliable results. The calculation should also include severe personal injury accidents (SI).

Concerning the period under review, experience has shown that periods of 3-5 years are appropriate to prevent general trends and changes in the infrastructure having a large impact on the calculation of the safety level.

2.1.2 Accident Costs

When analysing accidents of different categories, each accident should be weighted by their respective accident severity. Accident costs (AC) are used to assign a monetary value to different accident types and severity values and hence increase their comparability.

It is well known that differing approaches are applied in European countries to estimate AC. As long as these national accident cost values are used only to determine a ranking of road sections within a country, the results are not affected by the different accident cost calculations. ACs are widely used for calculating the cost-benefit ratio of remedial (road safety) measures, including national construction costs.

Mean Costs per Accident (MCA) have to be calculated as a function of accident severity c and the road type for each country. These values represent the structure of injuries (e.g. the number of fatalities seriously injured and slightly injured people in 100 accidents of the category under review) and are, therefore, strongly affected by differences in severity definitions. For each road section within the network, accident costs (AC) of each severity level c are calculated by multiplying the number of accidents A(c) with the mean cost per accident MCA(c):

Accident cost AC [€]

$$AC(SI) = A(SI) \cdot MCA(SI)^{2}$$
$$AC(SI + MI + SD) = A(SI) \cdot MCA(SI) + A(MI) \cdot MCA(MI) + A(SD) \cdot MCA(SD) \quad (1)$$

Where

A(c)	Number of accidents of a specific accident category c in t ≥ 3 years	[A]
MCA(c)	Mean cost per accident as a function of accident category c (Table1)	[€/A]
SI	Severe personal Injury accidents	
MI	Minor personal Injury accident	
SD	Severe material Damage-only accident	

Table 1: Mean cost per accident MCA(c) in €/A for evaluation of the current accident situation as a function of accident category (c) and road category for different European countries

Mean cost per accident [€/A]						
	Motorways			Secondary roads		
	Accident category					
Country	**SI**	**MI**	**SD**	**SI**	**MI**	**SD**
A**	320.000			290.000		
B**	315.000			285.000		
CH**	340.000			305.000		
D	300.000	31.000	18.500	270.000	18.000	13.000
DK**	335.000			300.000		
E**	245.000			220.000		
F	515.000	36.500	-	550000	40.000	-
FIN**	300.000			270.000		
GB**	300.000			270.000		
GR**	185.000			165.000		
I**	300.000			270.000		
N**	300.000			270.000		
NL**	335.000			300.000		
P**	200.000			180.000		
S**	295.000			265.000		

2000 price level

Usually the accident costs are related to the period of one year, which results in:

Annual average accident cost AC_a [€/year]

[2] It is possible to distinguish between fatal and serious injury accidents:
AC(SI) = A(F) · MCA(F) + A(S) · MCA(S)
Where
F Fatal accidents
S Accidents with seriously injured people
** Dummy values derived from German data (cost and casualty structure) by multiplication with factor representing GDP ratio to be updated later based on national data.

$$AC_a(SI) = \frac{A(SI) \cdot MCA(SI)}{t}$$

$$AC_a(SI + MI + SD) = \frac{A(SI) \cdot MCA(SI) + A(MI) \cdot MCA(MI) + A(SD) \cdot MCA(SD)}{t} \qquad (2)$$

Where

t	Period of time under review	[years]

2.1.3 Accident Densities

Accident densities (AD), respectively accident cost densities (ACD), describe the average annual number of accidents, respectively, of overall costs incurred to the economy by accidents occurring over a 1 km length of a road section.

The density can be calculated as the ratio of the annual number of accidents respectively accident costs and length of the road section on which the accidents occurred.

Accident density AD [A/(km · a)]

$$AD = \frac{A}{L \cdot t} \qquad (3)$$

Accident cost density ACD [1000 €/km · a)]

$$ACD = \frac{AC}{1000 \cdot L \cdot t} = \frac{AC_a}{1000 \cdot L} \qquad (4)$$

Where

A	Number of accidents in t years	[A]
L	Length of road section	[km]
t	Period of time under review	[years]
AC	Accident cost in t years	[€]
AC_a	Annual average accident cost	[€/year]

The density is thus a measure of the (length-specific) frequency at which accidents have occurred during a specific period over a specific road section.

2.1.4 Accident Rates

The kilometre-related accident figures of road sections are given by accident rates and accident cost rates.

Accident rate AR A/(10^6 veh · km)]

$$AR = \frac{10^6 \cdot A}{365 \cdot ADT \cdot L \cdot t} = \frac{10^6 \cdot AD}{365 \cdot ADT} \qquad (5)$$

Where

ADT	Average daily traffic in t years	[veh/24 h]

Accident cost rate (ACR) [€/(1000 veh · km)]

$$ACR = \frac{1000 \cdot AC}{365 \cdot ADT \cdot L \cdot t} = \frac{10^6 \cdot ACD}{365 \cdot ADT} \qquad (6)$$

Accident rates (AR) describe the average number of accidents along a road section per one million vehicle kilometres travelled. Accident cost rates (ACR) describe the corresponding average cost as the result of road accidents which have occurred along this road section per 1000 vehicle kilometres travelled.

Critical accident rate (CAR)

This criterion compares the accident rate at a site with the average accident rate calculated in a group of sites having similar characteristics (reference population). The basic assumption is that sites having similar characteristics should also have similar safety levels. The critical accident rate defines the minimum accident rate value at which a site is considered hazardous.

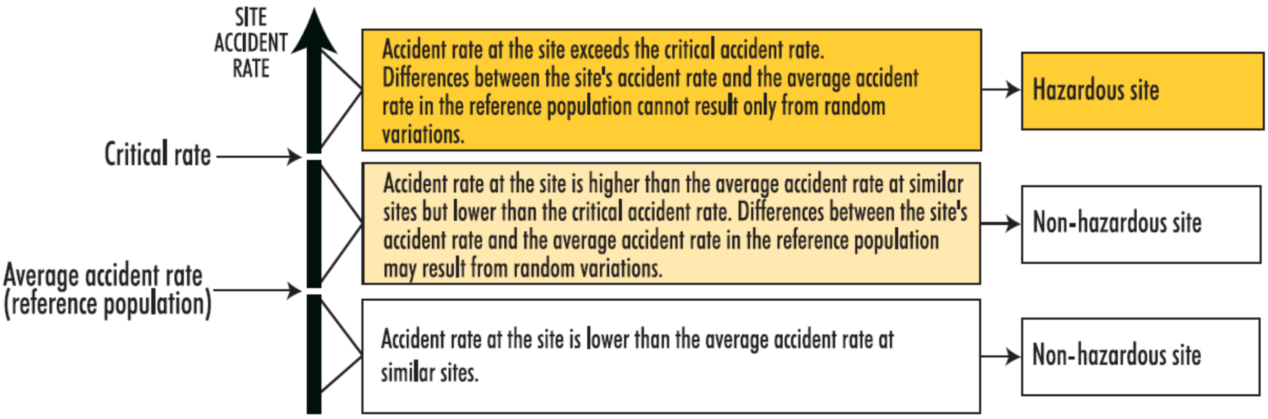


Figure 4: Comparison of (average) accident rate and critical accident rate (Source: PIARC Road Safety Manual, 2003, page 112)

Several road features have an influence on accident risk. Main rural roads, for example, which are designed and operated to higher standards than those for secondary rural roads, are usually safer in terms of accidents per vehicle-km. Therefore, the potential for improvement depends to a large extent on the nature of the site under study and the modifications that can be envisioned.

As a consequence, distinct reference populations should be defined to help determine what constitutes a representative safety level for a given type of site. Such populations are defined by taking into account the main road features having an impact on safety. For example, a reference population may be defined for two-lane + intersections in urban areas with stops on the minor legs, another population for T-intersections on similar roads, etc.

The procedure to calculate the CAR is as follows:

1. Calculate the accident rate (AR) at each site
2. Calculate the average accident rate for each reference population

$$R_{rp} = \frac{\sum f_j \times 10^6}{365.25 \times P \times \sum L_j \times Q_w} \qquad (7)$$

Where:

R_{rp} = average accident rate (acc./Mveh-km)
F_j = accident frequency at site j
P = period of analysis (years)
L_i = length of section j (km)
Q_w = weighted Average Annual Daily Traffic (AADT)

$$Q_w = \frac{\sum(Q_j \times L_j)}{\sum L_j} \tag{8}$$

Q_j = AADT of site j

Determine the minimum accident rate that warrants a detailed safety analysis

Relative Severity Index (RSI)

This criterion is based on the following considerations:

1) The severity of trauma sustained in any given accident is affected by several factors, such as the impact speed, impact point on the vehicle, type of vehicle, age and health condition of the occupants, protection devices, etc. Consequently, two accidents of the same type occurring at the same location may cause quite different trauma levels.

2) The average accident severity, as computed on a large number of similar accidents having occurred in similar road environments, is seen as a more stable indicator than the trauma level sustained in a single accident.

The relative severity index (RSI), therefore, ascribes to each accident type a weight that is not related to its actual severity, but instead to the average severity of several accidents having occurred under similar conditions. The average severity is best expressed in monetary terms, i.e. severity multiplied with the respective accident cost factor.

The procedure to calculate the RSI is as follows:

a.) For each reference population:

- Calculate the average cost of each accident type in the reference population
- Calculate the RSI and the average RSI ($\overline{RSI}$) at each site

$$RSI_j = \sum f_{ij} \times C_i \tag{9}$$

Where:

RSI_j = relative severity index at site j
f_{ij} = frequency of a type i accident at site j
C_i = average cost of a type i accident

$$\overline{RSI}_j = RSI_j / f_j \tag{10}$$

Where:

f_j = total accident frequency of site j

- Calculate the population average RSI ($\overline{RSI}_{rp}$):

$$\overline{RSI}_{rp} = \frac{\sum\sum(C_i \times f_{ij})}{\sum f_j} \tag{11}$$

- Determine the minimum value of $\overline{RSI}$ that warrants a detailed safety analysis

2.2 Geometric Parameters Affecting Road Safety

Knowledge about the impacts of road geometry is an important precondition of a detailed and serious accident analysis. The following chapters give an overview of the geometric factors which influence the driver's speed (driving behaviour[3]) and the geometric factors usually correlated with accident analysis results.

2.2.1 Geometric Parameters and Velocity

2.2.1.1 Definition and Indicators of Driving Behaviour

At present, there are no detailed driving behaviour models: all scientific works based on the investigation of objective indicators assume that driving behaviour is the vehicle control in longitudinal and transverse direction.

Common parameters to describe and analyse driving behaviour are speed, acceleration and lateral position.

Speed

Speed is the distance travelled divided by the time of travel. Speed is an important value in road design; several design parameters are influenced by speed (design speed or 85th percentile speed[4]).

Basically, there are two different speeds: the speed which is influenced by the traffic facility and the environment, respectively, and the speed which is additionally influenced by traffic. To investigate the impacts of road geometry and environment, only the first one should be considered. For this purpose, the "spot speed" (speed in a defined spot at a defined time) should be used.

Acceleration

Acceleration is defined as the rate of change of speed over time. Longitudinal acceleration is a value of speed change and can be used (as well as the centrifugal acceleration) as a criterion which gives information about how fast a driver changes speed or which speed is considered as acceptable at a curve.

Lateral Position

Lateral position is the position of the vehicle within a lane or at least within the carriageway. It is a geometrical value, which is the distance between the roadside or centre of the road and the vehicle's longitudinal axis. This indicator gives the possibility to analyse the driven track and is a good indicator to investigate the "*corner cutting*" in the curves.

[3]The multiple complex factors affecting driver behaviour are not considered in this handbook: a good in-depth analysis is made in the book of Gert Weller "The psychology of Driving on Rural Roads" –VS Verlag 2010.
[4] The 85th percentile speed is the speed which 85% of the vehicles are not exceeding.

Straight Sections

On straight sections, the driving speed depends above all on the legal speed limit, the environment and current traffic conditions. In general, speed on straights is high, particularly if there is no influence of other vehicles. Usually the longer the straight, the higher the speed and consequently the risk: in all the design guidelines, the maximum length of straights is restricted to avoid high speeds.

Curve Radius

In numerous research projects, the influence of curve radii on driving behaviour (speed) was evaluated (e.g. FIEDLER 1967, KÖPPEL/BOCK 1979, DAMIANOFF 1981, SCHNEIDER 1986, STEIERWALD/BUCK 1992, LIPPOLD 1997). Figure 5 shows some functional approaches of the last decades. Especially in the range of small radii, the approaches differ extremely from each other: one reason is the development of cars in the past. Modern chassis allow people to drive faster, but still safely, through a curve.

These investigations showed a huge impact of curve radii smaller than 250 m; the impact decreases in curve radii greater than 350 m. In general, speed investigations in curves are characterised by a variance above 20 km/h, which shows the variety of impact factors. It is proved that other geometric parameters of curves, such as heading change, length, etc., must also be considered.

Regarding road safety, one of the main problems is the transition from a straight alignment to a curve with a small radius. It is considered proven that the smaller the radius, the lower the speed, and therefore the higher the speed difference in consecutive curves of different radii. The absence of a good relationship between consecutive elements leads to high accident frequencies: on a short distance, drivers have to decelerate the vehicle up to the curve speed. In this situation, usually drivers brake too late and enter the curve too fast, causing run-off accidents, or they compensate their speed by “corner cutting”, which might result in a crash with incoming vehicles.

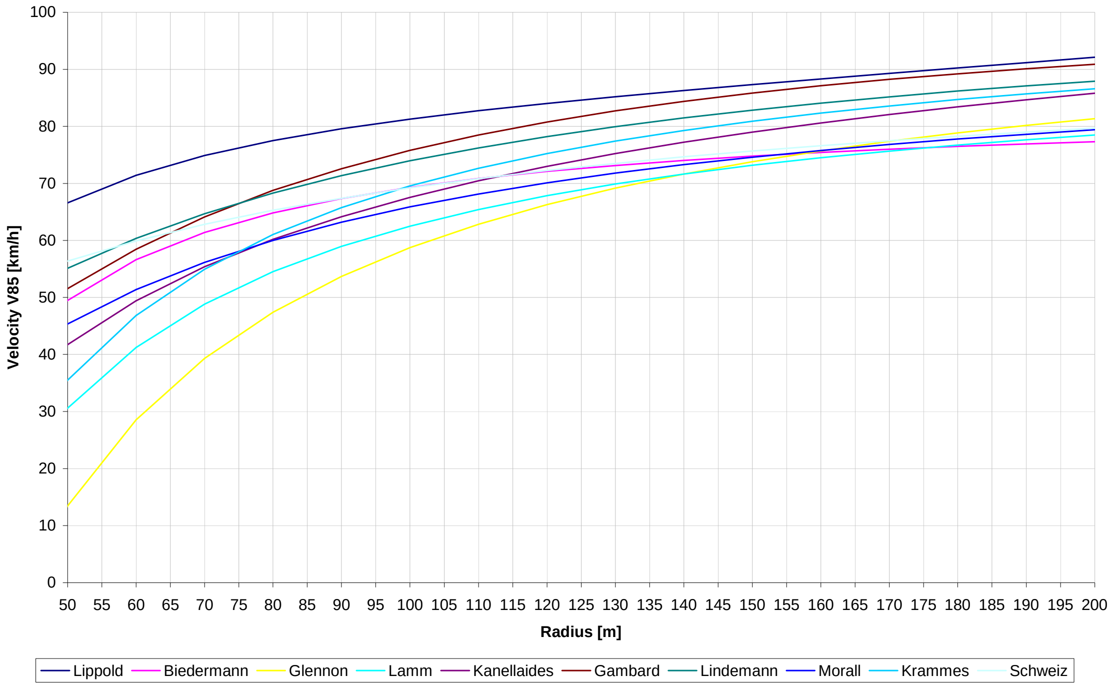


Figure 5: Curve radius and velocity (several international approaches)

Super elevation

"A transition zone between the tangent and the horizontal curve is needed to gradually introduce the super elevation. In parts of this zone, the road profile becomes flat on its outer side, which can lead to water accumulation and contribute to skidding. The end of this flat zone must be located before the start of the curve and special attention must be paid to the quality of drainage in that area." (PIARC, 2003)

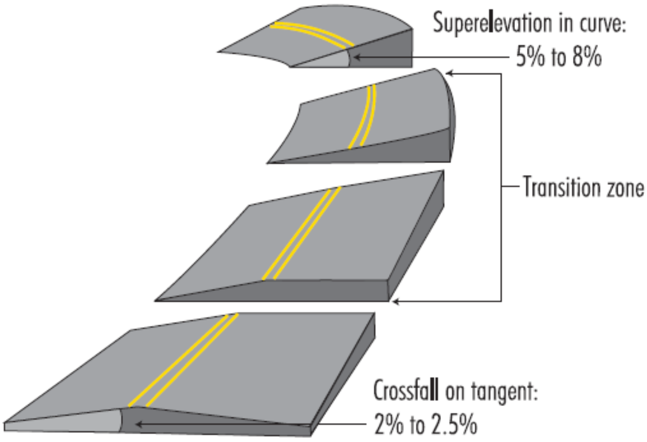


Figure 6: Super elevation in development Road Safety manual (PIARC, 2003)

Grade

The influence of a grade is only important above a certain value. The reason for this is the development of automotive engines in the last years. In former times, investigations showed an impact of grades above 2% (DIETRICH 1965, TRAPP 1971, TRAPP/OELLERS 1974, KÖPPEL/BOCK 1979). Today, only grades above 6% influence the speed of vehicles (LIPPOLD 1997).

Steep downgrades are critical because of the fast increasing speed, while step upgrades are critical because they might lead to great differences in speed between lorries and cars.

Curvature Change Rate (CCR)

Various research projects have shown a correlation between the Curvature Change Rate[5] (CCR) and speed behaviour (e.g. KÖPPEL/BOCK 1979, BIEDERMANN 1984, LIPPOLD 1997). CCR above 100-150 gon/km has an impact, for lower CCR the speed is influenced by non-geometric parameters such as legal speed limit, environment, etc. Analogous to the models for single curves, further parameters have to be considered to analyse the impact of CCR (e. g. road width).

The transition between road stretches with huge differences in CCR from a straight alignment into a road stretch with many curves might also be critical due to high speed differences.

Width

The road width (or lane width) is the main indicator of a cross section: there are different opinions about its influence on safety. Former investigations have shown a small impact of the lane width on driving behaviour (TRAPP 1971, LAMM 1973, TRAPP/OELLERS 1974).

KÖPPEL/BOCK (1979) have investigated the influence of lane width in connection with CCR and determined a lower level of speed with similar CCR and decreasing lane width. LIPPOLD (1997) also verified this

[5] CCR is defined as the absolute angular change in horizontal direction per unit of distance.

correlation for single curves and CCR sections. In his investigation, the lane width is differentiated within three groups: 5-6m, 6-7m and 7-8m. Lanes wider than 6m have the same correlation, so the impact of lane width over such a value is very low. Widths below 6m differ significantly.

Consecutive Elements

Driving behaviour is also influenced by directly consecutive elements, especially by their parameter differences, which result in a speed profile which is not homogeneous. Several research works prove that high speed differences might be dangerous.

KOEPPEL/BOCK (1970) have determined an interaction between the curve radius and the average curve speed if the change of radius is less than 20%. The results of this investigation were included in the German guideline in 1973 (RAL-L-1 1973). LEUTNER (1974) also proved large differences in the speed profiles on roads with a discontinuous alignment. AL-KASSAR et al. (1981) determined an increasing accident risk as a result of inhomogeneous speed behaviour in unbalanced radii.

LIPPOLD (1997) compared speed behaviour and accidents on roads with and without balanced alignment. There were significantly fewer accidents if the alignment was continuous. The results of his research are given in Figure 7. Within the diagram, accidents which happened in S-curves or in transition sections between a tangent and a curve (circle symbol) and accidents which happened in consecutive curves (triangle symbol) are distinguished.

The figure shows that especially in transitions from a bigger radius into a smaller radius, the accident risk is significantly higher. Based on this study, the German guideline was improved concerning its requirements for balancing consecutive elements (curves).

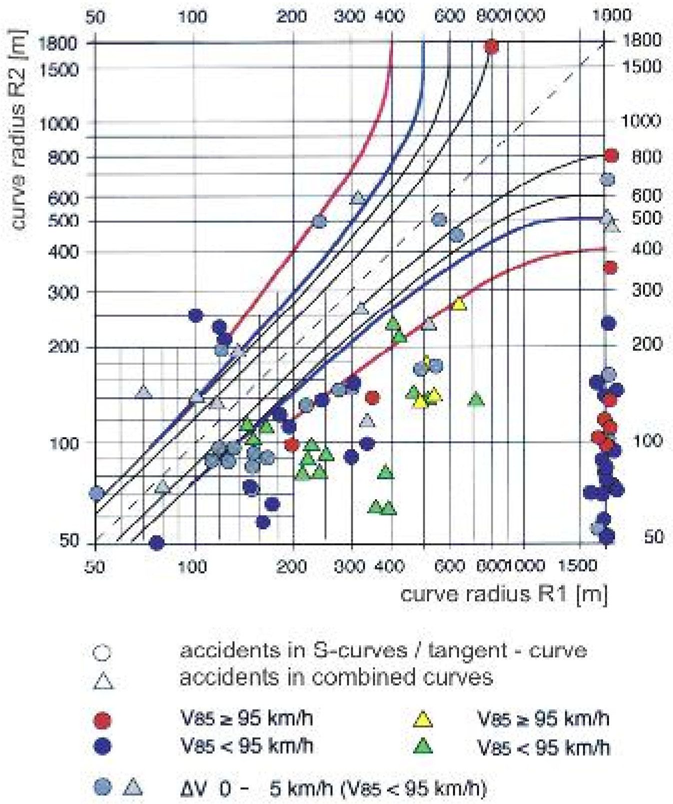


Figure 7: Speed differences and accidents of consecutive curves (LIPPOLD 1997)

Spatial Elements

Spatial elements are based on the combination of design elements for the horizontal and vertical alignment and simplify the evaluation of the spatial alignment.

WEISE et al. 2002 investigated spatial elements regarding their influence on driving behaviour. The results showed that the speed is lower in straight crests with grade switch than in straight sags with grade switch. Similar results were obtained for curved spatial elements. Higher speeds were measured in curved crests with grade change than in curved crest with grade switch. Furthermore, speed differences became higher with increasing curve radius. A similar speed level was determined for small curve radii, and this again shows the dominant impact of the curve radius.

2.2.2 Geometric Parameters and Accidents

Numerous scientific investigations have worked out the importance of geometric parameters as an influencing factor on road safety. In the existing literature the following parameters are especially mentioned:

- Horizontal plan
    - Radius
    - Degree
    - Curvature Change Rate
    - Balanced elements
    - Radii ratio
- Vertical plan
    - Grade
    - Radius
- Cross section
    - Lane width
    - Shoulder width
- Sight distance

Some of these parameters interact, such as the curvature change rate and the sight distance, so they cannot be discussed separately.

2.2.2.1 Horizontal Alignment

Curve Radius

Most investigations showed that increasing radii cause lower accident frequency. Radii smaller than 500m (McBEAN 1982), or 600m (JONSTON 1982), are associated with higher accident rates. OECD (1976) suggested radii smaller than 430m as critical, and it is proven that most accidents in curves are run-off accidents. KREBS/KLÖCKNER (1977) found a high number of accidents caused by speeding in small curves.

LEUTZBACH/ZOELLMER (1988) found that the AR, as well as the aACR, decreases up to the radii value of 1000m. Greater radii are again characterised by increasing accident rates and cost rates. These results confirm the investigation of KREBS/KLÖCKNER (1977) which show that the safety benefit decreases in radii above 400m.

In GLENNON et al. (1985), the curve degree has been used as a parameter instead of the curve radius. Road segments of a length of 1km, consisting of a curve and tangents of at least 200m were investigated: in general, the results did not show a different relationship.

An increasing accident rate in radii below 1000m and greater than 3300m was shown in the investigation of HEDMAN (1990). The model of ZEGEER et al. (1991) gives two general conclusions: the narrower the road, the higher the number of accidents and the smaller the radius, the higher the number of accidents.

His model suggests a higher influence of the curve length than the curve degree (or radius), except in small curves where the length is much less important than the curve degree.

In HAMMERSCHMIDT (2006), ACR for single curves has been calculated (Figure 8). Single curves with radii of 50-150m have shown high ACR; smaller radii are less critical due to their associated lower speeds. Radii above 150m show lower ACR.

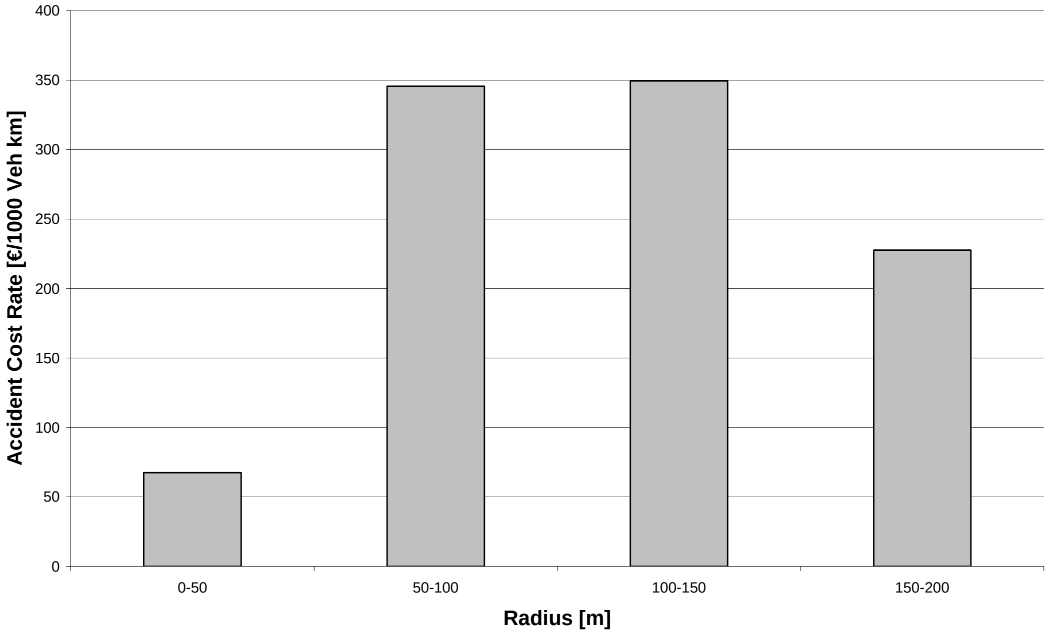


Figure 8: Accident cost rate and radius of single curve, HAMMERSCHMIDT (2006)

All investigations pointed out an important impact of the curve radius on road safety. In fact small radii above 50m up to 150m are characterized by a higher accident frequency as well as accident severity. The most typical accident type is the run-off the road accident. There are different opinions concerning at which radius the impact decreases (within the range from 400m to 600m).

Curvature Change Rate (CCR)

Various research projects have shown that the Curvature Change Rate (CCR) as a value for consecutive elements correlates with safety relevant parameters. The CCR characterises a combination of consecutive elements, in spite of the radius which represents only a single element. The background is that identical radii could cause a different driving behaviour and therefore a different accident risk (DILLING 1973, KOEPPEL/BOCK 1970, DURTH et al. 1983). Therefore, the CCR is a more appropriate value to describe the geometric properties of several elements.

PFUNDT (1969) and BABKOV (1975) investigated the relationship between the number of curves and the number of accidents. They found that roads with many curves are characterised by fewer accidents than roads with few curves. KREBS/KLÖCKNER (1977) derived a correlation between the CCR and accident indicators: the higher the CCR, the higher the AR and ACR. HIERSCHE et al. (1984) investigated roads with modern and historical alignment. Due to an increasing CCR, they found a progressive incline of AR on historical alignments but a decline on roads with modern alignment.

These results were also proved in DURTH et al. (1988). Analogous to HIERSCHE (1984), they investigated modern and historical alignments. The results show that roads with similar CCR and continuous alignment are characterised by lower accident risk than roads with a discontinuous alignment. In general, a higher CCR is associated with higher AR and cost rates. LEUTZBACH/ZOELLMER (1988) derived a slight increase of the AR related to the CCR. At CCR=100 gon/km, the increase stops and the AR becomes lower while the CCR increases. They assume that two different effects are overlapping: on the one hand, the number of accidents increases according to the traffic volume and, on the other hand, the average of accident severity decreases because the increasing CCR causes a lower speed. Due to the various accident types, LEUTZBACH/ZOELLMER (1988) found that the number of driving accidents and accidents in longitudinal direction increases with the CCR. This trend is also shown by the AR which increased twice. These results show a higher risk of driving accidents if the horizontal alignment is characterised by many curves.

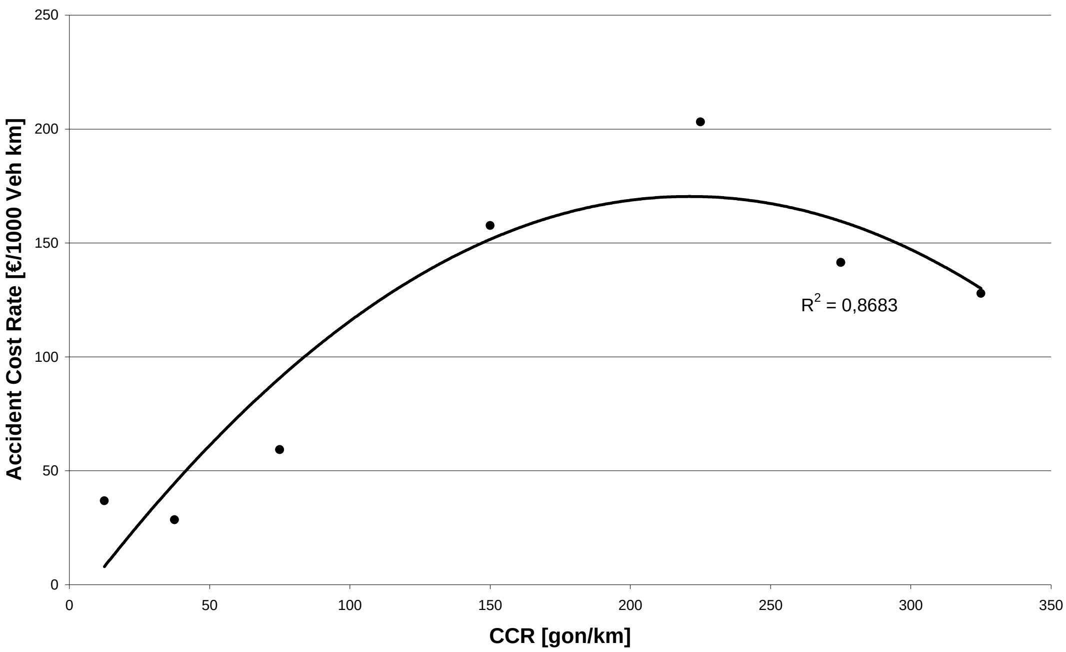


Figure 9: Accident cost rate and CCR (HAMMERSCHMIDT 2006)

The study of HAMMERSCHMIDT (2006) investigated the relation between CCR and accident parameters on 500km of secondary rural roads. The results are given in Figure 9. CCR of about 150 gon/km-250 gon/km have especially shown high AR; CCR below 100 caused less than 25% accident costs and CCR above 250 are characterised by a decline of ACR again because of low speeds.

A correlation between the CCR and accident indicators was shown in numerous research projects. The CCR is an appropriate value to characterise a road stretch with many curves. On such road sections, driving behaviour is not influenced by single elements but by the combination of consecutive elements: it is known that within these sections with similar geometry, the speed driven is approximately constant. Due to the effects on driving behaviour, the accident indicators have to be influenced as well. In general, it is proven that the higher the CCR, the higher the risk of an accident.

The severity of accidents decreases with the increasing of CCR, because of declining speed: this is the main difference between road stretches of similar geometry (CCR=const.) and single elements which discontinue the alignment.

Transition Tangent – Curve/Balanced Alignment

Investigations of CCR have shown that consecutive elements influence driving behaviour and therefore road safety. It is known that a discontinuous alignment causes a higher accident risk than a continuous alignment. Due to these facts, modern road design guidelines require a so called *balanced alignment*, where the ratio of radii of consecutive elements is comprised within a defined range. The balanced consecutive elements avoid discontinuous transitions and the speed does not need to change abruptly: therefore, the risk of an accident decreases.

LAMM et al. (1999a) investigated the element combination tangent–curve. They determined a negative influence of curve smaller than 150m. But curves up to 300m must also be rated as safety critical (LAMM et al. 1999b). The research work of LIPPOLD (1997) pointed out that transition from a straight line into curve smaller that 100–200m are characterised by a high accident frequency.

In LEUTZBACH/ZOELLMER (1983), consecutive curves were analysed. The coefficient between the radii of the current curve and the previous curve were compared to the AR and ACR. In LIPPOLD (1997), accidents occurring in consecutive curves were investigated. The findings are that the accident frequency is high on stretches where the alignment changes from large into small curves. Such combinations are inappropriate, but combinations with smaller differences may also cause accidents. LIPPOLD improved the so called “radii tulip” which is shown in Figure 10.

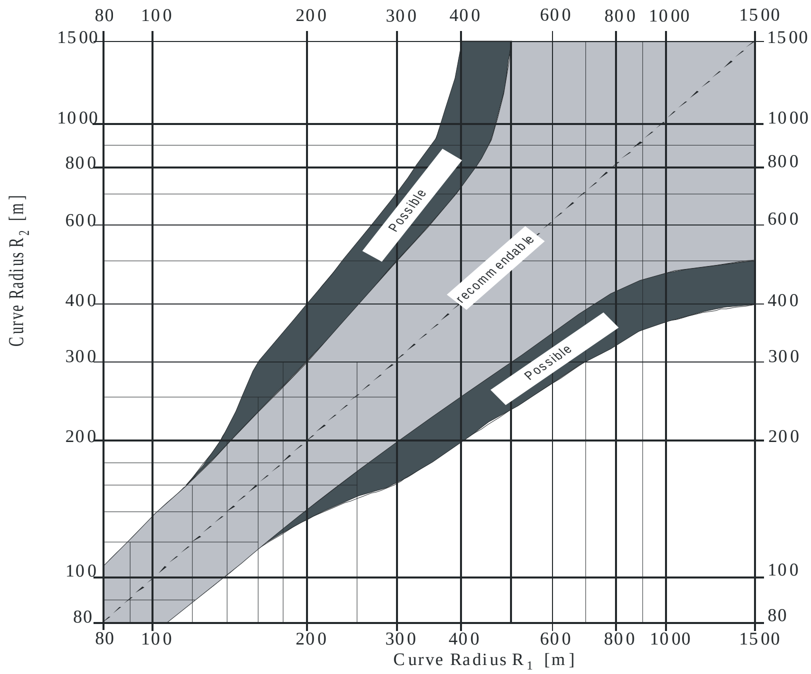


Figure 10: Ratio of consecutive curves, LIPPOLD (1997)

The investigation resulted in a definition of recommendable, possible, and unacceptable radii combinations based on determined AR as well as ACR. The investigation of LAMM et al. (1999a) shows similar results. Radii ratios below 0.8 result in a significant increase in AR, and above 0.8 the impact becomes low.

The balancing of consecutive elements such as straight–curve and curve–curve has an important influence on road safety. The transition between straights and curves is safety critical if the curve radius is below 200m.

2.2.2.2 Vertical Alignment

In contrast to the horizontal alignment, the vertical alignment has a smaller impact on road safety.

Grade

Over the last decades, numerous research works showed a different influence of grades on road safety.

KREBS/KLÖCKNER (1977) have determined an influence of high grades above 6-7% on AR. Lower grades are characterised by small impact. In HIERSCHE et al. (1984), downgrades and upgrades were investigated separately concerning AR and a beneficial interval between 0% and ±2% was determined: the accident risk decreases slightly on downgrades >2%.

LEUTZBACH/ZOELLMER (1988) investigated nine grade classes on 1273km and determined a slight incline of AR due to increasing grades. This incline is higher for grades ≤3% than in the interval 3-6%. They assumed that the higher the grade, the lower the accident severity. DURTH et al. (1988) found a larger increase of accidents in sections with grades above 7%. Steeper grades are generally associated with higher AR. HOBAN (1988) confirmed the fact that grades above 6% are associated with higher AR.

HEDMAN (1990) found that grades of 2.5% and 4.0% increase accidents by 10% and 20% compared to horizontal road sections. ZEGEER et al. (1992) showed that downgrades are characterised by a higher accident risk. MIAOU (1996) worked on the relation between the change of grade and accident risk. He also determined a different influence of down- and upgrades.

LAMM et al. (1999a) classify grades into three groups: 0 to 4% safe, <6% small impact and >6% relevant impact.

The results of investigations into the existing literature have changed opinions about the influence of grades on road safety. Due to the development of automotive engineering, the impact has declined. Today an increasing accident risk in steep downgrades is proven.

Vertical Curves

Vertical curves are distinguished in crests and sags. Both elements deal with different safety problems.

Safety problems associated with vertical curves are distinguished into two groups: sight distance problems and distortion of horizontal curves.

The radius of crests mainly influences the sight distance. Therefore, the minimum for a crest radius is usually limited to guarantee a required stopping sight distance. In most countries, the stopping sight distance is defined as a minimum sight distance, allowing drivers to perceive an obstacle and stop the vehicle safely. Crests which occlude unexpected curves are also dangerous. However, problems of crest are problems of sight distance. Sags do not deal with sight distance problems during thr day, but at night sight is restricted by the light beam of the vehicle.

More important is the effect of distortion which is associated with sags. In contrast to crests, sags cause an optical enhancement of horizontal curves, so that curves may appear larger than they are. This may result in an inappropriate speed and eventually an accident. It is proven that curved sags are characterised by a higher AR (DURTH et al. 1988). Crests also influence the optical appearance of horizontal curves.

2.2.2.3 Lane width

Generally, most studies agree that lower AR are attributed to wider lanes. But it seems that there is an optimal lane width of around 3.50m. Studies have also noted that approaches should base themselves more on the parameters of the cross section, at least on traffic volume.

ZEGEERetal (1981), ZEGEER/COUNCIL (1993) and McLEAN (1985) have shown that widths of 3.4-3.7m show the lowest AR. In LEUTZBACH/BAUMANN (1983), the effect of cross section and traffic volume was investigated. The accident rate on cross sections with 6.50m width of the carriageway is four times higher than cross sections with a width of 12m. A similar effect is shown by HIERSCHE et al. (1984), who investigated the German standards. 90 km of road were redesigned, corresponding to the national guidelines. According to the regression analysis, the AR has shown a decrease, but the ACR increased with increasing carriageway width. That means that the severity of accidents became higher while the number of accidents was reduced. In LEUTZBACH/ZOELLMER (1989), a decline of the AR was determined up to a width of 8.5m. Roads with a wider cross section have shown an incline again.

TRB (1987) pointed out that, lanes wider than 3.70m do not contribute to higher safety because they may result in unsafe manoeuvres such as over-taking despite oncoming traffic. Another reason is the higher speed on wider lanes, which leads to more accidents. VOGT/BARED (1998) have developed a model which is based on investigations with lane width widening in Minnesota and Washington. They figured out that the higher lane width increment, the lower the accident risk. LAMM et al. (1999) found a significant decline of AR up to 7.5m cross sections. COOUNCIL / STEWART (2000) analysed data of four US states to develop a prediction model for non-intersection and non-intersection related accidents. The results were statistically significant for two states only and indicate huge differences regarding the benefits of widening cross sections. In North Carolina, widening the surface by 1m reduces accidents by 14%, in California by 34%.

ELVIK et al. (2004) also figured out that a decline of ACR occurs if the cross section is widened by a maximum of 3m. Wider cross sections do not attribute to a positive influence on road safety.

All the above-mentioned works have pointed out a decline in accident risk for wider cross sections. This positive trend is proven up to a certain lane width; wider cross sections are characterised by a lower safety benefit or even by increasing accident risk.

2.2.2.4 Shoulder width

There are various opinions about the impact of shoulder width or shoulder in general. In the literature, several positive as well as negative aspects are discussed. As an obstacle free zone, the shoulder gives drivers the possibility to regain control after losing control over the vehicle. Shoulders also provide space for emergency stops, but might cause a dangerous situation when the vehicle re-joins traffic. Furthermore, shoulders may be used for travel as well to allow faster traffic to pass.

The study of ZEGEER et al. (1981) has shown that increasing the shoulder width is associated with a decline in accidents. A 21% reduction in total accidents was determined on roads with shoulders of 0.9-2.7m, compared to roads without shoulders. They suggest that for roads without shoulders, the optimum shoulder width is about 1.5m. An investigation by TURNER et al (1981) has shown that on two-lane roads with unpaved shoulders, the AR is much higher than on two-lane roads with paved shoulders and still higher than on four-lane roads without shoulder. A multi-variate model was developed by ZEGEER et al (1987), based on data from seven states of the USA. The model considers ADT, lane width, shoulder width and type, roadside hazard and terrain as variables. The results are: increasing the width of a paved shoulder by 1 ft reduces accidents by 6%, increasing the width of an unpaved shoulder reduces accidents by 4%, and paving 1 ft. of a shoulder reduces accidents by 2%.

Similar results were worked out by HEDMAN (1990), who found an accident reduction when shoulders increase up to 2m; above 2m the benefit became less. For two-lane roads, a reduction of accidents by 1-3% and injuries of 2-4% when the shoulder is widened by one ft is given by HADI et al. (1995). Up to a shoulder width of 3m, an accident reduction was determined in ODGEN (1996). MIAOU (1996) indicates a reduction of single-vehicle accidents by 8.8%, related to one ft widening.

STEWARD/COUNCIL (2000) analysed data from four US states and developed a prediction model for non-intersection and non-intersection related accidents. The parameter for shoulder width was statistically significant. Regarding the determined correlations, there are differences, whereas the results for California, Minnesota and Washington are somehow similar (especially above 11.5 m), but the result for North Carolina is completely different. In North Carolina, widening the shoulder by 1m reduces accidents by only 12%, but in Minnesota by 26%, in California by 29% and in Washington by 39%.

In general, the design of shoulders regarding the pavement and width has a positive influence on road safety. These effects were shown in numerous research works over the last years. As well as the road width, the positive effect becomes smaller up to a certain shoulder width. Wider shoulders have no positive impact. Paved shoulders also influence positively safety, especially on narrow roads.

2.2.2.5 Sight Distance

As anywhere else on the road, the sight distance at any point of a horizontal curve must be sufficient to allow safe stopping manoeuvres, and will therefore be adapted to speed observed on site.

In general, sight distance affects road safety, since the sight distance is the result of the geometry overlapped with the existing terrain and the influence of geometric parameters is proven.

In KREBS/KLÖCKNER (1977), various radii which correspond to different sight distance were investigated. The radii and sight distances were subdivided into groups. Especially in curves with small radii (R < 400 m), the AR is much higher than in other curves if the sight distance is shorter than 99m. With increasing sight distance, the difference between the curves gets smaller.

On sites with short sight distances due to vertical curves (e.g. crests), the accident frequency is 52% higher (TRB 1987). The mentioned study has developed a model to determine the cost effectiveness of lengthening crests. They concluded that a reconstruction of such a site has a cost benefit when:

- Design speed is more than 33 km/h above the operating speed
- Traffic flow exceeds 1500 veh./d
- High volume intersection
- Sharp curve
- Steep downgrade, and/or
- Lane drop

GLENNON (1987) pointed out that improving sight distances in curves are associated with high cost effectiveness, especially when low cost measures such as clearing vegetation, etc., were realised. He found that improving sight distances on crests is only effective if the road is characterised by a high traffic volume.

HEDMAN (1990) found that ARs decrease with increasing sight distance. But if the sight distances are above the stopping sight distance but below the overtaking sight distance, drivers may start overtaking manoeuvres even though the sight distance is too short for passing. In LAMM et al. (1999a), high ARs were determined for sight distances shorter than 100m. Above 150m, no further positive effect was determined.

ELVIK/VAA (2004) worked out that improving sight distance does not lead inevitably to a decline in accident risk. They figured out that improvements in short sight distances of 200m to more than 200m caused a significant worsening of accident risk.

Several research works have demonstrated the influence of sight distances on road safety. Short sight distances are frequently related to high accident frequency. On the other hand, larger sight distances (which may suggest the possibility of overtaking, even if the full overtaking sight distance does not exist) might cause accidents.

2.3 Other Factors affecting Road Safety

2.3.1 Road surface conditions

Traffic, weather conditions and ground conditions expose road surfaces to wear and tear. Ruts, cracks and unevenness in the road surface reduce driving comfort and can be a traffic hazard. They may make it more difficult to keep a motor vehicle on a steady course. Besides this, large holes in the road surface can damage vehicles and lead to the driver losing control of his vehicle. Friction and evenness are two important characteristics that influence road safety.

2.3.1.1 Friction

One such contributing factor that has been discussed and evaluated over the years about road surface characteristics is skid resistance (friction) of roadway pavements under various weather and ageing conditions.

Skid resistance of pavements is the friction force developed at the tyre-pavement contact area. In other words, skid resistance is the force that resists sliding on pavement surfaces (Figure 11). This force is an essential component of traffic safety because it provides the grip that a tyre needs to maintain vehicle control and stop in emergency situations.

Skid resistance is critical in preventing excessive skidding and reducing the stopping distance in emergency braking situations.

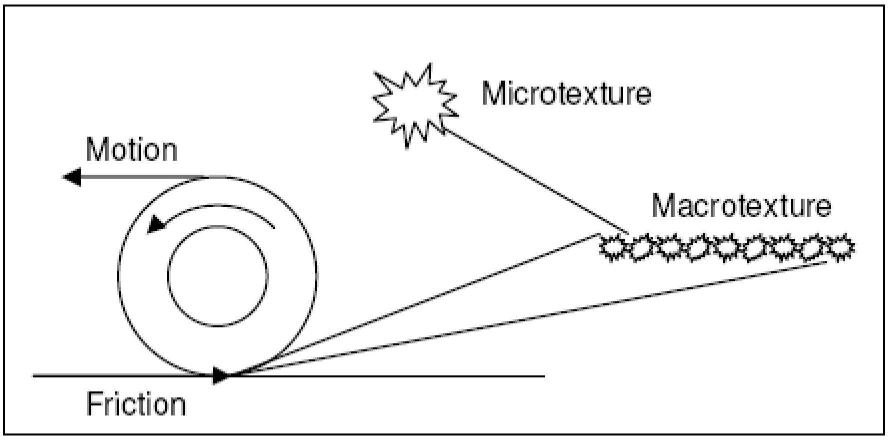


Figure 11: Friction Force and its Properties

Skid resistance has two major components: adhesion and hysteresis (Cairney, 1997). Adhesion results from the shearing of molecular bonds formed when the tyre rubber is pressed into close contact with pavement surface particles. Hysteresis results from energy dissipation when the tire rubber is deformed when passing across the asperities of a rough surface pavement.

These two components of skid resistance are related to the two key properties of asphalt pavement surfaces that are micro-texture and macro-texture.

Micro-texture refers to irregularities in the surfaces of the stone particles (fine-scale texture) that affect adhesion. These irregularities are what make the stone particles feel smooth or harsh to the touch.

Macro-texture refers to the larger irregularities in the road surface (coarse-scale texture) that affects hysteresis. These larger irregularities are associated with voids between stone particles. The magnitude of this component will depend on several factors. Macro-texture is also essential in providing escape channels to water in the tire-surface interaction, thus reducing hydroplaning.

A European study reports that increased macro-texture reduces total accidents under both wet and dry conditions (Roe, et al. 1998). Furthermore, this study shows that increased macro-texture reduces accidents at lower speeds than previously believed.

There are two other road surface texture properties that are less significant than micro and macro-texture in the generation of skid resistance, yet a key component in the overall quality of the pavement surface, namely mega-texture and roughness (unevenness).

Mega-texture describes irregularities that can result from rutting, potholes, patching, surface stone loss, and major joints and cracks (McLean and Foley, 1998). It affects noise levels and rolling resistance more than it affects skid resistance.

Roughness refers to surface irregularities larger than mega-texture that also affects rolling resistance, in addition to ride quality and vehicle operating costs. It provides a good overall measure of the pavement condition and is usually computed through the International Roughness Index (IRI).

These properties of pavement texture are the features of the road surface that ultimately determine most tyre-road interactions, including wet friction, noise, splash and spray, rolling resistance, and tyre wear. At the 18th World Road Congress, the Committee on Surface Characteristics of the World Road Association (PIARC) proposed the wavelength range for each of the categories shown in Figure 12 (PIARC, 1987). Sandberg listed their influence in more detail in Table 2 (Sandberg, 1997).

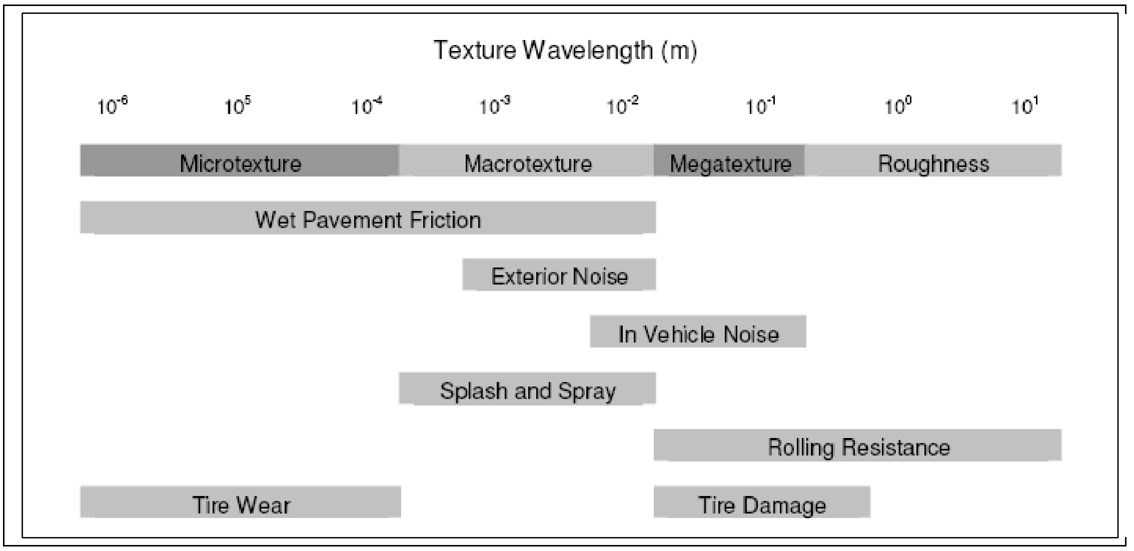


Figure 12: Texture Wavelength (m) Influence on Surface Characteristics.

Table 2: Influence of Texture on Some Variables

Effect on Vehicle, Driver or Environment	Road Surface Characteristic of Importance	Magnitude of the Influence
Friction	Macrotexture Megatexture Microtexture	High Moderate Very high
Rolling Resistance/ Fuel Consumption/ Air Pollution	Macrotexture Megatexture Unevenness	High Very high High
Tire Wear	Macrotexture Microtexture	Moderate Very high
Exterior Noise	Macrotexture Megatexture	Very high Very high
Water Runoff	Macrotexture	High
Splash and Spray	Macrotexture	High?
Light Reflection	Macrotexture Microtexture	High Little known
Interior Noise	Macrotexture Megatexture Unevenness	High Very high High

Different numerical values of skid friction are used around the world. In Sweden, road surface wet friction is measured with fixed slip devices (Skiddometer BV-11 or Saab Friction Tester, SFT). Friction values of 0.5 are desirable. Finland established the levels of acceptable friction as a function of speed as shown in Table 3 (Wallman and Ström, 2001, Larson 1999). Values were obtained following Finnish standards for testing (PANK 5201 or TIE 475).

In the UK, a policy was developed to establish acceptable friction levels for different road and traffic situations. Friction levels are called investigatory levels where an investigation or surface treatment needs to be made if friction is at or below this level. Table 4 summarises the values taken with the Side force Coefficient Road Inventory Machine (SCRIM) device.

Table 3: Typical Skid Resistance Values in Finland

Speed (km/h)	Speed (mph)	Acceptable friction
≤ 80	≤ 50	0.4
≤ 100	≤ 60	0.5
≤ 120	≤ 75	≥ 0.6

Table 4: U.K.'s Investigative Skid Resistance Values

Skid Resistance Measure	Site Category	Skid Resistance Value
SCRIM at 50 km/h	A - Motorway (mainline)	0.35
	B - All-purpose dual carriageway – non-event sections	0.35
	C - Single carriageway – non-event sections	0.40
	D - All-purpose dual carriageway – minor junctions	0.40
	E - Single carriageway – minor junctions	0.45
	F - Approaches to and across major junctions	0.45
	G1 - Grade 5 to 10% longer than 50 m	0.45
	G2 - Grade > 10%, longer than 50 m	0.50
	H1 - Curve with radius < 250 m not subject to 65 km/h speed limit or lower	0.45
	J - Approach to roundabout	0.55
	K - Approach to traffic signals, pedestrians crossings, railway level crossings or similar	0.55
SCRIM at 20 km/h	H2 - Curve with radius < 100 m not subject to 65 km/h speed limit or lower	0.60
	L - Roundabout	0.55

Porous asphalt surfaces offer high values of skid resistance and contribute to the removal of water from the pavement surface. A summary of the mixture characteristics for different porous pavements as used in the USA and Europe is provided in Table 5.

Table 5: Gradation Used for Internally Draining Asphalt Mixes

	Percent Passing				
Size	Oregon	Typical Europe	Swiss	Belgium	France
25.0 mm	99 - 100	-	-	-	-
19.0	85 - 96	100	-	-	-
14.0	-	-	-	100	100
12.5	60 - 71	-	-	-	-
11.2	-	90 - 95	-	-	-
10.0	-	-	100	-	55
9.5	-	-	-	-	-
8.0	-	28 - 40	-	-	-
6.3	17 - 31	-	-	-	23
5.0	-	18 - 23	-	-	-
4.75	-	-	-	-	-
2.75	-	-	-	-	-
2.36	-	-	-	-	-
2.0	7 - 19	10 - 12	-	-	14
710 µ	-	6 - 8	-	-	-
250	-	4 - 6	-	-	-
90	-	2 - 4	-	-	-
74	1 - 6	-	-	-	-
Air Voids (%)	5.7 - 10	17 - 22	14 - 20	16 - 28	24
Thickness (mm)	1.5 - 2.0	40 - 50	40 - 50	40	42
Permeability (1/s)	-	0.06 - 0.12	0.06 - 0.12	0.0078 - 0.023	0.02

A study by the Finnish National Road Administration examined the extent to which drivers take pavement slipperiness into consideration *(*Wallman and Ström, 2001; Heinijoki, 1994*)*. Drivers were asked to evaluate the roadway slipperiness on a scale measured and divided into four categories of friction coefficients (f):

- Good grip (f > 0.45);
- Fairly good grip (0.35 < f < 0.45);
- Fairly slippery (0.25 < f < 0.35); and
- Slippery (f < 0.25).

The results showed that drivers were poor at evaluating actual road conditions. Less than 30 per cent of the evaluations coincided with the measured values, and more than 27 per cent differed by two to three of the categories listed above. According to the study, as friction values decreased, the relationship between the drivers' estimation of friction and actual conditions increased. Consequently, the skid resistance of the pavement did not a have significant influence on driving speed.

In 1984, the international Scientific Expert Group on Optimizing Road Surface Characteristics of the OECD indicated that in the USA, any reduction in friction was associated with a steady increase in accidents *(*OECD, 1984*)*.

Detailed analyses revealed a linear crash-skid resistance relationship as the proper function for interpreting the data *(*OECD, 1984*)*. This behavioural function conflicts with other relationships obtained from Europe. A study of high-speed secondary roads in Germany suggested a non-linear relation, with a higher slope for low friction values than for high friction values (Figure 13).

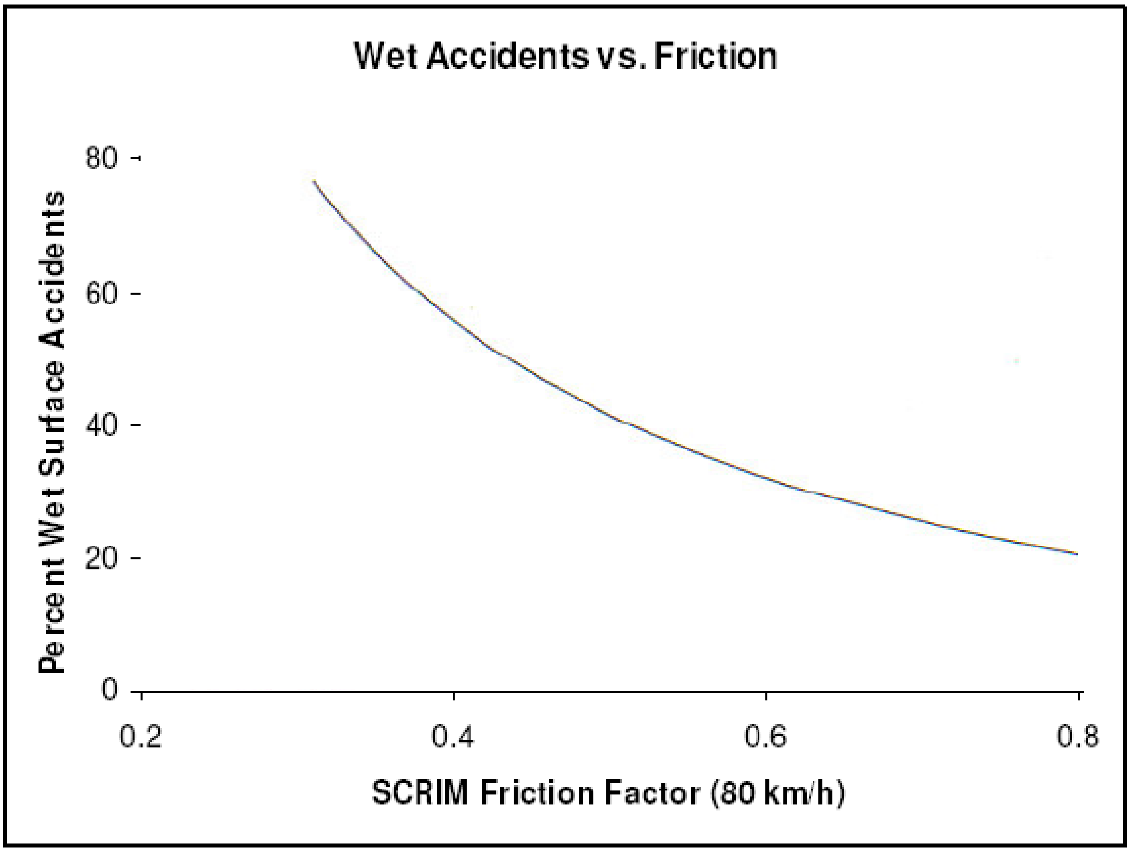


Figure 13: Non-Linear Relationship between Wet-Pavement Crashes and Friction

Wallman and Astrom (2001) also reported a similar regression analysis in Germany by Schulze (1976). Figure 14 shows the general trend of the increasing percentage of wet surface crashes with the decreasing friction level (Wallman and Astrom 2001).

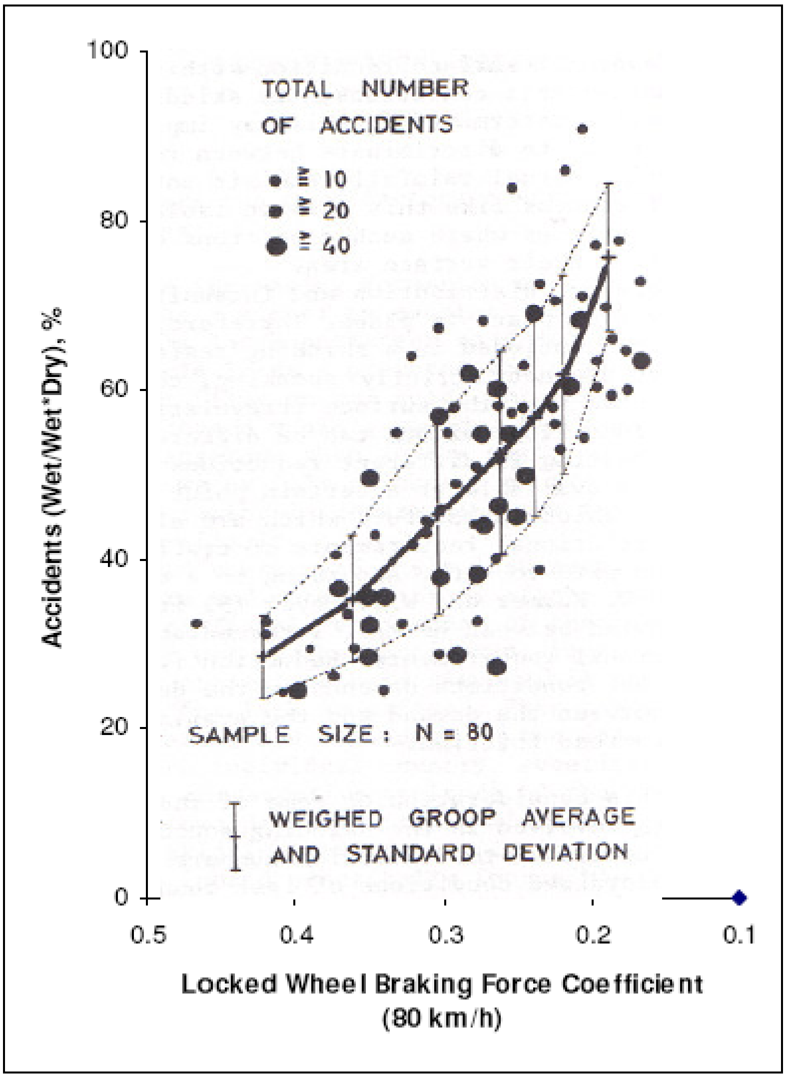


Figure 14: Percentage of Wet-Pavement Accidents and Friction

Another study described by Wallman and Astrom with similar behaviour is the Norwegian Veg-grepsprosjektet. In this study, comprehensive friction measurements and roadway observations were completed, resulting in the assessment of crash rates for different friction intervals as summarised in Tables 6 and 7.

Table 6: Crash Rates for Different Friction Intervals

Friction Interval	Accident Rate (personal injuries per million vehicle kilometers)
< 0.15	0.80
0.15 – 0.24	0.55
0.25 – 0.34	0.25
0.35 – 0.44	0.20

Table 7: Crash Rates at Different Roadway Conditions

Roadway Condition	Accident Rate (personal injuries per million vehicle kilometers)
Dry bare roadway, winter	0.12
Wet bare roadway, winter	0.16
Slush	0.18
Loose snow	0.30
Ice	0.53
Hoarfrost	0.53
Packed snow	0.31
Bare ruts	0.12
Black ice in ruts	0.30
Dry bare roadway, summer	0.14
Wet bare roadway, summer	0.18
Note that rates for slush and ruts are not reliable	

The Nordic TOVE project provided similar results for two-lane highways in Denmark (Figure 15) for friction values obtained with a side force device, Stradograph.

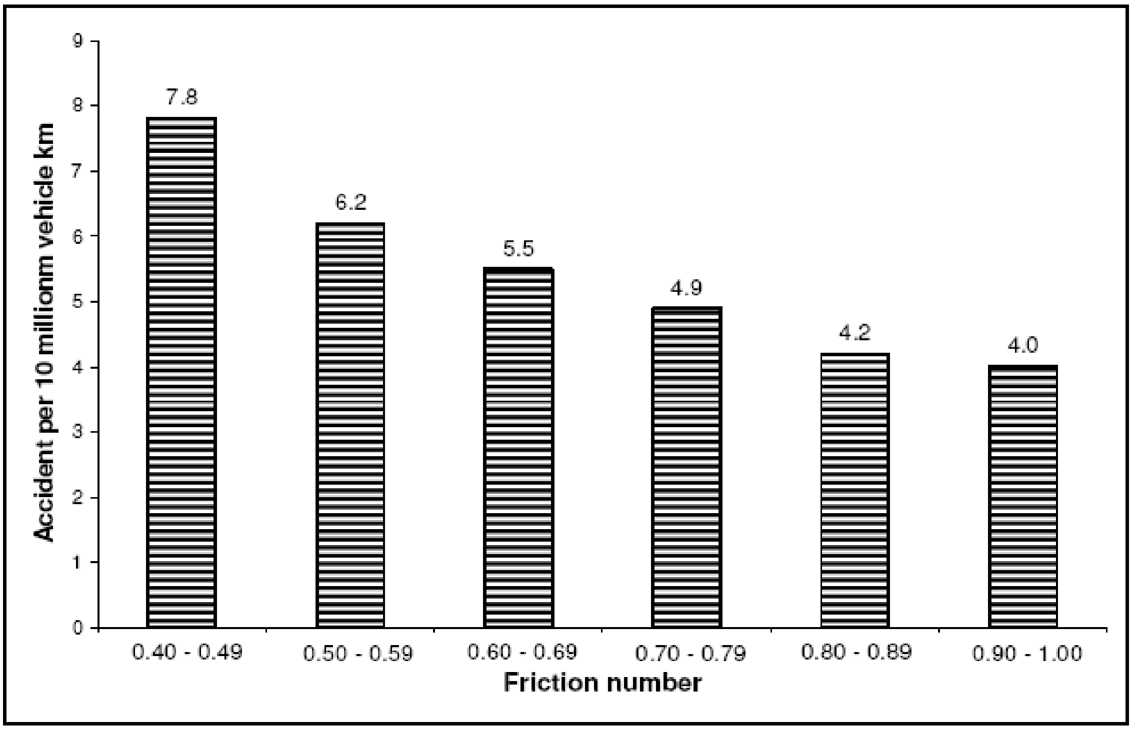


Figure 15: Crash Rates as a Function of Friction

International literature includes some Spanish studies about the relationship between bitumen properties and adherence.

I. Pérez Barreno analysed the relationship between bitumen properties and the bituminous mixes rutting resistance. A good linear relationship has been observed between the inverse of the different values from binder properties, and the results from the wheel-tracking tests of the mixtures on conventional and modified binders.

M. Á. Rodríguez Valverde et al. observed that cold-mix paving technology based on bitumen emulsions involves complex phenomena of a mainly kinetic character. The key stage of bitumen film formation on aggregates, in order to obtain high-performance dense-graded cold mix asphalt, is the emulsion breaking. The bituminous phase and aqueous phase break their colloidal equilibrium in this step. The speed of this stage is used to classify emulsions manufactured upon different conditions. A suitable parameter to quantify these differences is the breaking time. In this work, an objective and reliable method to measure easily the characteristic time during phase separation is explained. This approach improves the qualitative results of conventional assays designed to this task and requires a little amount of materials (emulsion as well as aggregates). Besides, the experimental conditions are closer to real ones with few initial restrictions.

Potti el al. (2003) designed a generation of emulsions in order to provide excellent adhesion between layers and reduce excess tack

2.3.1.2 Evenness

Evenness is a measure of the regularity of a road surface. All types of road surfaces (rigid, flexible, gravel, etc.) deteriorate at a rate which varies according to the combined action of several factors: axle load of vehicles; traffic volumes; weather conditions; quality of materials; construction techniques.

These deteriorations have an impact on the road surface roughness by causing cracking, deformation or disintegration.

Various indicators can serve to estimate the quality of the longitudinal evenness of a road surface, but the International Roughness index (IRI), developed by the World Bank in the 1980s, is the one most used today.

The IRI measures the vertical motion of the suspension of the vehicle travelling on the road under standardised testing conditions (metres of vertical displacement per kilometre driven). One of the main advantages of the IRI over older measurement methods is its reliability. The standardised testing conditions facilitate both repeatability and comparison of results. Typical IRI values range between 0m/km and 20m/km (“0” representing perfect conditions).

The measurement of the transverse profile of the pavement allows the detection of various types of problems: inadequate camber, lane/shoulder drop-off, rutting, etc.

A number of road administrations use rut depths as a trigger to road surface remedial actions. The presence of ruts makes lateral shifts more difficult and increases discomfort and manoeuvre difficulties. Moreover, the presence of ruts can cause water accumulation, thereby increasing the risk of aquaplaning. The situation is particularly hazardous for two-wheeled vehicles. A rut depth of 20-25mm is often considered critical. It can be measured manually or with laser devices.

The pavement condition can also be expressed in terms of Present Serviceability Rating (PSR). The PSR ranges from 0 to 5 (very poor to very good), as defined in Table 8, and includes a description of ride ability, physical distress such as cracking, and rehabilitation needs.

Table 8: Variability of PSR

Pavement Condition Rating (Use full range of values)	
PSR & Verbal Rating	Description
5	
Very Good	Only new, superior (or nearly new) pavements are likely to be smooth enough and distress free (sufficiently free of cracks and patches) to qualify for this category. Most pavements constructed or resurfaced during the data year would normally rated very good
4	
Good	, although not quite as smooth as these described above give a first class ride and exhibit few, if any, visible signs of surface deterioration. Flexible pavements may be beginning to show evidence of rutting and fine random cracks. Rigid pavements may be beginning to show evidence of slight surface deterioration such as minor cracks and spalling
3	
Fair	The riding qualities of the pavements in this category are noticeably inferior to those of new pavements, and may be barely tolerable for high speed traffic. Surface defects of flexible pavements may include rutting, map cracking and extensive patching. Rigid pavements in this group may have few joint failures faulting and cracking.
2	
Poor	Pavements in this category have deteriorated to such extent that they affect the speed of free-flow traffic. Flexible pavements may have large patches and deep cracks. Distress includes ravelling cracking, rutting and occurs over 50% , or more, of the surface. Rigid pavements distress includes joint spalling, faulting patching, cracking, scaling and may include faulting.
1	
Very Poor	Pavements in this category are in an extremely deteriorated condition. The facility is passable only at a reduced speeds, with considerable disconfort. Large potholes and deep cracks exists. Distress occurs over 75% or more of the surface
0	

When the evenness of a whole road section has sharply deteriorated, users tend to reduce their speed in order to maintain their comfort at an acceptable level, thus minimising potential safety impacts. The friction of the road surface can be improved in several ways:

Surface Treatment - Any application applied to an asphalt pavement surface to restore or protect the surface characteristics.

Chip Seal - A surface treatment in which the pavement is sprayed with asphalt (generally emulsified) and then immediately covered with aggregate and rolled. Chip seals are used primarily to seal the surface of a pavement that has non load-associated cracks and to improve surface friction, although they also are commonly used as a wearing course on low-volume roads. This is typically used to extend the life of the pavement surface by sealing out moisture, which can cause major damage to pavement until major repairs can be made.

Diamond Grinding - A process that uses a series of diamond tipped saw blades mounted on a shaft or arbour to shave the upper surface of a pavement in order to remove bumps, restore pavement ride ability, and improve surface friction.

Grooving - The process used to cut slots into a pavement surface to provide channels for water to escape beneath tyres, improve skid resistance and reduce the potential for hydroplaning.

Sandblasting - A procedure in which compressed air is used to blow sand particles at a pavement surface to abrade and clean the surface. Sandblasting is a construction step in partial-depth patching and joint resealing.

Sand Seal - An application of asphalt binder, normally an emulsion, covered with a fine aggregate. It may be used to improve the skid resistance of slippery pavements and to seal against air and water intrusion.

Slurry Seal - A mixture of slow-setting emulsified asphalt, well-graded fine aggregate, mineral filler, and water. It is used to fill cracks and seal areas of old pavement, restore a uniform surface texture, seal the surface to prevent moisture and air intrusion into the pavement, and improve skid resistance.

Pavement resurfacing – This treatment consists of laying a new road surface with extra good friction on the top of the old surface, such as porous or drainage asphalt providing high friction characteristic even in rain condition.

Pavement Reconstruction - Complete removal and replacement of the existing pavement structure, which may include new and/or recycled materials, in order to improve surface friction.

Winter maintenance
Colder areas obviously require winter maintenance of road consisting in:

- Snow clearance
- Sanding icy areas
- Salting (chemical de-icing)
- Increasing maintenance preparedness
- General increase in the standard of winter maintenance
- Snow screens in areas exposed to snowdrifts

2.3.2 Roadside Design

The hazardousness of the roadside influences accident occurrence and severity. The Interactive Highway Safety Design Model (IHSDM) takes the quality of roadside design into account. Therefore, an accident modification factor (AMF_9) based on Zegeer et al. was developed. As no satisfactory studies about the relationship between roadside design and accidents could be found, AMF_9 was derived directly from the base model for roadway sections presented in the following equation.

$$AMF_9 = \frac{\exp(-0{,}6869 + 0{,}0668 \cdot RHR)}{\exp(-0{,}4865)}$$

Where:

RHR = roadside hazard rating for the highway segment considering both sides of the road

Figure 16 shows the possible values for AMF_9, and gives a description of the corresponding rating, with an example of a typical road for each rating.

RHR	AMF[9]	Description	Example for typical roadway
1	0.87	Wide clear zones greater than or equal to 9m from the pavement edge line Side slope flatter than 1:4 Recoverable	
2	0.94	Clear zone between 6 and 7.5m from pavement edge line Side slope about 1:4 Recoverable	
3	1	Nominal or base condition Clear zone about 3m from pavement edge line Side slope about 1:3 or 1:4 Rough roadside surface Marginally recoverable	
4	1.07	Clear zone between 1.5 and 3m from pavement edge line Side slope about 1:3 or 1:4 May have guardrail (1.5 to 2 m from pavement edge line) May have exposed trees, poles, or other objects (about 3 m from pavement edge line) Marginally forgiving, but increased chance of a roadside collision	

RHR	AMF 9	Description	Example for typical roadway
5	1.14	Clear zone between 1.5 and 3m from pavement edge line Side slope about 1:3 May have guardrail (0 to 1.5m from pavement edge line) May have rigid obstacles or embankment (within 2 to 3m of pavement edge line(Virtually non-recoverable	
6	1.22	Clear zone less than or equal to 1.5m Side slope about 1:2 No guardrail Exposed rigid obstacles within 0 to 2m of the pavement edge line Non-recoverable	
7	1.31	Clear zone less than or equal to 1.5 m Side slope 1:2 or steeper Cliff or vertical rock cut No guardrail Non-recoverable with high likelihood of severe injuries from roadside collision	

Figure 16: Definitions of the Roadside Hazard Ratings used with the Accident Prediction Algorithm

2.3.2.1 Slope flattening

To reach a high level of road safety, it is advisable to build embankments as flat as possible. A slope should never be built steeper than 3:1, because drivers are not able to control vehicles on those slopes - the vehicle would overturn.

Embankments with slopes between 3:1 and 4:1 are passable if they are uniform, which means that there should not be any type of important irregularities down to the point where the slope ends.

Embankments with slopes less steep than 4:1 are acceptable and drivers can recover vehicles that get beyond control and ascend again to the road. Slopes should be built in a robust way to minimise problems when a vehicle is forced to drive on them. Figure 17 shows the chance of single vehicle accidents (only one vehicle is involved) on different slopes compared to a slope of 1:7.

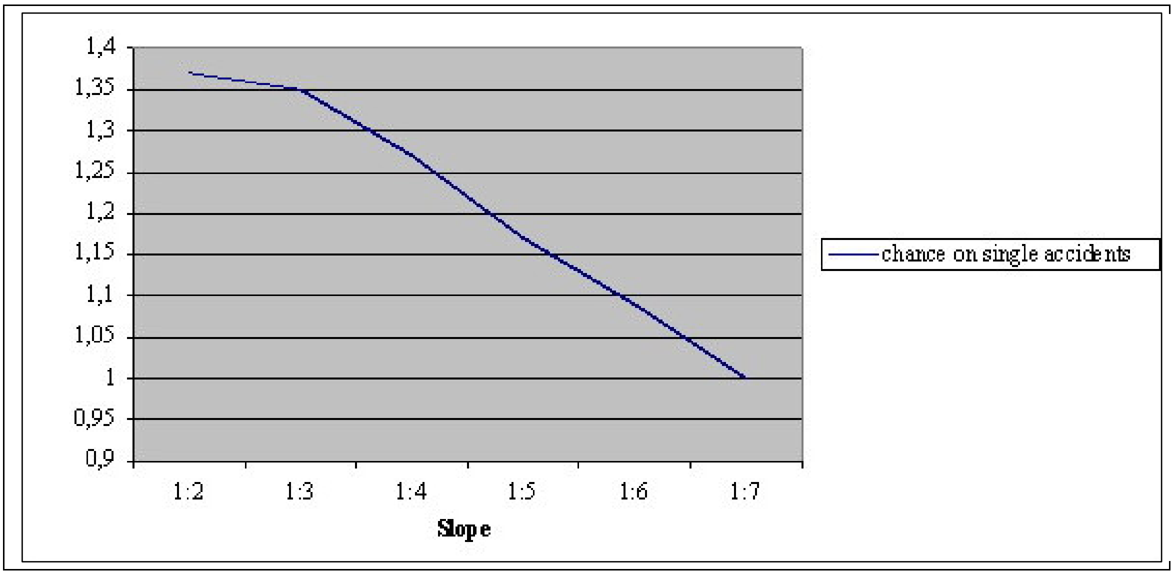


Figure 17: Chance of single vehicle accidents on different slopes compared to a slope 1:7

The measures to improve "roadside safety" are the following:

Increasing the distance to fixed obstacles –An *out-of-control* vehicle leaving its lane tries to come back on the road. If the roadside is "forgiving", in the multitude of cases this manoeuvre should be possible. If there were obstacles (trees, very steep embankments, etc), it would almost inevitably lead to an accident. For that reason, obstacles should be situated as further from the roadside as possible. Uncovered roadside gutters involve a serious risk, even given the slightest inattention. Walls of subsurface drainage structures should be situated adequately. Studies show that the larger the distance between roadside and obstacles, the fewer the accidents and the less severe are the remaining accidents. Recommendations for obstacle-free zones in the Netherlands are:

Table 9: Recommended widths for obstacle free zones according to Road Safety handbook

Bandwidth	Obstacle free zone		
	100 Km/h	80 Km/h	60 Km/h
normally	8.00 m	6.00 m	4.50 m
minimum	6.00 m	4.50 m	3.00 m

In special occasions, it may be advisable to build an even wider obstacle-free zone:

− To comply with the necessary stopping sight distance
− On road stretches where higher speeds are allowed

Installation of safety barrier systems

Crash barriers should only be installed if their existence reduces the impact of potential accidents, as the fundamental purpose of crash barriers is to prevent vehicles from abandoning the road in an uncontrolled way and hitting an object, which brings it to a violent halt or a fall down a side slope. In other words: the probable consequences of the accident should be considered as more serious than those provoked by the proper collision with the crash barrier. A collision with the barrier should cause neither the roll-over of the vehicle nor such a deceleration as to cause serious damage to the occupants of the vehicle itself: in fact, the human brain remains permanently damaged if a deceleration of 80g (g=9.81 m/sec2) is applied for more than 3 milliseconds, heart and lungs as well cannot tolerate values greater than 60g for more than 3 milliseconds.

The vehicle will have to be brought back on one such trajectory not to become a danger for the other circulating vehicles on the same roadway: this means that the rebound trajectory must have the lowest possible angle related to the road axis. Such a result can be obtained with the absorption from the barrier of the greatest possible percentage of the vehicles transversal acceleration.

Two typologies of safety barriers exist:

− Iron (double and triple wave) or wood (for environmental mitigations)

− Concrete (New Jersey)

The first ones are constituted by a series of iron vertical supports from one or more metallic horizontal bands double or triple wave shaped, with several division elements; sometimes, due to environmental mitigation needs, the horizontal bands are in reinforced wood.

The transversal component of the speed is absorbed by the plastic deformation of the barrier and the vehicle.

New Jersey is constituted by blocks of concrete that introduce a particular profile able to produce the following valuable effects for a car or a heavy vehicle:

−Reduction of the kinetic energy, due to creeping along the profile and the negative job of the gravity forces;

−Straightening of the vehicle's wheels and the consequent assessment of the trajectory in a direction parallel to the road axis.

−Avoiding, due to the continuity of the barriers, bumping against more rigid and stronger elements (the supports of the metallic barriers).

Edge-line treatments

Road engineers attempt to improve the visibility of highways by delineating the road ahead and there is a number of edge-line treatments that can reduce the incidence and severity of run-off-road type crashes, particularly those that have been used to either alert a driver to the imminent departure of their vehicles from the roadway and/or to reduce the danger once they have actually left the paved surface.

Edge-line treatments include: rumble strips; increased number of posts on bends; installation of raised pavement markers; they provide a sufficiently large and ideally paved recovery zone (such as around motorways).

2.3.3 Forgiving Roadsides

Analyses of fatal road accidents in the European Union show that 45 per cent are single vehicle accidents. These accidents are primarily classified as run-off-road accidents, where the vehicle leaves the road and enters the roadside. A roadside is called unforgiving if hazardous objects such as trees are placed at an inappropriate distance to the road so that the risk of severe accidents is increased.

The European Road Directors (www.cedr.fr) declared the implementation of forgiving roadsides as one of the most promising short-term measures to increase road safety. The purpose of this concept is to avoid crashes of errant vehicles or to minimise crash consequences.

The goal of Work Package 1 of the IRDES (www.irdes-eranet.eu) project was to collect and harmonise common standards and guidelines for roadside treatments. Initially, this deliverable introduces typical roadside hazards, which are the basis for appropriate counter-measures. The main part of this report comprises the results and findings of relevant literature, guidelines and standards dealing with roadside treatments.

Summarising the literature study, three categories of treatment are proposed:

1. The removing or relocation of potentially dangerous roadside objects
2. The modification of roadside objects or design
3. The shielding of roadside objects

These three categories determine the main structure of the report. The first category mainly comprises recommendations for so-called safety zones. These are obstacle-free areas beyond the travel lane in order to avoid collisions. Additionally, these zones assist drivers to perform easy recovery manoeuvres. Especially for road planning, an appropriate safety zone should be considered.

If hazardous obstacles cannot be removed or relocated, they need to be modified. Crashworthy structures or breakaway devices are common examples for modifications. Moreover, the design of slopes and ditches are relevant factors for a safe road.

In many cases, removing or modifying hazardous objects is not possible or economically advisable. Isolating or shielding the drivers from the respective objects helps to minimise the severity of a crash. Safety barriers and attenuators at bridge abutments are good examples of this kind of treatment.

2.3.3.1 Definition of roadside

According to the RISER project, a roadside is defined as the area beyond the edge line of the carriageway. There are different views in literature on which road elements are part of the roadside or not. In this report, the median is considered as roadside, since it defines the area between a divided roadway. Therefore, all elements located on the median are considered as roadside elements as well. Figure 18 depicts a roadway cross section (cut and embankment section) including some roadside elements. In this specific figure, the roadside can be seen as the area beyond the traffic lanes (or carriageway). The shoulders are thus part of the roadside, since the lane markings define the boundaries. The slopes, the clear zones (also called safety zones) or the tree are examples for roadside features that will be described in the following chapters in detail.

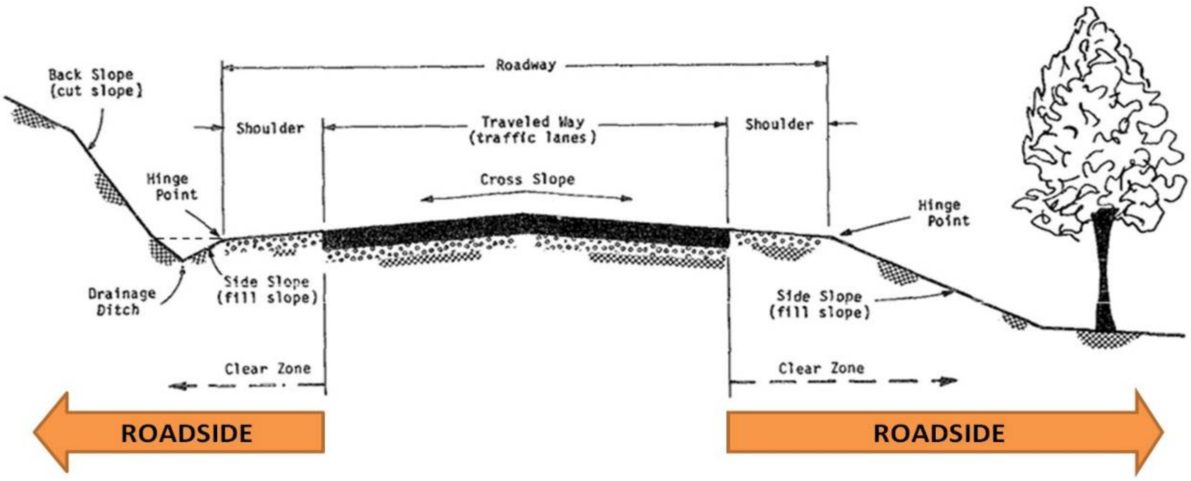


Figure 18: Roadway cross section with examples for roadsides with clear zones

2.3.3.2 Forgiving vs. self-explaining

Forgiving and self-explaining roads are two different concepts of road design which aim at reducing the number of accidents on the whole road network. Even if this paragraph only deals with forgiving roadsides, the term “self-explaining” needs to be defined in order to differentiate it from the term “forgiving”.

According to literature self-explaining roads are based on the idea that appropriate speed or driving behaviour can be induced by the road layout itself. They therefore reduce the need for speed limits or warning signs. It is generally known that multiple road signs in complex traffic situations can lead to information overload and an increasing risk of driving errors. Herrstedt (2006) writes that a safe infrastructure depends on a road-user-adapted design of different road elements such as markings, signs, geometry, equipment, lighting, road surface, management of traffic and speed, traffic laws, etc. The idea behind self-explaining roads is to design the road according to an optimal combination of these road elements.

In short, it can be said that self-explaining roads aim at preventing driving errors, while forgiving roads minimise their consequences. The first priority of forgiving roadsides is to reduce the consequences of an accident caused by driving errors, vehicle malfunctions or bad roadway conditions. This must be focused on treatments to bring errant vehicles back on to the lane to reduce injury or fatal run-off accidents. If the vehicle still hits a road element, the second priority is to reduce the severity of the crash. In other words, the roadside should forgive the driver for their error by reducing the severity of run-off road accidents.

Information taken from Deliverable 1 (State of the art report on existing treatments for the design of forgiving roadsides) of the IRDES project:

IRDES (Improving Roadside Design to Forgive Human Errors) is 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 European Commission. The funding partners of this cross-border funded Joint Research Programme are the National Road Administrations of Austria, Belgium, Finland, Hungary, Germany, Ireland, Netherlands, Norway, Slovenia, Sweden and UK.

2.3.4 Road markings

In order to drive safely and comfortably, drivers are dependent on reference points in the proximity of the vehicle and further ahead in the direction they are driving. In the dark in particular, but also in other poor visibility conditions (for example in fog), such reference points are essential when it is hard to identify the road from its surroundings.

At complicated intersections, it is important for road users to be able to find the right place on the carriageway using reference points. Road markings are intended to:

- Direct traffic by indicating the path of the carriageway and marking the road in relation to the surroundings;
- Warn road users about specific or hazardous conditions related to the road alignment;
- Control traffic, for example by reserving certain parts of the road for certain traffic groups and allowing or prohibiting overtaking and lane-changing;
- Supplement and reinforce information given by means of traffic signs.

The following road markings can further improve safety:

- Longitudinal lines on the road surface made of retro-reflective paint or plastic
- Shoulder rumble strip (edge lines)
- Combination of several types of road markings.

2.3.5 Road lighting

Most of the information that drivers use in traffic is visual. Visual conditions can therefore be very significant for safe travel. In the dark, the eye picks up contrast, detail and movement to a far lesser extent than in daylight for all road users. In particular, in the dark the risk increases more for younger drivers than for older age groups and more for pedestrians than for people travelling by motor vehicle.

Around 35% of all police-reported injury accidents occur in the twilight or the dark. The percentage of accidents in the dark is highest for accidents involving pedestrians and accidents where vehicles run off the road. The objective of road lighting is to reduce the accident rate in the dark: lighting makes it easier to see the road, other drivers and the immediate surroundings of the road.

In some countries, road and street lighting is reduced during certain periods in order to save energy. The usual way of reducing lighting is to turn off every other lamp with the effect of halving the level of lighting. The effect of reducing lighting on the number of accidents is the subject of studies, since halving the level of lighting is associated with an increase of about 15-25% in the number of accidents at night.

Aspects connected with the lighting of the road also have to be considered in the building of the roads of the new generation. This concerns the assurance of suitable parameters for:

- The luminosity of the surface of the road;

- The evenness of the lighting of the road;

- The limitation of the dazzle;

- The visual leading by the lighting system.

The luminosity (density of luminous intensity in a given direction) of the surface of the road is the measure of brightness from what the given surface is noticed by the observer. The better the reflecting properties of the road surface, the larger quantity of light will be returned and the surface will be seen to be brighter. The definite level of luminosity will assure good visibility on the road. On the basis of research, it is known that for the lighting of street to the level of 0.5CD/m^2 (intensity of lighting 2.5 lx), the ability of perception is 10%, and for the value of luminosity of 2CD/m ^{2} (intensity of lighting 10 lx), the ability of perception is 85%.

The evenness of the lighting of the road is the ratio of minimum luminosity to the average luminosity of the surface of the road. The smaller the relation (the least evenness), the worse will be ability of perception of objects against the background of the surface of the road. For example, reducing evenness from 0.4 to 0.2 causes a reduction from 85% to 55% of the ability to notice objects, which means a deterioration of about 65%.

Dazzle occurs when there are excessively garish sources of light against the dark background in the field vision. The degree of the loss of visual efficiency depends both on the construction of the lighting case, and on the road lighting installation treated as a whole.

This effect weaken the quality of vision, for example lowering the indicator of visual efficiency caused by dazzle about 20% causes a fall in the ability to notice objects from 85% to 70%.

Lighting bindings hung over the road give additional information to the driver about the direction of the turn of the road. Driveways and exits from the main road should be illuminated by the different types of lighting. This can be carried out, for example, by cases hung at different heights or equipped in different colours of light. This means the driver will already receive information in advance about the direction of the road.

2.3.6 Traffic volume and traffic composition

Traffic volume is generally defined as the number of motor vehicles using a road per unit of time. Pedestrians, cyclists and other road users[6] tend not to be included, usually because there is no reliable count of their numbers. The volume of travel includes passengers in addition to drivers.

The relationship between exposure and accidents can be expressed in terms of a mathematical function of the following form:

Number of accidents = ▯ Q^b

Q is a measure of traffic volume, raised to the exponent *b*;

▯▯is a scaling constant.

The coefficient b shows the percentage of change in the number of accidents when traffic volume changes by one per cent, or equivalently the elasticity of accidents with respect to traffic volume. A sample of results taken from a Norwegian doctoral dissertation (FridstrØm 1999) shows that the total number of injury accidents increases by almost 1% if traffic volume increases by 1%. Accidents involving multiple vehicles or road users, such as pedestrians and cyclists, increase slightly more than 1% when traffic volume increases by 1%. Single vehicle accidents increase by less than 1% when traffic volume increases by 1%. The traffic volume considered above is defined regardless its composition.

In literature, the accident prediction models link the number of accidents to the traffic composition, assuming the percentage of heavy vehicles as an input variable.

2.3.7 Junctions, intersections and driveways

Accesses and intersections are some of the most frequent sources of risk. When traffic coming from another road is introduced to a road, a conflicting traffic flow is created. This includes traffic coming from local, public and private ways.

The following sections deal with the most important features that influence safety at intersections and ends with a comparison of different intersection types and some recommendations for intersections between secondary roads and roads of other categories.

2.3.7.1 Driveways or access points

Driveway density

The separation of points where decisions have to be made, the elimination of unforeseeable events and the control of access from lateral properties are reasons why highways have a higher level of safety than other roads.

In the following paragraph, the word “access” makes reference to a point where traffic is introduced from other streets, including local, public, private and commercial roads.

By access control, roads can be made safer. Access control means to space, reduce or eliminate the variety of events to which the driver has to respond. It is one of the most important factors in accident reduction. It is possible to reduce the number of accesses to a road, for example, by building or using a lateral road or street to which adjacent properties have access. Further away, this lateral road has access to the main road.

[6] In rural areas, other road users could be horse riders, donkeys and chariots. Shepherds are also using some spots mainly to cross these roads; sometimes they are also users when they, for example, bring cows back to the farm using the roads between the field and the farm.

This modus operandi has considerable influence on the safety level of roads with elevated traffic density. The adequate choice of spacing between accesses and the position of intersections also has a significant impact on capacity.

Studies exist that mention that the accident frequency augments rapidly when the density of accesses rises. This indicates that the number of accesses should be reduced.

Often it is not possible or practical to eliminate the accesses, although reducing the conflict level in access points can moderate the negative effects of accesses. For example by:

- Reducing the number of accesses
- Eliminating left turns
- Providing lateral (parallel) roads/ streets
- Providing lanes for turnarounds
- Providing acceleration/deceleration lanes

Left turns are as dangerous as lateral accesses, so the engineer should try to reduce the number of left turn possibilities. This does not mean that all left turns should be completely eliminated, but the amount reduced and those that remain made safer.

Another excellent solution is the construction of grade separated left-turn possibilities instead of crossing the oncoming traffic.

Several studies have been conducted to prove the speculation that there is a relation between the access point, driveway density and accident occurrence.

Within the framework of a study conducted by the Committee on access management (Transportation Research Circular 456), the following function to describe the relation was found:

$$\text{Accidents/ MVkm} = 1{,}199 + 0{,}0047 \cdot X + 0{,}0024 \cdot X^2 \quad (13)$$

Where:

X = access point per km

The figure for different densities of access points is shown in Figure 19.

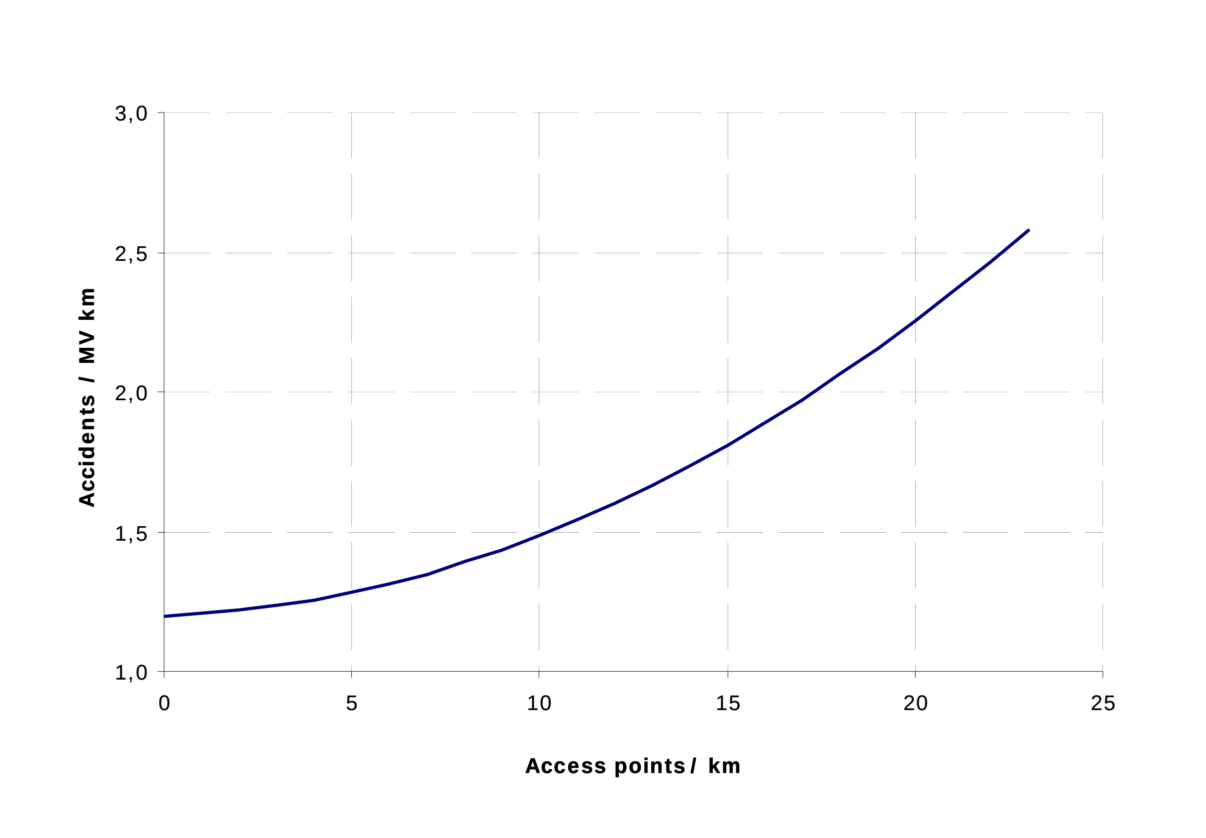


Figure 19: Accidents per Mvkm for different access point densities

Another study by Muskaug ended with an estimate for accident rate for six ADT classes. The study deals only with injury accidents. Hauer fitted the date into a function:

$$\text{Accidents/MVkm} = 0.2 + (0.05–0.005 \cdot \text{Ln}\,[\text{ADT}]) \cdot \text{DD} \qquad (14)$$

Where:

ADT = Average Daily Traffic

DD = Driveway Density

The following figure shows the six ADT classes mentioned above:

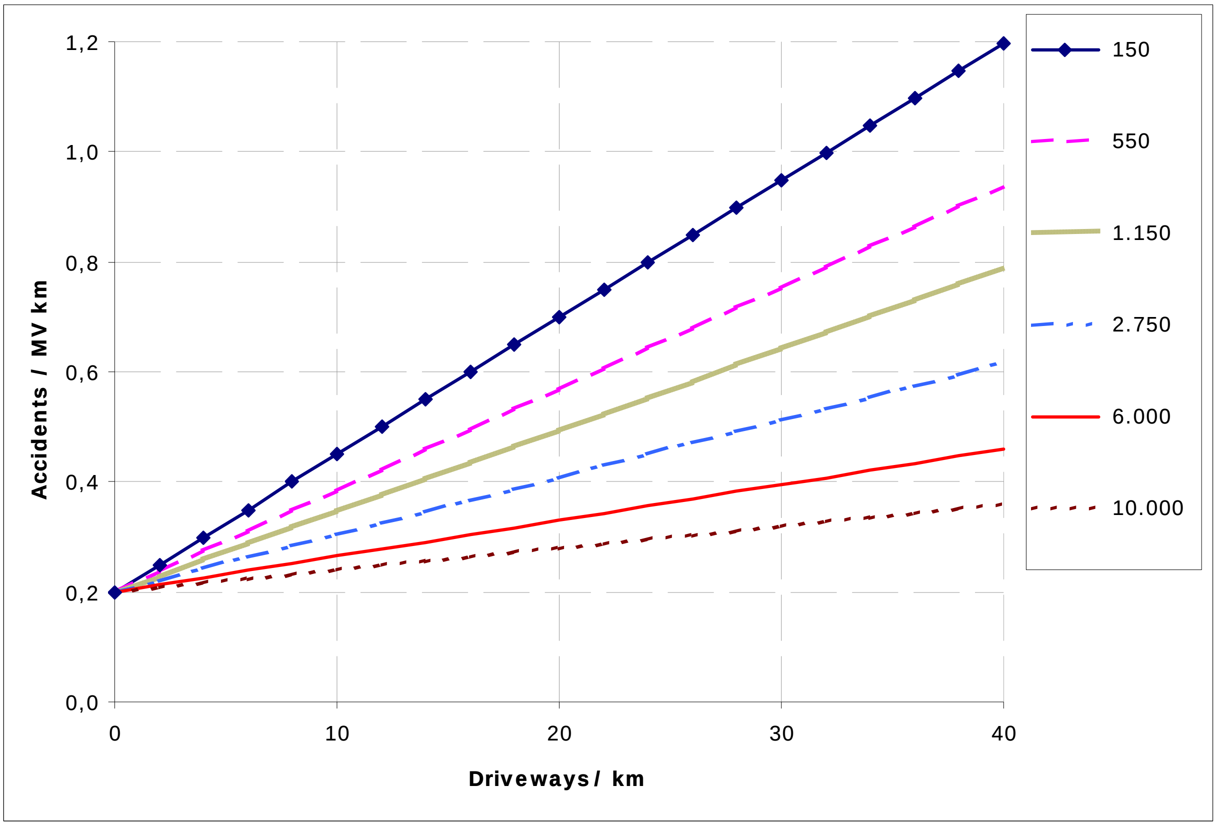


Figure 20: Accidents per Mvkm for different access point densities

2.3.7.2 At-grade intersections

Intersection skew angle

The Interactive Highway Safety Design Model (IHSDM) defines the skew angle of an intersection as the derivation of an intersection angle of 90˚, or in other words the absolute value of the difference between 90˚ and the actual angle between the major legs and minor legs of an intersection. This absolute value is always within a range from 0˚ to 90˚. The nominal or base condition of intersection skew angle is 0˚ of skew that can be found at a rectangular intersection where major and minor legs cross at 90˚: from a traffic safety point of view, this intersection angle is recommended. The value of the Accident Modification Factor (AMF) for intersection skew angle is the same independently of whether the minor leg is STOP-controlled or YIELD-controlled.

For a four-leg intersection where the angles of the intersection legs differ to the left and the right of the major road, they are averaged. For example, if one leg forms a 50˚ angle and the other intersects at 20˚, then the average would be 35˚ [SKEW = (20+50)/2 = 35˚]

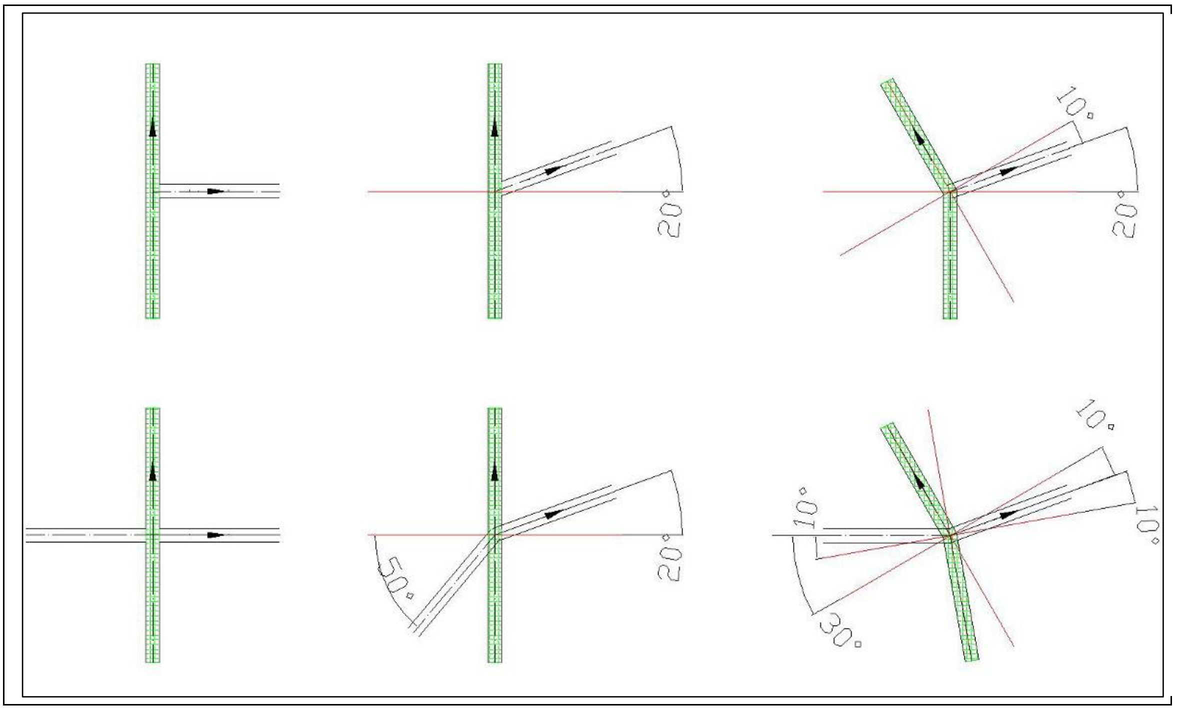


Figure 21: Skew angles for different intersection forms

Sign controlled (STOP-controlled and YIELD-controlled)

The IHSDM distinguishes between three-leg STOP-controlled (YIELD-controlled) intersections and four-leg STOP-controlled (YIELD-controlled) intersections. Intersections with more than four legs (multi-leg) have not been addressed in the initial version of the IHSDM accident prediction algorithm.

The reduced equation to calculate the AMF for intersection skew angle (AMFSKEW) for a three-leg STOP-controlled intersection is:

$$AMF_{SKEW,3LEG} = Exp\ (0{,}0040 \cdot SKEW) \qquad (15)$$

The reduced equation to calculate the AMF for intersection skew angle (AMF_{SKEW}) for a four-leg STOP-controlled intersection is:

$$AMF_{SKEW,4LEG} = Exp\ (0{,}0054 \cdot SKEW) \qquad (16)$$

in both:

SKEW = intersection skew angle as described previously

The value for all way STOP-controlled intersections is:

$$AMF_{SKEW,STOP} = 1{,}00$$

These AMF apply to total intersection accidents.

Three-leg signalised intersections (just as multi-leg signalised intersections) have not been addressed in the initial version of the IHSDM accident prediction algorithm. The model only provides an AMF for four–leg signalised intersections. This value is:

$$AMF_{SKEW,LIGHT} = 1,00$$

for all cases of skew angle.

Intersection traffic control

The nominal or base condition for STOP-controlled intersections in the IHSDM is an intersection with STOP signs only on the minor leg(s). Minor-road YIELD-controlled intersections are treated identically to minor-road STOP-controlled intersections in the accident prediction algorithm. In this case this is:

$$AMF_{MINOR,STOP} = 1,00$$

The other possible traffic control is that *all* ways are STOP-controlled. Lovell and Hauer studied accidents on intersections from the USA and Canada and found that an all-way STOP-controlled intersection experiences 47% fewer accidents than a two-way STOP-controlled intersection. As a result, they set the AMF (applies to total intersection-related accidents) for all-way STOP controlled intersections to:

$$AMF_{ALL,STOP} = 0,53$$

It could be deduced, therefore, that all-way STOP-controlled intersections are related to fewer accidents and thus the conversion from minor-road to all-way STOP-controlled intersections will always reduce accident occurrence.

The expert panel recommended that all-way STOP-control should only be used when the established warrants are met. This is necessary to discourage the indiscriminate use of all-way STOP-control. All-way STOP control is most appropriate for lower-speed roadways with relatively equal traffic volumes on all legs of the intersection.

Intersection left-turn lanes

Table 10 shows the value of the AMF for left-turn lanes that are specified for use in the IHSDM. AMF_{LTL} depends on the type of intersection, the type of traffic control on that intersection and the number of approaches (legs) on which left-turn lanes are installed. If there are no left-turn lanes on any major legs to the intersection (nominal or base condition) AMF_{LTL} is set to 1.00. The AMFs in the subsequent table are based on FHWA-RD-02-089 and other sources evaluated by the IHSDM expert. All AMFs apply to total intersection-related accidents.

Table 10: AMFs for Installation of Left-turn Lanes on the Major Legs of Intersections

Intersection type	**Intersection traffic control**	**One approach (leg) on which left-turn lanes installed**	**Both approaches (legs) on which left-turn lanes installed**
Three-leg intersection	STOP-controlled	0.56	N/A
Three-leg intersection	Signal-controlled	0.85	N/A
Four-leg intersection	STOP-controlled	0.72	0.52
Four-leg intersection	Signal-controlled	0.82	0.67

Intersection right-turn lanes

Table 11 below shows the values of the AMF for right-turn lanes that are specified for use in the IHSDM. AMF_{RTL} depends on the intersection type, the type of traffic control on that intersection and on the number of approaches (legs) on which right turn lanes are installed. If there are no right-turn lanes on any major legs to the intersection (nominal or base condition) AMF_{RTL} is set to 1,00. The AMFs in the subsequent table are based on FHWA-RD-02-089 and other sources evaluated by the expert panel.

All AMFs apply to total intersection-related accidents.

Table 11: AMFs for Installation of Right-turn Lanes on the Major Legs of Intersections

Intersection type	Intersection traffic control	One approach (leg) on which right turn lanes installed	Both approaches (legs) on which right turn lanes installed
Three-leg intersection	STOP-controlled	0.86	N/A
Three-leg intersection	Signal-controlled	0.96	N/A
Four-leg intersection	STOP-controlled	0.86	0.74
Four-leg intersection	Signal-controlled	0.96	0.92

Roundabouts

Roundabouts are normally used in the following situations:

- Intersections between two secondary roads;
- On accentuated locations such as city-borders and change of road categories.

A roundabout (single lane) is the safest form of intersection, because:

- The real speed of the drivers is very slow. The lower the speed, the lower the chance on accidents or hospital injured/deaths.
- On a roundabout there is a reduction of possible conflict situations. Each connecting road is one well-organised situation.

A single lane roundabout is safer than a roundabout with two lanes. This applies especially to simple material damage on the collided objects and less to the injured (hospital/deaths) as a result of an accident.

Roundabouts are relatively easy to understand because of their simplicity and uniformity in functioning. Apart from that, they provide a comfortable possibility to turn to the opposite direction (U-turn) and find the right exit (by driving another round). At roundabouts, there exists the possibility to subsequently incorporate an additional leg if there is enough clearance. (up to four legs).

In most western European countries such as the UK, France, Spain, Germany, Switzerland, Norway, Portugal, the Netherlands, etc., roundabouts have been established and in some cases are already quite widespread.

According to Ourston et al. (1995) the most important operational element of a modern roundabout is the YIELD-control at the entry, which allows the circulating traffic to always keep moving. This operational procedure also works well with heavy traffic. And since no weaving distance is necessary, the roundabouts remain compact.

But more features exist that characterise this kind of intersection and at the same time make it the safest at-grade intersection type. These characteristics of modern roundabouts are:

- The path of entering traffic aims at the centre of the central island and is deflected slowly around it, which leads to speed reduction, increased awareness and thus to accident reduction.

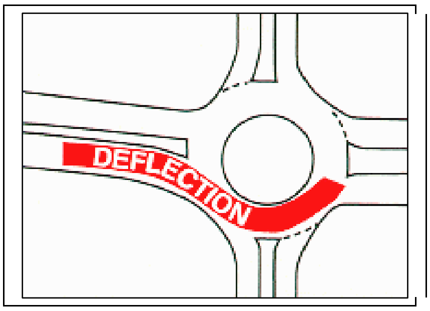


Figure 22: Skew angles for different intersection forms

- To control entry speed and deter left turns, all approaches are provided with splitter islands
- Low number of conflict points at a roundabout compared with other junction types
- Separation of conflict points
- One-way operation of circulating carriageway
- Availability of enough sight distance at the approaches
- Crosswalks are not allowed across the circulatory roadway
- Parking inside the roundabout is not allowed

A further safety advantage of roundabouts is that the only movement at the entry and exit is a right-turn. This reduces accident frequency and severity compared to intersections where left-turns are allowed (left-turn head-on accidents) or legs are arranged in a perpendicular way (crossing traffic can lead to right-angle accidents).

Generally, it can be said that roundabouts reduce accident frequency as they are implemented around the world.

When converting different junction types into roundabouts, several countries conducted "before-after-studies" to show the effect of this measure in accident reduction. In general, quite large reductions were found, with the exception of accidents involving two-wheelers, where the reductions were rather small.

According to a study conducted in 1994 in the Netherlands, a 95% reduction in injuries of vehicle occupants was achieved as many conventional intersections were replaced by modern roundabouts. Other countries found similar results in accident reduction.

Table 12 illustrates the results of several international studies regarding accident reduction.

Table 12: Mean accident reductions in various countries

Country	**Mean Reduction (%)**	
	All Accidents	**Injury Accidents**
Australia	41 - 61%	45 - 87%
France		57 - 78%
Germany	36%	
Netherlands	47%	95%
United Kingdom		25 - 39%
United States	37%	51%

An important characteristic of roundabouts regarding accident frequency is the number of legs, as a British study clearly illustrates. Table 13 (Kennedy et al, 2005) shows, as it was to be expected, that the accident frequency increases with the number of arms.

Table 13: Accident frequency at U.K. roundabouts by number of arms 1999 - 2003

Nº of legs	Nº of sites	Accident frequency	Severity (% of fatal and serious accidents)
3	326	0,79	9,3
4	649	1,79	7,1
5	157	3,66	7,1
6	30	5,95	5,2
All	1162	1,87	7,2

Table 14: Accident frequency at roundabouts in different countries

Country	Reference	Nº. of roundabouts in study	Accident frequency	Total Nº of accidents
Australia	Quoted in NCHRP 264 (1998)	290	0.60	174
Australia[1]	Arndt and Troutbeck (1995)		4.00	-
France	Guichet (1997)	12,000	0.11	1,320
Denmark	Jorgensen (1990)	63	1.0 to 1.25	71
New Zealand	Harper and Dunn (2003)	95	0.51	48
The Netherlands[2]	Schoon and Van Minnen (1994)	16	0.75	12
The Netherlands[2]	Van Minnen (1993)	46	0.23	11
Switzerland[3]	Spacek (2004)	32	0.85	27
UK	Maycock and Hall (1984)	84	2.36 to 4.38	283
UK	Current	1,162	1.77	2,057
US[4]	NCHRP Synthesis 264 (1998)	11	1.50	17

Sites overseas		396	**0.603**	239
European sites		13,403	**0.282**	3,780
All sites		13,799	**0.291**	4,019

1 Estimated for double lane roundabouts; includes property damage only accidents

2 Casualties per roundabout per year

3 Estimated

4 Single lane roundabouts in Maryland and Florida

Table 14 shows accident frequencies from several countries as well as medium accident frequencies for Europe, overseas and for all sites. The medium accident frequencies for all sites and Europe are very similar, due to the fact that the biggest samples come from European countries.

In 1999, Luis Serrano Sadurní and Fernando Gutiérrez Parra conducted a before-after study to analyse the influence of the implantation of roundabouts in traffic accidents. They classified three types of cases where intersections have been converted into roundabouts:

- Intersections without traffic light. Each leg of the intersection would be an approach to the future roundabout. This case is called: **“intersection roundabout”** they studied 12 cases
- Intersections with traffic light. Each leg of the intersection would be an approach to the future roundabout. This case is called: **“intersection with traffic light roundabout”** they studied four cases
- Sites where a roundabout is situated at present but where no intersection has been in the past. This case is called: **“nothing roundabout”** they studied six cases

The changes in accident occurrence when contemplating accidents from 1996-1999 are shown in Table 15.

Table 15: Comparative table of results commensurate with accident severity

Parameter	**Type 1** **Intersection ? Roundabout** **12 cases**	**Type 2** **Intersection with traffic light ? Roundabout** **4 cases**	**Type 3** **Nothing ? Roundabout** **6 cases**
Nº of accidents	-61.20%	-66.70%	+10.50%
Nº of fatal accidents	-48.62%	-72.90%	-73.92%
Nº of injury accidents	-72.04%	-73.59%	-61.47%
Nº of implicated veh.	-70.00%	-65.54%	-18.13%
- Sign: reduction		+ Sign: augmentation	

The positive value (no reduction but augmentation in accidents) means that there are now accidents in a place without accidents, because there was no intersection.

Additionally, investigators tried to relate accident occurrence on roundabouts with the characteristic of the intersections. The Swedish researchers Brüde and Larson developed a model that takes the number of legs (three-leg or four-leg), the maximum local speed limit (70 km/h or 50 km/h) and the number of entry lanes (one or two) into account.

Collision Rate $CR = 0{,}1353 \cdot 0{,}86^{3leg} \cdot 1{,}88^{speed70} \cdot 1{,}20^{2lanes}$

The three dummy variables represent:

- The number of arms
  (^{3leg}= 1 if there are 3 arms, 0 with 4 arms)
- The maximum local speed limit
  (^{speed70}= 1 if the maximum local speed limit is 70km/h, 0 if 50km/h) and
- The number of entry lanes
  (^{2lanes}= 1 if there are 2 entry lanes, 0 if there is just 1 entering lane)

Injury accidents in [acc./10^6 veh. entering the junction] are given by:

$A = 0{,}8178 \cdot CR^{1{,}6871}$

Table 16 shows the possible results for Collision Rate (CR) and number of injury accidents per 106 vehicles for the Swedish model. As expected, three-leg roundabouts with a local speed limit of 50 km/h and just one entering lane have the lowest injury accident rates, compared to four-leg roundabouts with a local speed limit of 70 km/h and two entering lanes, which have the highest injury accident rates.

The table shows, given an average daily traffic (ADT= 15.000 vehicles per day) entering in the junction, the yearly accident rate in the various combinations of cases: three or four legs, 50 or 70 Km/h, one or two entering lanes.

Table 16: Results for Swedish accident model by Brüde and Larson

3-leg	1	1	1	1	1	1	1	1
4-leg	0	0	0	0	0	0	0	0
local speed limit = 70 km/h	1	1	1	1	1	1	1	1
local speed limit = 50 km/h	0	0	0	0	0	0	0	0
2 entering lanes	1	1	1	1	1	1	1	1
1 entering lane	0	0	0	0	0	0	0	0
Collision Rate: CR	0,2625	0,2188	0,1396	0,1164	0,3052	0,2544	0,1624	0,1353
Injury acc: A [acc./10^6veh.]	0,0856	0,0630	0,0295	0,0217	0,1105	0,0812	0,0381	0,0280
Position	7	5	3	1	8	6	4	2

ADT	**15.000**							
Injury acc./year	0,4689	0,3447	0,1616	0,1188	0,6047	0,4446	0,2085	0,1533
	one injury acc. every 2,1 years	one injury acc. every 2,9 years	one injury acc. every 6,2 years	one injury acc. every 8,4 years	one injury acc. every 1,7 years	one injury acc. every 2,2 years	one injury acc. every 4,8 years	one injury acc. every 6,5 years

Comparison of intersection types

The accident frequency and severity varies with the intersection type. The difference in accident rate is attributed to speed differences and differences in number and type of the conflict points.

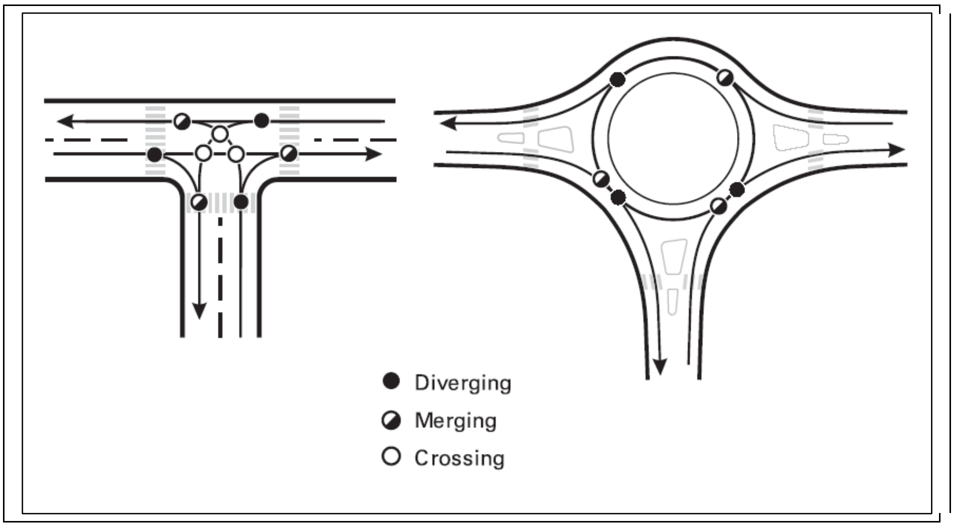


Figure 23: 9 conflict points of a 3-leg intersection and 6 conflict points of a 3-leg roundabout

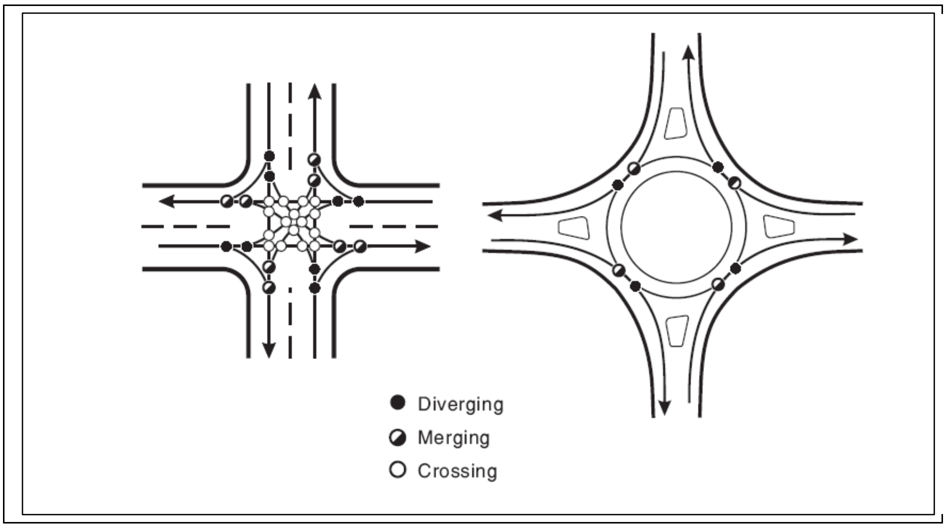


Figure 24: 32 conflict points of a 4-leg intersection (Standard intersection) and 8 conflict points of a 4-leg roundabout

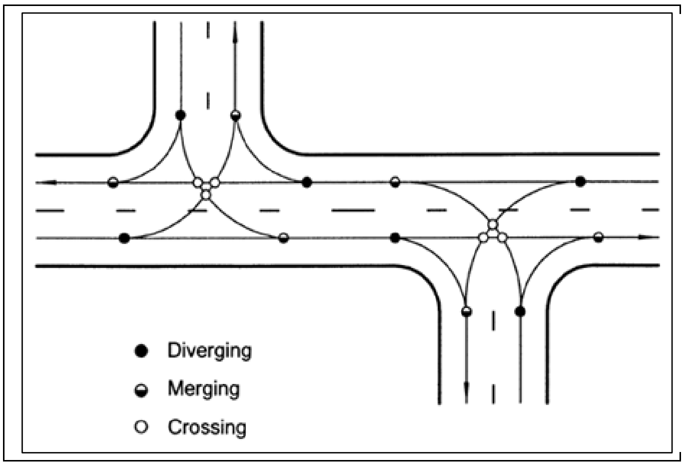


Figure 25: 18 conflict points of a staggered intersection (2 closely spaced T-intersections)

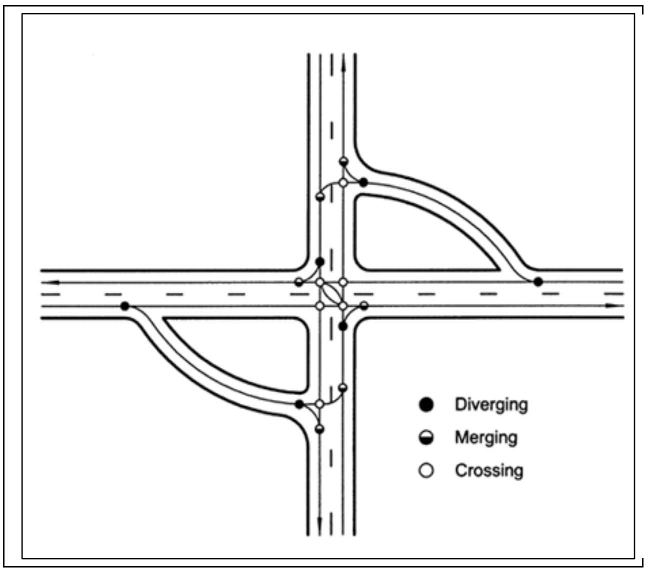


Figure 26: 18 conflict points of a 4-leg intersection with two jug handles

Conflicts can be divided into three basic categories, in which the degree of severity varies, as follows:

- *Queuing (diverging) conflicts*. These conflicts are caused by a vehicle running into the back of a vehicle queue on an approach. These types of conflicts can occur at the back of a through-movement queue or where left-turning vehicles are queued waiting for gaps. These conflicts are typically the least severe of all conflicts because the collisions involve the most protected parts of the vehicle and the relative speed difference between vehicles is less than in other conflicts.
- *Merge and diverge conflicts.* These conflicts are caused by the joining or separating of two traffic streams. The most common types of crashes due to merge conflicts are side swipes and rear-end crashes. Merge conflicts can be more severe than diverging conflicts due to the higher possibility of collisions to the side of the vehicle, which is typically less protected than the front and rear of the vehicle.
- *Crossing conflicts.* These conflicts are caused by the intersection of two traffic streams. These are the most severe of all conflicts and the most likely to involve injuries or fatalities. Typical crash types are right-angle crashes and head-on crashes.

Traffic operation improves with fewer conflict points. Thus 3-leg roundabouts are safer than 3-leg intersections etc.

A study conducted in 1994 by Schnüll et al. deals with the safety comparison of the basic junction forms - crossroad and staggered junction - on roads outside build-up areas. The aim of their research work was to develop recommendations for the areas of use of the basic junction forms crossroads and staggered junction. Some of the results of the accident investigation are summarised in Table 17.

Table 17: Characteristic accident values for different intersection types (Schnüll et al. 1994)

	Crossroads	**Crossroads equipped w. Signals without left-turn filter and turned off at night**	**Crossroads equipped w. signals +left-turn filter+ not turned off at night**	**Partial Grade Separated**	**Staggered Junction**
Mean Accident Rate [acc./10^6veh.]	0,93	1,31	0,86	0,94	0,84
Accident Cost Rate [DEM/10^3veh.]	80,40		36,80	38,60	37,20
Accident of Medium Seriousness [DEM/acc.]	86.000	41.000 - 44.000	41.000 - 44.000	41.000 - 44.000	41.000 - 44.000

The investigation into the determination of the causes of accident implies that, due to the system by which they operate, crossroads have a significantly higher accident risk than staggered junctions and other junction forms.

For this reason, crossroads should be used only on roads with low traffic volume and low traffic speeds and should be avoided where possible. Crossroads with rather high traffic volume and high speeds should be equipped with traffic lights or other junction types such as roundabouts or staggered junctions should be used.

Compared to crossroads, staggered junctions also have a higher performance (sum of all vehicles driving into the junction) supposing an average turning-off fraction. Crossroads: 12,000 veh/ day and staggered junctions 15,000 veh/ day.

Schnüll et al. investigated a large number of assessment criteria such as characteristic accident values, performance, environmental compatibility and cost-effectiveness and came to the result that staggered junctions in contrast with crossroads have in principle only advantages. But they also mention that a comparative assessment should be performed between: 1) basic junction forms partial grade separated, 2) roundabout and 3) crossroads equipped with traffic lights.

Another study by Eckstein et al. conducted in 2002 also compared the safety of junction types. They came to the following findings, amongst others:

- Accident cost rates of junction depend on basic type (junction design) and traffic control
- Accident cost rates of junctions are independent of traffic volume
- Junctions influence the safety of neighbouring road sections
- Small roundabouts have the lowest accident cost rates and therefore the best safety level
- Small roundabouts are followed by half cloverleaf junctions (the crossing road is grade separated)
- T-intersections are safer than crossroads but since two T-intersections are needed to dissolve one crossroad, it cannot generally be said that the sum of two T-intersections is safer than one crossroad (in contrast to Schnüll et al.)
- Traffic lights increase the safety level only when used with more than two phases
- STOP/YIELD-controlled T-intersections and crossroads have the lowest safety level. Traffic lights with two phases do not increase the safety level.

Table 18 below points out which intersection type is recommendable for intersections between secondary roads and roads of other categories.

Table 18: Recommended intersection type for intersections between secondary roads and roads of other categories.

	Secondary road	
	Two lanes (2x2)	**Single lane (2x1)**
Primary road: *slip roads*	- Roundabout, or - all way stop/yield controlled with traffic light and possibly speed reduction measures	- Roundabout, or - all way stop/yield controlled possibly with traffic light and/or speed reduction measures
Secondary road:		
Two lanes (2x2)	- Roundabout, or - all way stop/yield controlled with traffic light and possibly speed reduction measures	- Roundabout, or - all way stop/yield controlled possibly with traffic light and/or speed reduction measures
Single lane (2x1)	- Roundabout, or - all way stop/yield controlled with traffic light and possibly speed reduction measures	- Roundabout, or - all way stop/yield controlled possibly with traffic light and/or speed reduction measures
Local road	- Avoid as much as possible	- Roundabout, or - All way stop/yield controlled possibly with speed reduction measures
Bicycle lanes	- Split level junction	- Split level junction, or - Roundabout/traffic light
Public transport lanes	- Split level junction	- Split level, or - Guarded level crossing

Roundabout: A roundabout, as mentioned earlier, is the safest form of intersection (all legs on the same level).

Stop/yield controlled intersections: The design of stop/yield-controlled intersections must support the right of way. Because of this reason and reasons of traffic safety, the following design elements are necessary:

- A left turn lane on the main road

- A lane separation island on the side road
- A maximum of one single lane for through traffic per direction
- A maximum of one single lane on the side road.

Conclusions

The amount of traffic explains more than half of the variation in accident ratings on stop/yield-controlled intersections. The influence of the amount of traffic on side roads is more than the amount of traffic on the main road.

When stop/yield-controlled intersections with three legs are compared with stop/yield-controlled intersections with four legs, it seems that three-leg intersections are safer than four-leg intersections.

The lane separation on the side roads should not be too high because of the chance of collisions.

Intersections with traffic lights

Stop/yield-controlled intersections are normally provided with traffic lights because of problems with the capacity or flow of traffic. A traffic light could also be used just because of traffic safety.

For safety reasons, the traffic lights should operate for 24/24 hours.

Grade-separated intersections

The capacity of an at-grade crossing should be controlled by the characteristics of the main road. In some cases, rather the vehicles that approach from the minor legs control the number of vehicles that can pass through the junction. Apart from the mentioned capacity problems, these intersections provide many opportunities for vehicle conflicts and therefore are likely to have an elevated number of accidents.

One out of a number of possible solutions to the problem is the conversion into a grade-separated intersection. From the safety point of view, the provision of grade-separated intersections is very advantageous, but the initial construction costs when compared to at-grade intersections are rather large. Therefore, the planning engineer should carefully weigh up and use the following conditions to justify his decision. A grade-separated intersection should be provided:

- If a free movement of the through traffic is desired
- If an existing traffic bottleneck is to be eliminated
- If an existing accident black spot is to be eliminated
- If the economic losses due to traffic delays are considerably high (on a long-term consideration, the initial construction costs can be inferior to the costs for fuel, tyres, oil, repairs and accidents, as well as the time costs of the road-users)
- If topographic difficulties make the construction of an at-grade intersection more expensive than a grade-separated intersection

2.3.7.3 Lighting of junctions/intersections

In 1976, Rockwell, Hungerford, and Balasubramanuan conducted a study to investigate the performance of drivers approaching intersections equipped with special reflective delineators and signs or illumination. A significant finding from observing 168 test approaches was that the use of roadway lighting significantly improved driving performance and earlier detection of the intersection, whereas signing, delineation and new pavement markings showed marginal changes in performance.

In 1996, Bauer and Harwood found that at rural four-leg STOP-controlled intersections, lit intersections had 21% fewer total and injury accidents than unlit intersections. However, no similar effect was observed for total intersection accidents, and the opposite was observed for urban four-leg STOP-controlled intersections. These results were based on accidents at all times of day (daytime plus nighttime).

A study by Blower, Campbell, and Green (1993) indicates that truck accidents in Michigan are more frequent at night and in rural settings; the combination of the two is deemed to imply less lighting.

2.4 References

RISER consortium. D06: European Best Practice for Roadside Design: Guidelines for Roadside Infrastructure on New and Existing Roads. RISER deliverable, February 2006

Matena et al.: Road Design and Environment – Best practice on Self-explaining and Forgiving Roads. RIPCORD-ISEREST deliverable D3, 2005

Herrstedt: Self-explaining and Forgiving Roads – Speed management in rural areas. Paper presented in ARRB Conference, October 2006

U.S. Department of Transportation. Roadside improvements for local roads and streets. Federal highway administration, USA, October 1986

BABKOV: Road Conditions and Traffic Safety, Miv Publishers, Moskau, 1975, Soviet Union

BIEDERMANN: Straßentrassierung auf der Grundlage von Geschwindigkeiten aus Sehfeldun-tersuchungen, Dissertation, Darmstadt, Technische Hochschule Darmstadt, Fakultät für Wasser und Verkehr, 1984, Germany

COUNCIL, STEWARD: Safety effects of the conversion of two-lane rural to four-lane rural roadways based on cross-sectional models, Transportation Research Board Annual Meeting, 2000

DURTH, W., BIEDERMANN, B., VIETH: Einflüsse der Erhöhung der Geschwindigkeiten und Beschleunigungen von Fahrzeugen auf die Entwurfsgeschwindigkeit
In: Straßenbau und Straßenverkehrstechnik, Bonn- Bad Godesberg, H.385, 1983, Germany

DURTH, W., BALD, J.S., WOLFF, N.: Wirksamkeit trassierungstechnischer Ausgleichsmaßnahmen bei Unter- und Überschreitung von Trassierungsgrenzwerten
Schlussbericht des Forschungsauftrages FA 2.076G81E des Bundesministeriums für Verkehrs, Darmstadt, 1986, Germany

ELVIK, R. / VAA, T.: The handbook of road safety measures; Amsterdam; Heidelberg [u.a.] : Elsevier, 2004

GLENNON, J., NEWMAN, T., LEISCH, J.: Safety and operational considerations for design of rural curves, Report No. FHWA/RD-86/035, Federal Highway Administration, Washington, D.C., 1985, U.S.A.

HAMMERSCHMIDT, A.: Einfluss ausgewählter Entwurfsparameter auf das Unfallgeschehen
Studienarbeit, TU Dresden, 2006, Germany

HIERSCHE / LAMM / DIETERLE / NIKPOUR: Auswirkungen von Ausbaumaßnahmen gemäß RAS-L auf die Verkehrssicherheit zweispuriger Straßen
In: Straßenbau und Straßenverkehrstechnik, Bonn – Bad Godesberg, H.431, 1984, Germany

HEDMAN: Road design and safety
VTI Rapport 351A, pp 225-238, Swedish Road and Traffic Research Institute, Linkoping, 1990, Sweden

HOBAN: Selecting appropriate geometric standards for rural road improvements
Compendium of technical papers, 58th Annual Meeting, pp 332-340, Institute of Transportation Engineers, Washington D.C., 1988, U.S.A.

JOHNSTON, I.R: Modifying Driver Behaviour on Rural Road Curves
Proc 11th Australian Road research Board Conference 11(4), pp 115-134, 1982, Australia

KOEPPEL, BOCK: Kurvigkeit, Stetigkeit und Fahrgeschwindigkeit
in: Straße und Autobahn, H.8, Kirschbaum Verlag Bonn, 1970, Germany

KREBS, H.G., KLÖCKNER: Untersuchungen über Unfallraten in Abhängigkeit von Straßen- und Verkehrsbedingungen außerhalb geschlossener Ortschaften
in: Forschung Straßenbau und Straßenverkehrstechnik; Bonn – Bad Godesberg, Heft 223, 1977, Germany

LAMM, R.: Beeinflusst die Überlagerung von Lage- und Höhenplankrümmungen das Un-fallgeschehen?
in: Straßen- und Tiefbau, H.1-3, 1982, Germany

LAMM, R., BECK, A., ZUMKELLER K.: Analyse von Zusammenhängen zwischen Verkehrssicherheit und Straßenentwurf auf Außerortsstraßen
in: Straßen- und Tiefbau; Heft 12, Seiten 6 – 12; 1999

LAMM, R., PSARIANOS, B., MAILAENDER T.: Highway design and traffic safety engineering handbook; New York, McGraw-Hill, 1999

LEUTNER, R.: Fahrraum und Fahrverhalten
Veröffentlichungen des Institutes für Straßenbau und Eisenbahnwesen der Universität Karlsruhe, 1974, Germany

LEUTZBACH, W., BAUMANN: Zusammenhang zwischen Verkehrsunfällen und Verkehrsbedingungen auf zweispurigen Landstraßen in Abhängigkeit vom Straßenquerschnitt
Forschungsauftrag 3.123 G 80 F des Bundesministeriums für Verkehr, 1983, Germany

LEUTZBACH, W., ZOELLMER, J.:Zusammenhang zwischen der Verkehrssicherheit und den Elementen des Straßenentwurfs
Forschung Straßenbau und Straßenverkehrstechnik, Bonn – Bad Godesberg, Heft 545, 1989, Germany

LIPPOLD, Ch.
Weiterentwicklung ausgewählter Entwurfsgrundlagen von Landstraßen
Dissertation; Fachbereich Wasser und Verkehr der technischen Hochschule Darmstadt; Darmstadt, 1997, Germany

McBEAN, P.A.
The influence of road geometry at a sample of accident sites
Laboratory Report LR1053, 16 p., Transport and Road Research Laboratory, Crowthorne, 1982, United Kingdom

McLEAN, J.R.
Accident-width relationship for single-carriageway rural roads
Australian Road Research 15(4), pp 271-275, 1985, Australia

MIAOU, S. P.
Measuring the Goodness-of-Fit of Accident Prediction Models
Report No. FHWA-RD-96-040, Federal Highway Administration, 1996, U.S.A

OGDEN, K.W.

Safer roads: A guide to road safety engineering
Institute of Transport Studies, Department of Civil Engineering,Monash University Melbourne, Avebury Technical, 1996, Australia

OECD
Hazardous road locations: Identification and counter-measures
Organisation for Economic Cooperation and Development, 108 p., OECD, Paris, 1976, France

PFUNDT
Vergleichende Unfalluntersuchungen auf Landstraßen
Forschung Straßenbau und Straßenverkehrstechnik, Bonn – Bad Godesberg, Heft 82, 1969, Germany

TRB
Transportation Research Board: Designing safer roads
Special Report 214, 319 p, TRB, Washington D.C., 1987, U.S.A.

TURNER, D. S. / FAMBRO, D. B. / ROGNESS, R. O.
Effects of paved shoulders on accident rates for rural Texas highways
Transportation Research Record 819, pp 30-37, 1981

ZEGEER / DEEN / MAYES
Effect of lane and shoulder widths on accident reduction on rural two-lane roads
Transportation Research Board 806, pp 33-43, Washington D.C., 1981, U.S.A.

ZEGEER / STEWART / REINFURT / COUNCIL / NEUMAN / HAMILTON / MILLER / HUNTER
Cost-effective geometric improvements for safety upgrading of horizontal curves
Report FHWA-RD-90-021, FHWA, Washington, D.C., 1991, U.S.A.

ZEGEER / TWOMEY / HECKMAN / HAYWARD
Safety Effectiveness of highway design features
Federal Highway Administration, Vol.2, Alignment, Washington D.C., 1992, U.S.A.

ZEGEER / COUNCIL
Highway design, highway safety and human factors
Transportation Research Circular 414, pp 20-34, Transportation Research Board, Washington D.C., 1993, U.S.A.

Cairney, P: Skid Resistance and Crashes – A Review of the Literature. Research Report No. 311, ARRB Transport Research Ltd, Vermont South Victoria, Australia, 1997.

Roe, Parry, Viner: High and Low Speed Skidding Resistance: The Influence of Texture Depth. TRL Report 367. Crowthrone, U.K., 1998.

McLean J., G. Foley: Road Surface Characteristics and Condition – Effects on Road Users. Research Report No. 314, ARRB Transport Research Ltd, Vermont South, Victoria, Australia, 1998.

PIARC: Report of the Committee on Surface Characteristics. World Road Association (PIARC), XV__ World Road Congress, Brussels, Belgium, 1987.

Sandberg U. Influence on Road Surface Texture on Traffic Characteristics Related to Environment, Economy, and Safety. A State-of-the-art Study Regarding Measures and Measuring Methods. VTI notat 53A. Swedish National Road and Transport Research Institute, 1997.

Wallman, C.G., Ström H: Friction Measurement Methods and the Correlation between Road Friction and Traffic Safety – Literature Review. Project Code 80435, Swedish National Road and Transport Research Institute, Linköping, Sweden, 2001.

Larson, R.M. Consideration of Tire/Pavement Friction/Texture Effects on Pavement Structural Design and Materials Mix Design. Office of Pavement Technology, HIPT, 1999.

Heinijoki H: Kelin kokemisen, rengaskunnon ja rengustyypin vaikutus nopenskäyttäytymiseen (Influence of the Type and Condition of Tires and Drivers' perception of Road conditions on Driving Speed). FinnRA reports 19/1994, Finnish Road Administration, Helsinki, 1994.

Wallman C.G. Driver Behaviour on Winter Roads, a Driving Simulator Study. VTI rapport 419A, Statens väg- och transportforskningsinstitut, Linköping, 1995.

Öberg G. Vädrets och väglagets inverkan på personbilshastigheten. VTI notat No. 62, Statens väg- och transportforskningsinstitut, Linköping, 1994.

Schulze K.H., A. Gerbaldi, J. Chavet: Skidding Accidents, Friction Numbers, and the Legal Aspects Involved. In Transportation Research Record: Journal of the Transportation Research Board, No. 623, TRB, National Research Council, Washington, D.C., 1976.

I. Pérez Barreno. Influencia del ligante en la resistencia a deformaciones plásticas de las mezclas bituminosas. Revista Carreteras, Nº 130, 2003.

M. Á. Rodríguez Valverde et al.. Velocidad de rotura de las emulsiones bituminosas en contacto con áridos. Revista Carreteras, Nº 130, 2003.

Potti el al.. Emulsiones termoadherentes para riegos de adherencia. Revista Carreteras, Nº 127, 2003.

C.J. Bester – The effect of road roughness on safety – Department of Civil Engineering University of Stellenbosch, 2002

C. V. Zegeer, D. W. Reinfurt, J. Hummer, L. Herf, and W. Hunter: "Safety Effects of Cross-Section Design for Two-Lane Roads", Transportation Research Record 1195, Transportation Research Board, 1988

Zeeger C., Reinfurt D., Hummer J., Herf L., Hunter W. – Safety effects of cross-section design fort two lane roads – FHWA-RD-87/008, 1987

M.Roine, R. Kulmala: Accident models for major roads in Finland. Links on single carriageways outside densely populated areas – Research Report 730, VTT, 1990.

Kalakota K.R., Seneviratne P.N – Accident prediction models for two-lane rural highways – north Dakota State University – 1994

"Guide for Monitoring and Enhancing Safety on the National Truck Network", Federal Highway Administration, Washington, D C, 1986

J. A. Cirillo: "Safety Effectiveness of Highway Design Features", Volume 1, Access Control, 9 p, Federal Highway Administration, Washington, D C, 1992

Committee on access management: "Driveway and street intersection spacing", Transportation Research Board, Transportation Research Circular 456, Washington, D.C., 1996

Ezra Hauer: "Access and Safety", Professor (Emeritus), Department of Civil Engineering, University of Toronto, Toronto, April 15, 2001

R. Muskaug: "Risiko på norske riksveger", Institute of Transport Economics, Oslo, 1985

D.W. Harwood, F.M. Council, E. Hauer, W.E. Hughes, and A. Vogt: "Prediction of the expected safety performance of rural two-lane highways", FHWA-RD-99-207, December 2000

Interactive Highway Safety Design Model (IHSDM): "Crash Prediction Module Engineer's Manual", September 30, 2004

J. Lovell and E. Hauer: "The Safety Effect of Conversion to All-Way STOP Control", Transportation Research Record 1068, Transportation Research Board, 1986

Eduardo Fernández de Villalta Ferrer-Dalmau: "Intersection morphology and design", in CARRETERAS magazine, Spain, Nov.-Dez. 2004

Leif Ourston and Joe G. Bared: "Roundabouts: A Direct Way to Safer Highways", in PUBLIC ROADS online magazine, Volume 58, No. 2, Autumn 1995

J. Kennedy, J. Peirce and I. Summersgill: "Review at accident research at roundabouts" National roundabout conference U.K., Draft 2005

C. Shoon and J. Van Minnen: "The Safety of Roundabouts in the Netherlands", TRAFFIC ENGINEERING AND CONTROL, pp. 142-148, March 1994

"Roundabouts: An Informational Guide", Federal Highway Administration Report No. FHWA-RD-00-067, U. S. Department of Transportation, Washington, D.C., June 2000

J. Kennedy, J. Peirce and I. Summersgill: "Review at accident research at roundabouts" National roundabout conference U.K., Draft 2005

Luis Serrano Sadurní and Fernando Gutiérrez Parra: "La influencia de la implantación de glorietas en los accidentes de tráfico", Asociación Técnica de Carreteras, RUTAS magazine, p.33- 37, Madrid, Mar.-Apr. 1999

U. Brüde and J. Larson: "What roundabout provides the highest possible safety from a traffic safety point of view?", VTI meddelande 864 and 865 Nordic Road and Transport Review № 2, 2000

R. Schnüll and T. Richter: "Sicherheitsvergleich der Knotenpunktgrundformen Kreuzung Und Rechtsversatz an Straßen außerhalb bebeuter Gebiete", Forschung Straßenbau und Straßenverkehrstechnik, Heft 683, Bonn: Bundesministerium für Verkehr, Bau und Wohnungwesen 1994

K. Eckstein and V. Meewes: Sicherheit von Landstraßen-Knotenpunkten, Institut für Straßenverkehr Köln, Nr. 40, Köln 2002

NetTOM eLearning Workshop: July 2004, TOM609, "Highway Engineering" on: http://cbdd.wsu.edu/edev/NetTOM_ToT/Resources/Other/TOM609/index.htm, downloaded: 19. Sep. 2005

L. Staplin, K. W. Gish, L. E. Decina, K. H. Lococo, D. L. Harkey, . S. Tarawneh, R. Lyles, D. Mace and P. Garvey: "Synthesis of human factors research on older drivers and highway safety", Volume II: Human Factors and Highway Safety Research Synthesis, FHWA-RD-97-095, Federal Highway Administration, October 1997

K. M. Bauer and D. W. Harwood: "Statistical Models of At-Grade Intersection Accidents", Report No. FHWA-RD-96-125, Federal Highway Administration, 1996

D. Blower, K.L. Campbell and P.E. Green: "Accident rates for heavy truck-tractors in Michigan", Accid Anal Prev., 25(3):307-21, Jun. 1993

3 Vulnerable Road Users

Secondary road design standards mainly originate from what was used decades ago, with standards intended for a different mix of traffic and different types of vehicles. Safety features for the vulnerable road users such as pedestrian crossing facilities, cycle lanes, forgiving roadsides, signs, and markings might not even be there. And with the increased motorisation and vehicles capable of higher speeds, vulnerable road users (VRU) are in even more danger.

VRU are mainly those unprotected by an outside shield, namely pedestrians and cyclists; elderly people, children and disabled persons; Powered Two-Wheelers (motorcycles, mopeds and light mopeds = PTW) are also to a large extent unprotected, so they are referred to as vulnerable too.

In the EU, around 32% of people killed on rural roads are VRU: 10% pedestrians, 5% cyclists and 17% riders of mopeds or motorcycles. Their share varies between countries (**Error! Reference source not found.**27). In Switzerland, Luxembourg, Italy, Slovenia, France, Austria, the UK, Greece, Cyprus, Germany and Spain, the share of PTW deaths is higher than in other countries and can only be partly explained by a higher share of motorcyclist riders. In the Netherlands, and to a lesser extent also in Belgium, the share of cyclists is higher than in other EU countries. Since 2001, deaths have been falling in all categories of road users, except for motorcyclists (ETSC Pin Report, 2010).

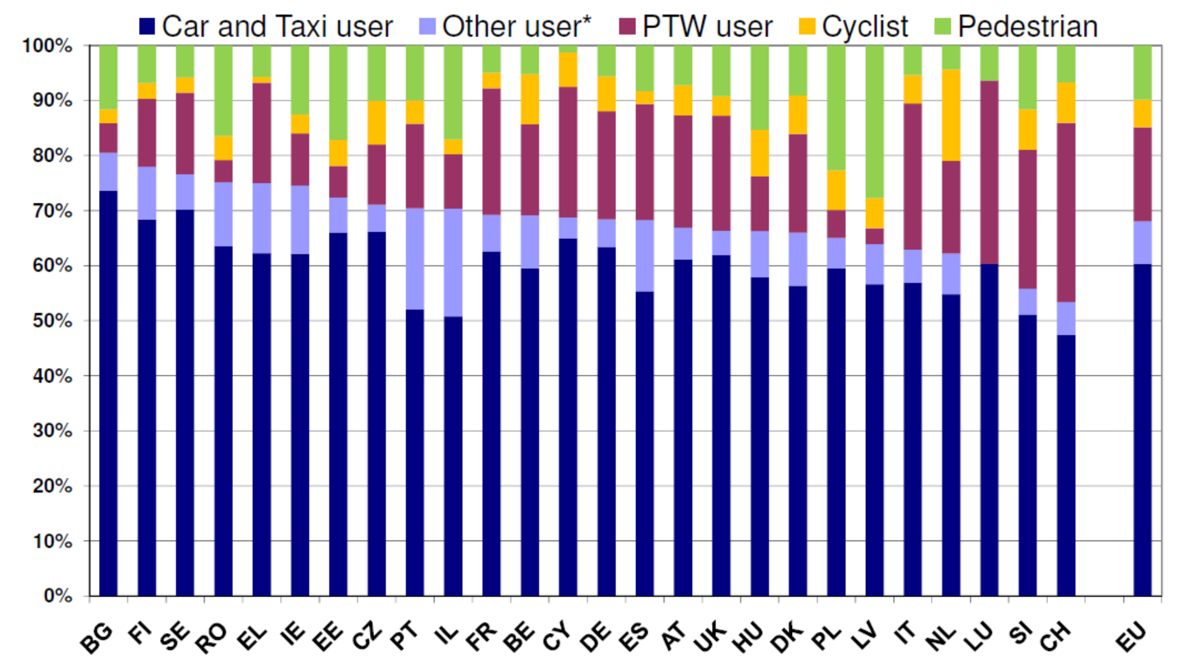


Figure 27: Deaths on rural roads by road user groups (2007-2009 average), source: ETSC, 2010

Since PTW have a difference in speed to other VRU, they are often only on second thought regarded as vulnerable. On one hand, PTWs are much faster than pedestrians or cyclists; on the other hand, such speed becomes a higher risk, e.g. in the presence of roadside obstacles. Another risk factor is the difference in mass between the colliding opponents.

There is no place for large mass and/or speed differences in an actual safe road because this emphasises the vulnerability differences between the various types of road user; even if the complete separation of unequal road user types is of course the best solution, in the majority of the cases this is not possible. One alternative solution is for the driving speed to be limited to a safe speed. Other possible treatments are a less aggressive road design, which means more self-explaining and more forgiveness. Safe roads are those where the road alignment reduces the risk of having crashes, as well as reducing the negative effects of the crash.

It should become common practise within the holistic approach of road safety management to include VRU safety; or to use (separate) checklists for VRU e.g. in RSI or RSA, to guarantee the specific focus on that road user group.

3.1 Cyclists and Pedestrians

Accidents involving pedestrians and cyclists are less prevailing on rural than on urban roads. However, where pedestrians and cyclists are involved in rural road accidents, the outcomes are typically severe due to the often high speeds of traffic and the human body's limited tolerance of crash forces at speeds above 40km/h. The personal risk to each cyclist and pedestrian is very high, so where they are present their safety needs are important.

3.1.1 Cyclists

Safety specifics of the road sections and intersections regarding cyclists are described here in more detail, based on international research studies and design guidelines.

3.1.2 Road Sections

Dutch Design Manual for bicycle traffic (CROW, 2007) figure 28,indicates the option diagram for the choice of a suitable cycle facility for road sections outside built-up areas, based on the function of the road, speed and intensity of motor vehicles and cyclists.

				Bicycle traffic road section function	
Function		Speed (km/h)	Intensity (pcu/day)	basis network	(main)cycle route (I_{cycle}> 2,000/day)
Motorised traffic road section function	Estate access road	60	1 - 2.500	combined traffic	cycle street, if I_{pcu} < 500 pcu/day 1)
			2.000 - 3000	cycle lane or cycle track	cycle track, or perhaps lanes
			> 3000	cycle track	
	District access road	80	irrelevant	cycle/moped track parallel road	

1 Plus any additional requirements in the area of safety

Figure 28: The option diagram for road sections outside built-up areas (CROW, 2007)

According to this option diagram, the combined traffic is only possible if the volumes of motorised and bicycle traffic are low and the maximum speed is limited to 60km/h. From an intensity of about 2500 pcu/day, bicycle facilities should be considered. The percentage of heavy and farm vehicles should also to be taken into consideration.

Hard shoulder

New Zealand guidelines state without any exact value that where significant cyclist activity is present, the most important counter-measure is to provide sufficient space on a road shoulder of consistent width, and ensure the road shoulder provides an appropriately clean and smooth surface for cyclists so they will use it. While full design widths are desirable, even modest shoulders are beneficial.

Pinch points where the roadway narrows and cyclists need to move close to or into the traffic are a particular hazard. The extent of narrowing should be reduced as much as possible or managed by measures such as warning signs and marking, speed reduction measures or active signs.

Figure 29: Secondary road with high volumes of motorised traffic and cyclists. Road marking and signing to highlight the presence of cyclists. (South Moravia region, CZ)

Figure 30: Unsuitable shoulder and warning sign with "share the road" reminder (photo by Allen McGregor)

Cycle lane

Where cyclist volumes are considerable, greater separation is desirable. Danish guidelines recommend that on roads with cycle tourists and roads with more than 100 cyclists per day, the paved shoulder should be 1.5m wide, but a cycle track or cycle lane (e.g. advisory cycle lane where there is not enough space and the traffic volume is not so high) is preferred. Dividing verges between the cycle track and the carriageway are a good solution on roads with high speeds and few junctions per km of road. The width of the verge should be determined on the basis of an overall assessment of desires regarding vegetation, requirements concerning visibility and distance from solid objects and space conditions. The design of the start and end of cycle tracks is an important part of the detailed design. The start and end of a cycle track should be formed as a smooth transition between road and track as a direct continuation of the pavement of the track and without edges.

Figure 31: Advisory cycle lane on rural road in Holland

Cycle paths

Two-way cycle paths are established mainly through recreational areas as shortcuts between towns or along major roads with few junctions. They have an independent cross-section, entirely separated from any nearby road.

Figure 32: Cycle path along the rural road connects the adjacent village with town Prostejov in central Moravia region (CZ). It is used mainly for commuting traffic.

Figure 33: Cycle path connecting two villages in central Moravia region (CZ) is used instead of busy rural road

Cycle paths along roads should only be established after a safety assessment in relation to other solutions. They should not be established along roads where there are many side roads, driveways, etc., across the path. Safety problems arise where a cycle path crosses side roads, because it is often difficult for motorists to realise that cyclists can come from the “wrong” direction. From a road safety perspective, it is usually best to place the cycle path on the side of the road that has the fewest side roads, driveways etc. At junctions of paths and roads and at the ends of paths, conflicts arise between cyclists and motorists. It is particularly the case that the party that has the obligation to give way should recognise the problem. It is important to have uniformly good visibility conditions on both sides of the junction. There are many solutions that can make cyclists aware of and accept the obligation to give way where paths cross roads. Stop signs or give-way markings can be used; humps, undropped kerbs and upward inclines can be established approaching the road, or speed-reducing exit constructions. Finally, access barriers can be used to impose the obligation to give way to cyclists. This is an effective solution, but a lot of bother for path users. Sometimes access barriers are used to prevent motor vehicles from entering the path, but here bollards with reflectors are just as good. Access barriers should therefore be used only rarely. They should be sited about 5-7m from the edge of the road so that the cyclists are brought to a position with a good overview of the situation. The nearest barrier should always be on the right. The barriers and bollards should be lit and visible from the path at a distance of at least 30m.

Many cycle paths along highways end on the outskirts of a town. This termination can be combined with traffic-calming measures at a town gateway.

3.1.3 Intersections

A significant proportion of rural fatal and serious cyclist injuries (e.g. 30 % in New Zealand) result from intersection and driveway conflicts, with the severe injuries resulting from cyclists failing to yield to faster motor vehicles. These typically happen when turning left across traffic from behind and when entering from driveways and side roads.

Figure 34: Cycle route turns from very busy secondary road to the left to cycle path without any measure (South Moravia region, CZ)

Figure 35: Warning signs on very busy main secondary road in front of its crossing with minor road with busy cycle traffic – a black spot (South Moravia region, CZ)

Cyclists are also vulnerable when circulating around larger (or multilane) rural roundabouts with the diameter of the central island to be 20–40 m and when squeezed by heavy vehicles on the approaches when the rear of a heavy vehicle cuts in while turning right. For this reason, cycle lanes and marked shoulders are not recommended according to Danish guidelines and in many countries they are not even permitted for the approaches and circulating areas of most rural roundabouts. The safest option for rural roundabouts is to provide a separate cycle path. Usually cyclists on the path should cross the road with an obligation to give way to traffic on the road. To prevent cyclists from having to make too big a detour, a two-way cycle path may be a good solution. Less dynamic roundabouts with a central island of 10-20m in diameter may be used by cyclists in combined traffic.

Figure 36: Semi-rural roundabout with separated two-way cycle paths (near city of Otrokovice, CZ)

3.1.4 Pedestrians

Pedestrian accidents predominantly occur in urban areas, but pedestrian accidents in rural areas more often lead to pedestrian deaths. According to a review by Campbell, Zegger, Huang and Cyneski (2004), the pedestrian groups that are over-represented in pedestrian accidents are young pedestrians, pedestrians who had consumed alcohol and older pedestrians. According US data (the study from 2004), among all rural fatal pedestrian accidents, almost 90% involved a single vehicle. The commonly-accepted weekend period (Friday–Sunday) accounts for half of the fatalities. Almost all studies have found that males are over-represented based on their proportion of the population (US study from 1996 stated that 74% of all rural pedestrian fatalities involved males). Evidently, limited visibility plays a major role in the occurrence of rural pedestrian fatalities. Dark, unlit conditions existed for 64% of the accidents and 12% occurred on lighted roadways during the hours of darkness. 4% of rural fatal collisions with pedestrians were associated with a previous accident. According to accident data from New Zealand, fatal and serious pedestrian casualties are evenly split between those where a pedestrian was crossing a road and those where a pedestrian was walking along a road (in urban areas, accidents mainly occur when pedestrians are crossing the road). There is a significant group where pedestrians are unnecessarily standing or even lying on the road.

Where pedestrians are known to cross the road in significant numbers, the basics of adequate visibility, minimising crossing distances, speed management and clear delineation between the roadway and the pedestrian spaces are most important (e.g. tourist attraction areas, petrol stations, rest areas). For pedestrians walking along the road, having a place to walk outside the traffic lanes is important, as is street lighting for highways through small rural communities.

3.2 Risk factors regarding Powered Two Wheelers (PTW)

PTW safety issues must seen as part of a holistic approach for future RSI and RSA procedures. In this chapter, these aspects are provided separately as it is an additional aspect for most users.

The European project “2-BE-SAFE” has highlighted specific influences of road infrastructure on PTW accident risks (Activity 1.2). Some of the key outputs (literature) are summarised in the following paragraphs.

3.2.1 Type of area

A significant number of projects and papers related to the influence of infrastructure elements to the behaviour of PTWs can be traced in literature. However, the papers concerning PTW safety are much fewer. One of the major influential characteristics of the interaction of PTW accidents to infrastructure is the type of area. MAIDS (ACEM 2003) reports that most of the accidents (72%) take place in an urban area and approximately 25% take place in a rural area. Pearson and Whittington (2001) also state that approximately 70% of motorcycle injuries occur on local area roads in Australia.

ASSING (2002), a German study on the general development of accidents involving motorcycles using individual data of the official accident statistics concerning accidents involving injury to people in which at least one motorcycle (light motorcycle, motorcycle or moped) was involved, reveal that the highest degree of seriousness is to be found on roads outside built-up areas.

Furthermore, the crash severity depends on the location. Because most crashes at intersections happen inside urban areas where the speed is generally lower than outside urban areas, the crash severity is also much lower at these locations (ASSING 2002). By contrast, the percentage of crashes in curves is much higher outside urban areas.

Bridges can be problematic for motorcyclists. Issues develop if they are placed on bends or if they have a surface friction lower than that of the approach road (e.g. concrete or wood after an asphalt road) (NPRA 2004).

SPORNER (2006) analyses the main aspects and the particular risks for accidents on rural roads in cooperation with TÜV Bayern and some police stations with in the federal states of Bavaria and North Rhine Westphalia. For the first time, a global view on vehicle/driving behaviour and layout of roads is presented: If only one of the derived risk elements appears, it may be harmless, but in combination with others it can finally cause an accident. The study includes analytical investigated samples concerning the focal reasons that caused the accident, as well as a list of typical distinctive features due to the layout of the roads.

3.2.2 Road geometry and roadside installations

A serious consideration in PTW safety is the influence of road geometry, roadside installations such as barriers, posts and so on, as well as the markings. Miller (1997) reports that gravelled (rather than sealed) road shoulders, slippery road markings, slippery manhole covers/steel plates and uneven road surfaces are considered a danger to motorcyclists. Miller (1997) suggests that kerbs should be marked or painted with fluorescent material to ensure that they are more conspicuous in low light conditions

According to an in-depth study concerning safety situations in Germany, crests in the vicinity of curves and intersections, a high bendiness and high gradients are characteristics of roads with a high proportion of motorcycle crashes (Kuhn 2008)

Gerlach (2007), analysed data for road sections in which accidents occurred and compared this with sections where no accidents happened. This analysis by comparison provided the most important results of the project. It was possible to show that at road sections in which a) the angle changing throughout the entire section is more than 200gon/km, b) a maximum of 15 changes in the road direction per km occur, c) at least 50% of the roads are straight and d) the road section is longer than 2.0km, there is a higher risk potential for motorcyclists compared to the average potential for risk on comparative road sections.

Gerlach (2007) also emphasises that 18% out of 595 motorcycle crashes (only crash type: driving accident) occurred at crash sites, where the cross falls did not match the requirement of driving dynamics (super elevation in the inner curve). However, these “negative” cross falls mostly had a super elevation much below 2.5%. Furthermore, it could be shown that the recommended maximum cross fall of 8.0% was exceeded in some cases.

One particular analysis concerning the gradient comes up with the following result: the number of motorcycle casualties on road sections with a descending gradient between 4.0% and 10.0% is higher than on road sections with an ascending gradient lower than 4.0%. Accordingly, a descending gradient has a strong effect on motorcycle safety (Gerlach 2007).

An analysis which combines the effects of cross fall, gradient and direction of curve pointed out that most motorcycles crashes happen in left curves with descending gradient followed by right curves with descending gradient. Furthermore it could be found that especially in left curves with descending gradient, a negative cross fall is a major problem (Gerlach 2007).

Due to the fact that 78% of the investigated motorcycles crashes happen on roads with a bendiness of more than 200gon/km (60% of investigated routes), it could be proven that the bendiness of a road is a very important criterion from the safety point of view (Gerlach 2007).

MAIDS report (ACEM 2003) identified the contributing factors for each accident case study reported. Considering a roadway design defect as a condition which presented a danger for PTW riders (such as failure to install signs, built-in obstructions, curve with decreasing radius or inadequate distance to merge lines), data indicated that roadway design defects were present in 57 cases (6.2%) along the PTW pre-crash path, but did not contribute to the causation of the accident in 47% of those cases.

A roadway maintenance defect was reported in 146 cases (15.8%), being a primary or contributing factor in 25 cases (17.1% of cases involving a roadway maintenance defect). Weather made no contribution to the accident causation in 92.7% of the total number of cases, while there were 18 cases (2%) in which weather was identified as the primary contributing factor and was also reported to contribute to accident causation in 42 cases (4.6% of all cases).

MAG (2005) underlines that the major cause of injury when a rider comes into contact with a crash barrier is **exposed posts**. Several solutions have been developed; one system most widely used today involves the fitting of a secondary rail to the existing barrier; the so-called “motorcycle friendly barriers”. Following several motorcycle accidents (including fatalities) at the A2070 Cloverleaf Junction in Kent, the Highways Agency identified the German ‘Bike Guard’ system as best suited to improve rider safety. Analysis of accident statistics since this was introduced has shown that “no personal injury accidents have occurred”.

In relation to infrastructure elements, Elliot et al. (2003) made the following points:

- Parallel longitudinal grooves in the road surface (for example, to avoid aquaplaning) can also induce instability.
- While travelling on a road with markings on the path of travel, a potential leaning angle of 45° on dry tarmac can be reduced to 40° on dry road markings, and further to 25°on wet markings.
- Crossing profiled (markings running in a direction other than parallel to the direction of travel) road markings causes “strong steering impulses leading to deviations of about 100mm” from the motorcycle track. Furthermore, road markings cause surface water retention and can increase the possibility of aquaplaning.

Road markings, manholes and cattle grids can be more slippery than the road surface, especially when wet (NPRA 2004). Moreover, riding is affected by the presence of surveillance cameras; not-at-fault crash involvement at intersection is reduced in such a setting (Haque et al. 2009).

Some concern has been expressed over the potential for Vehicle Restraint Systems (VRS) to cause injury to motorcyclists. The following assertions are made (MacDonald 2002):

The current standards and specifications for roadside hardware, and the systems themselves, are not designed to take into account impact by motorcyclists.

The current European standard is not necessarily applied to minor roads;

There is a distinction between a safety fence and a safety barrier. The former consists of poles supporting one or more horizontal elements, whereas the latter tend to have a continuous surface.

Safety barriers are generally not considered to present the same type of hazard to motorcyclists as fences.

Gibson and Benetatos (2000) examined New South Wales fatal motorcycle crash records from 1998/1999, identifying three crash scenarios involving crash barriers:

- Motorcyclist is thrown into the air prior to impacting with the barrier;
- Motorcyclist separates from their bike and slides along the road before striking the barrier;
- Motorcyclist strikes the barrier whilst still on the bike.

They also concluded that the majority of fatal impacts were at a relatively shallow angle (<45°). The perceived risk of impacting a concrete barrier is less within this angle range compared to an impact with a barrier post from a w-beam or wire rope barrier. Morgan and Ogden (1999) suggest that impact forces are not as severe when colliding with a large surface area at a shallow attack angle. Gibson and Benetatos (2000) and Duncan et al. (2000) therefore argue that hitting an exposed post can result in more severe injuries. Impacts with guardrail posts reportedly cause injuries that are five times more severe than those from an average motorcycle accident.

ATSB (2000) examined any evidence or information regarding the safety implications of wire rope safety barriers. Concerning the use of road safety barrier systems, the study underlines that road safety barriers are an important and effective road safety measure. Motorcycle representatives argue that little consideration is given to the installation of barriers which are safe for all road users, and that the needs of motorcyclists are "largely ignored" in this matter. As accident reporting is not detailed enough to quantify the safety issue, they claim wire rope fences result in "unquantified trauma". ATSB (2000) recommended concrete barriers, and argued that when maintenance costs are taken into account, these can be a more economically viable option. Furthermore, they recommend that vehicle rollovers can be prevented by the use of 'F profile' concrete barriers, providing an overall beneficial solution. On the other hand, the ATSB's view was that wire rope safety barriers are "not currently a motorcycle safety problem", given only one recorded motorcycle casualty and no fatalities involving a wire rope safety barrier. Furthermore, they state that although motorcycle riders only make up 0.5% of road traffic, the authorities do have an obligation to address their safety issues. However, without evidence they could not remove a measure which has safety benefits for other road users.

In view of the APROSYS (2006) task concerning the impacts of motorcyclists into infrastructure, a review of existing literature on motorcycle-infrastructure interaction showed that collisions with an obstacle occur in 4.2% to 19.7% of motorcycle accidents depending on the area. Roadside barriers are involved in 2.4% to 4% of all PTW fatalities, constituting a particular hazard to PTW riders. The typical barrier impact location is a curve, and in about half of the cases the rider impacts in an upright position. In spite of this fact, research is mainly focused on the other half, involving a sliding impact position. Several counter-measures have been developed to reduce the injuries of the riders involved in this sliding impact position, such as a continuous additional rail mounted on roadside barriers.

As a result of an in-depth databases analysis, it was concluded that roadside barrier impact occurred under small angles at high speeds, mostly causing injuries to head and lower extremities (APROSYS 2006). Considering metal barrier impacts, the rail seems to be hit more often than the post. Tree and pole impacts are at least equally hazardous to PTW riders than barrier impacts.

MAG's position in relation to safety barriers in the UK is summarised below (MAG 2006):

- In 2003, there were 109 slight, serious or fatal motorcycle casualties where the rider hit the central barrier
- There were 144 collisions where the rider struck the near or offside crash barrier
- From 1999 to 2003, there were 1271 motorcycle casualties involving a collision with a central, near or offside barrier. 142 fatalities resulted from these collisions
- In 2003, 5.2% of all fatalities were crash barrier impacts

The paper points towards computer simulations and tests which reportedly indicate that "injuries will be severe if a rider hits the cables or exposed supporting posts of vehicle restraint systems" (MAG 2006). MAG's position in the paper is that vehicle restraint systems are designed with the majority of road users in mind, and that motorcyclists "are not given sufficient consideration". MAG suggests that vehicle restraint systems should be designed and tested for motorcycle safety, as well as for the safety of other road users.

When striking barriers, studies indicated that the dummy experienced more rapid deceleration/load when colliding with a steel barrier than a concrete barrier. Nevertheless, the research suggests that the deceleration during both would have resulted in severe or life threatening injuries (Berg et al. 2005). When the rider impacted with a steel barrier in an upright position, the crash tests showed that the dummy slid alongside and onto the barrier. Contact and snagging with parts of the barrier would have led to severe injuries in this instance. The rider was not decelerated by the concrete barrier, and although the measured dummy loads did not indicate a risk of life-threatening injury, kinetic energy was not dissipated, and this increases the risk of being deflected into oncoming traffic (Berg et al. 2005).

The results obtained from the simulated concrete barrier tests indicate that motorcyclists impacting in an upright position will experience low deceleration and sustain survivable injuries, unless they are catapulted over the barrier and strike the objects around which the barriers were built (Berg et al. 2005).

The results on the simulated wire rope barrier tests showed that (Berg et al. 2005):

- Riders are unlikely to clear these types of barriers. They are likely to get caught and decelerate very quickly;
- The wires are likely to guide the motorcycle into posts and lead to heavy impacts, increasing the risk of severe injury to the rider.

Impact with crash barriers/safety fences can result in serious injures for motorcyclists. There are today several means for improving the safety performance of existing barriers/fences in order to make them friendlier for motorcyclists. In particular, crash barriers which allow the rider to slide along the surface of the barrier without hitting any objects that concentrate the collision energy seem to lessen the risk of injury. Although at the moment is not possible to estimate how large the reduction in injury severity will be when crash barriers are modified, it is no doubt that this measure will result in some reduction of injury severity.

It is recommended that efforts should be given priority to improve barriers/fences located on sharp curves or on motorcycle accident black spots. Finally, Ulleberg (2003) concludes that it is also important to focus on the roadside area on locations where there are no fences/barriers, particularly by removing objects in the roadside area which the motorcyclists may hit in run-off-road accidents.

Regarding guardrail crashes, Gabler (2007) examined the Fatality Analysis Reporting System (FARS) database to identify guardrail crash trends in cases where a fatality has occurred. The primary results of the study were as follows:

- In 2005 for the first time, the number of motorcycles suffered more fatalities than car passengers or any other vehicle type involved in a collision with a guardrail;
- Motorcycles compose only 2% of the vehicle fleet in the USA, but account for 42% of fatalities involving a guardrail;
- Over two thirds of motorcyclists fatally injured in guardrail crashes were wearing a helmet;
- Approximately one in eight motorcyclists who were struck by a guardrail were fatally injured; a fatality risk over 80 times higher than for car occupants involved in a collision with a guardrail.

In Germany in 1986 and 1987, 15% of motorcycle fatalities involved crashes with guardrails (Koch and Brendicke, 1988). The solutions proposed by Brailly (1998) were the use of a shield on barriers to protect the rider from the upright sections of barrier. The study suggested introducing a 'safety zone' on barriers using this method of 'modesty rails', particularly on curves with a radius of less than 250m. The German solution has been to re-design the post and use an energy absorbing material.

3.2.3 Lighting and Visibility

A significant concern in PTW safety is visibility. Poor visibility (horizontal curvature, vertical curvature, darkness) is responsible for increased motorcycle injury severity (Savolainen and Mannering 2007). Poor sightline visibility and rider/bike conspicuousness are likely to contribute to motorcycle accidents at intersections (NPRA 2004). Moreover, riding in darkness without street lighting was related to severe motorcyclist injury (de Lapparent 2006, Pai and Saleh 2007, 2008).

Motorcyclists are found to be more vulnerable during the nighttime at both intersections and expressways (Haque et al. 2009). Injuries resulting from early morning riding, in general, appear to be the most severe, especially in junctions controlled by stop and give-way signs and markings (Pai and Saleh 2007).

DGT (2007) aimed to obtain the main PTW accident scenarios and identify their causes and consequences in a well-defined sampling area, i.e. the non-urban roads of the Spanish road network. The study focused on fatal accidents involving at least one motorcycle (rider or the occupant killed as a result of the accident) during the year 2007. The study shows that most of the accidents occur with enough lighting, good weather conditions and good roadway surface condition. Approximately three out four fatal accidents are located in conventional roads. Run-off accidents were reported in 60% of all cases, being the most frequent type of fatal accident. Roadside elements were found to be particularly hazardous to motorcycle riders, since these elements were impacted in approximately 35% of all fatal accidents. Within accidents including roadside elements, metal barrier collisions were reported in 18% of all cases.

Motorcyclists often experience reduced visibility when wearing glasses, visors or wind shields (NPRA 2004). Dew can build up quickly on motorcyclists' visors, windshields and glasses when entering a tunnel.

3.2.4 Type of collision

Concerning the type of collision, a French study (Brailly, 1998) concluded that the rate of fatal injuries per collision is five times higher than the national average if the rider strikes a barrier. Collisions with barriers account for 8% of all motorcycle fatalities and 13% of fatalities on rural roads.

At-fault crashes on expressways are found to increase when riding in the median lane, with higher engine capacity and when riding with a pillion passenger (Haque et al. 2009).

Head-on collisions with other vehicles while negotiating a curve make up 6% of person injury accidents, and 13% of fatal accidents (NPRA 2004). Collisions with stationary objects result in more severe injuries (Quddus et al. 2002, Lin et al., 2003, Keng, 2005, Savolaine and Mannering 2007). Motorcyclists were more injured while motorcycles were overtaking their collision partners and while vehicles made a turn (Pai and Saleh 2008).

At collisions at intersections between cars and motorcycles, the car drivers are usually at fault. A possible explanation for this is that the car drivers do not "see" motorcycles, either because the shape and colour of motorcycles make them blend with the background and hard to see or the car drivers just notice other cars, making them overlook motorcycles even though they are clearly visible (Glad 2001).

3.2.5 Junction Type

Junction type is a significant influential factor of PTW safety. Hurt et al. (1981) and de Lapparent (2006) note that the probability that a severe/fatal accident occurs at intersections is higher than the same probability at non intersections. The most common accident has been found to be the right of way violation (ROWV), where a vehicle pulls out from a side road onto a main carriageway into the path of an approaching motorcycle (Hurt et al. 1981, Haworth et al. 2005, de Lapparent, 2006, Crundall et al. 2008).

Pai and Saleh (2007, 2008) provide an extensive study into the interaction of junction type and motorcycle injury severity. In brief, the influential factors to motorcyclist injury severity at uncontrolled junctions are: elderly rider, greater engine size of motorcycle, riding in early morning, at the weekend and under fine weather; unlit street lights; riding on uncongested road; collisions with bus/coach or HGV. In the case of signalised intersections, identified critical parameters are the following: heavier engine size of motorcycle; collisions with bus/coach or HGV; riding under fine weather and on non built-up road; and type of collision.

Regarding interactions of junction type with gender and age, it has been reported that, once an accident has occurred, male riders, were more likely to be severely injured at signalised than at unsignalised junctions (Pai and Saleh 2007). Moreover, teenage riders were more prone to be severely injured than those aged 20–59 in accidents where stop, give-way signs or markings controlled the junctions, in contrast to findings regarding accidents at uncontrolled junctions (Pai and Saleh 2007). Collisions where older driver vehicles were making a turn and colliding with motorcycles happened mostly at unsignalised junctions (Pai and Saleh 2008).

Intersection accidents account for 30% of personal injury accidents, and 17% of fatal accidents. These types of accidents are more prevalent in 'moped' users. In 87% of such accidents, it was the obligation of the motorist to give way, whereas in 13% it was the motorcyclist who should have yielded. This would suggest that driver behaviour is the main factor in intersection accidents (NPRA 2004).

Unsafe speed greatly affects injury severity (Branas and Knudson 2001, Savolainen and Mannering 2007); the effect of speeding is intensified at unsignalised junctions (Pai and Saleh 2007).

More than half of motorcycle crashes with personal injury occur at intersections, respectively T-junctions including entrances and exits (ASSING 2002). However, these crashes are characterised by a relatively low severity (ASSING 2002). The crash severity is much higher for crashes in curves, especially in combination with slopes.

3.2.6 Pavement surface conditions

Concerning the pavement surface conditions, Shankar et al. (1996) emphasise pavement surface and type of highway impact on side-swipe collisions between motorcycles and other motorised vehicles at junctions. Wet pavement surface is found to cause at-fault motorcycle accidents at non-intersections (Haque et al. 2009). However, Savolainen and Mannering (2007) suggest that in certain circumstances risks could be mitigated by motorcyclists; for example, riding on wet pavement conditions, near intersections.

ASSING (2002) reports that in Germany during 1999, 83% of all motorcycle crashes occurred on dry road surfaces. In comparison, the percentage of all crashes with personal injury on dry road surfaces was only 66%. This difference could be explained by the fact that most motorcyclists use their bikes only during fair weather conditions.

In the PTW accident analysis conducted in MAIDS (ACEM 2003), roads were found to be dry and free of defects in 84.7% of all accidents, while roads were found to be wet in 7.9% in all collected cases. Road surface defects were present in 30% of cases.

Bitumen used in the repair of road surfaces have much lower skid resistance than for wet tarmac, causing steering problems when riders cross wet bitumen, particularly whilst leaning or braking in an upright position according to Elliot et al. (2003).

A well-known problem caused by an insufficient stiffness of a motorcycle frame is deterioration of stability (Brorsson and Ifner 1983). Serious injuries have been reported to be caused by motorcycles which suddenly begin to wobble or weave. Road surface actively contributed to 15% of crashes examined by the Victorian Motorcycle case control study (Haworth et al. 1997). The authors suggested that the important factors in these collisions were:

- Skid resistance (surface grip)
- Surface irregularities and potholes
- Loose materials
- Patch repairs
- Road markings

Pearson and Whittington (2001) state that motorcycles are very sensitive to changes in friction level between the road surface and tyres.

<u>Samples of risky areas:</u>

For PTW riders, a roadway maintenance defect caused the accident or was a contributing factor in 6.6% of all cases.

The presence of stationary objects which obstructs the view of the rider or the driver was found to be common causes of accidents

Roadside barriers presented a substantial danger to PTW riders, causing serious lower extremity and spinal injuries as well as serious head injuries. But that influence can vary strongly from country to country. That risk factor must be evaluated with local crash statistics.

Crash barriers are typically designed to guide and restrain errant vehicles, ranging from small cars to heavy goods vehicles.

A motorcyclist involved in an accident or a fall will come away from the motorcycle and slide along the road surface, with an initial speed equal to the speed of the motorcycle. During this sliding motion, the motorcyclist is at risk of impacting with 'roadside furniture' such as lamp-posts, sign-posts or crash barriers.

Existing regular crash barriers are often made of steel beams, mounted on supporting steel posts. The major cause of (fatal) injuries to motorcyclists coming into contact with a crash barrier is the fact that the sliding motorcyclist hits one or more of the supporting posts of the crash barrier.

Most 'road furniture' is designed with cars in mind and motorcyclist safety needs are not taken into account; this becomes clear by looking at the design and testing of conventional crash barriers. Since roads and roadsides should be safe for all road users, including motorcyclists, the best solution is to have "obstacle-free roadsides"; when an obstacle-free roadside is not achievable and crash barriers have to be placed, the safety of the PTW should be taken in the due consideration by using motorcycle-friendly barriers like in the following figure;

Other solutions are the use of concrete barriers in cases of higher PTW crash risk.

An important issue is that motorcycle safety does not just mean fewer injuries or fatality in crash events; it is important to decrease the crash numbers first. There must be preventative measures to ensure a low risk of accident.

Conclusions:

PTW safety can generally be separated into two levels (some samples below):

1. **Macroscopic level:**

- The type of area
- Carriageway type
- Road Installations and stationary objects
- Pavement surface conditions
- Junction type
- Geometry specifications

2. Microscopic level:

- Alignment:
    i. Cross fall and curve radius (radii smaller than 200m)
    ii. Curvature change rate
- Black spots for passenger cars
- Deficits (general unevenness, for example road surface waves and potholes)
- Skid resistance, friction value
- Road surface materiale.g. accumulation of bituminous binders and ruts
- Readability (=not-predictable road geometry)
- Visibility
- Obstacles

3.2.7 Most relevant risk factors

- Roadway design defects (failure in road construction, disharmonious trace geometry, curvature, unevenness, potholes, etc)Roadway maintenance defects

- Road surface condition (problems on wet roads, slippery bitumen on hot asphalt, poor skid resistance, etc)
- Collision with roadside barriers in a run-off accident (very high fatality rate)
- Critical curve radii (curve radii relations)
- “Negative” cross fall (cross fall does not match the requirement of driving dynamics)
- Combined effect of cross fall, gradient and direction of curve (most motorcycle crashes happen in left curves with descending gradient, followed by right curves with descending gradient; in left curves with descending gradient, a negative cross fall is a major problem)
- Intersections (poor sightline visibility and rider/bike conspicuousness are likely to contribute to motorcycle accidents at intersections)
- Road markings, manhole covers and cattle guards
- Poor visibility and speeding are a common multiplication of infrastructure related accident risk

3.2.8 References

Pedestrian Safety on Rural Highways, FHWA. 2004

Campbell, Zegger, Huang and Cyneski: A Review of Pedestrian Safety Research in the United States and Abroad, FHWA. 2004

Factors contributing to pedestrian and bicycle crashes on rural highways – summary report, FHWA. 2010

High-risk rural roads guide, NZ Transport Agency. 2011

Collection of Cycle concept, Denmark Road Directorate. 2000

Design Manual for bicycle traffic, CROW. 2007

ETSC PIN Report. 2010

SWOV Fact sheet - Vulnerable road users- February 2007

FEMA Federation of European Motorcyclists' Associations - POSITION STATEMENT DIRECTIVE ON ROAD INFRASTRUCTURE SAFETY MANAGEMENT- 19th April, 2007

FEMA - The road to success - July 2005

ACEM Association des Constructeurs Europeens de Motorcycles (2006): Guidelines for PTW-Safer road design in Europe, Brussels.

ACEM Association des Constructeurs Europeens de Motorcycles (2004), MAIDS (Motorcycle Accident in-depth Study)

APROSYS SP4 D413. Report on accident scenarios for motorcycle-mororcyclist-infrastructure interaction. State-of-the art. Future research guidelines.

ASSING (2002): Schwerpunkte des Unfallgeschehens von Motorradfahrern [Main aspects of motorcycle accidents], Berichte der Bundesanstalt für Straßenwesen, Schriftenreihe „Mensch und Sicherheit“, Heft M 137, Bergisch Gladbach.

Australian Transport Safety Bureau (ATSB) – Working party report, (2000). Review of Wire rope safety barriers

BALD, S.: Untersuchungen zu Determinanten der Geschwindigkeitswahl.; Bericht zum FP 8525/3 der BAST, Bereich Unfallforschung, Nr. 158, Bergisch Gladbach, April 1987, 119 S.; 1987.

BARSI T. S, FAERGEMANN C. AND LARSEN L. B. (2002). Road Traffic Accidents with Two-Wheeled Motor Vehicles During a Five-Year Period in Odense, Denmark, Traffic Injury Prevention, 3, 283–287.

Berg, Rucker, Gartner, Konig, Grzebieta and Zou (2005). Motorcycle impacts to roadside barriers – real world accident studies, crash tests and simulations carried out in Germany and Australia

BJÖRKETUN, U.: Relationships between Pavement Types and Traffic Accidents in Different Weather Conditions.; VTI Topics Vol.4 No.3, May 1985, S. 3-4.; 1985.

C Duncan, B Corben ,N Truedsson, C Tingvall, 01.12.2000, "CR 201: Motorcycle and Safety Barrier Crash-Testing: Feasibility Study", Monash University Accident Research Centre

CROSS, K.D.; FISHER, G.: A Study of Bicycle/Motor-Vehicle Accidents: Indentification of Problem Types and Countermeasure Approaches.; Vol. I, Final Report September.; 1977.

DE LAPPARENT M. (2006), Empirical Bayesian analysis of accident severity for motorcyclists in large French urban areas, Accident Analysis and Prevention, 38 (2), 260-268.

DfT – Department of Transport (2005): The Government's Motorcycling Strategy, London.

DGT (Dirección General de Tráfico, España). Estudio de accidentes con implicación de motocicletas en España. (*Motorcycle accident analysis study)*

EISENBERG, D.: The mixed effects of precipitation on traffic crashes.; Accident Analysis & Prevention Vol.36, 2004, S. 637-647.; 2004.

ELLIOTT M A, BAUGHAN C J, BROUGHTON J, CHINN B, GRAYSON G B, KNOWLES J, SMITH L R AND SIMPSON H (2003), Motorcycle safety: a scoping study, TRL Report TRL581, UK.

Elliott, Baughan, Broughton, Chinn, et al. (2003). Motorcycle Safety: A Scoping study

EURORAP – European Road Assessment Programme (2008): Barriers to change: designing safe roads for motorcyclists – position paper on motorcycle and crash barriers, Brussels.

FEMA – Federation of European Motorcyclists Association (2007): A European Agenda for Motorcycle Safety – The Motorcyclist´s Point of View, Brussels.

FEMA (Federation of European Motorcyclists Associations) Position Statement, 19.04.2007, "Directive on road infrastructure safety management"

FGSV - Forschungsgesellschaft für Straßen- und Verkehrswesen [German Road and Transportation Research Association] (2007): MVMot - Merkblatt zur Verbesserung der Verkehrssicherheit auf Motorradstrecken [Guideline for improving traffic safety along motorcycle routes], FGSV-Verlag, Köln.

Gabler (Virginia Tech), The risk of fatality in motorcycle crashes with roadside barriers.

GALVAGNINI, S.: Die Verkehrssicherheit der motorisierten Zweiräder.; Diplomarbeit am Institut für Straßenbau und Verkehrswesen der TU Wien, Abteilung für Verkehrsplanung und Verkehrstechnik, Wien, 29. Oktober 1985, 205 S.; 1985.

GERLACH, ODERWALD (2007): Schutzeinrichtungen am Fahrbahnrand kritischer Streckenabschnitte für Motoradfahrer [Measures for the enhancement of safety of motorcyclists at the edge of carriageways on critical road sections], Berichte der Bundesanstalt für Straßenwesen, Schriftenreihe „Verkehrstechnik“, Heft V 152, Bergisch Gladbach.

HAQUE MD. M., CHIN H. C. AND HUANG H. (2009), Modeling fault among motorcyclists involved in crashes, Accident Analysis and Prevention, forthcoming.

HAQUE MD. M., CHIN H. C. AND HUANG H. (2009), Modeling fault among motorcyclists involved in crashes, Accident Analysis and Prevention, forthcoming.

HARDY E., BAIRD T., (2009), Consultation, The Rider´s Perspective 2009, Motorcycle safety in Northern Ireland

HAWORTH, N., MULVIHILL, C., 2005. Review of Motorcycle Licensing and Training. Monash University Accident Research Center, Victoria, Australia.

HAWORTH, NARELLE AND ROWDEN, PETER (2006) Fatigue in motorcycle crashes. Is there an issue?. In Proceedings Australasian Road Safety Research, Policing and Education Conference, Gold Coast, Queensland.

Hessisches Landesamt für Straßen- und Verkehrswesen (2003): Maßnahmen zur Erhöhung der Verkehrssicherheit auf Motorradstrecken – Leitfaden [Measures to improve road safety along motorcycle routes – guideline], Leitfaden des Dezernats Verkehrssicherheit und Verkehrstechnik, Wiesbaden.

HORBERRY T., HUTCHINS R. AND TONG R. (2008), Motorcycle Rider Fatigue: A Review, Road Safety Research Report No. 78, February, Department for Transport, London, UK.

HORSWILL M. S. AND HELMAN S. (2003). A behavioral comparison between motorcyclists and a matched group of non-motorcycling car drivers: factors influencing accident risk, Accident Analysis and Prevention 35, 589–597

HURT, H.H., OUELLET, J.V., THOM, D.R., 1981. Motorcycle Accident Cause Factors and Identification of Countermeasures, Final Report to National Highway Traffic Safety Administration, U.S. Department of Transportation.

IHIE – Institute of Highway incorporated engineers (2008): IHIE Guideline for motorcycling, London.

JOHNSTON P., BROOKS C., SAVAGE H. (2008). Fatal and serious road crashes involving motorcyclists, Research and analysis report, Road Safety, Monograph 20 April Department of Infrastructure, Transport, Regional Development and Local Government, Canberra, AU.

KÜHN (2008): Analyse des Motorradunfallgeschehens [Analysis of motorcycle crashes], Gesamtverband der Deutschen Versicherungswirtschaft e.V. – GDV [German Insurance Association], Unfallforschung kompakt, Berlin.

LIN, M.R., CHANG, S.H., PAI, L., KEYL, P.M., 2003. A longitudinal study of risk factors for motorcycle crashes among junior college students in Taiwan. Accident Analysis and Prevention 35, 243–252.

M Macdonald (2002). Motorcyclists and Roadside Safety hardware, Presented at the A2A04 Summer meeting

Motorcycle Action Group (MAG), (2005). Motorcycle Friendly Crash Barriers

Motorcycle Action Group (MAG), (2006). Vehicle Restraint Systems; Safety Fences, Crash Barriers, Motorcyclists, Version 1.4

NATIONAL TRANSPORT COMMISSION (2001) Options for a Regulatory Approach toFatigue in Drivers of Heavy Vehicles in Australia and New Zealand. www.ntc.gov.au.

NMCU – Norwegian Motorcycling Union (2004): MC Safety - Design and Operation of Roads and Traffic Systems, Oslo.

OUELLET, J.V.; SMITH, T.A.; THOM, D.R.; KASANTIKUL, V.: Environmental Contributing Factors in Thailand Motorcycle Crashes.; INSTITUT FÜR ZWEIRADSICHERHEIT (Hrsg.): Sicherheit Umwelt Zukunft IV.; 2002.

PAI, CHIH-WEI AND SALEH, W. (2007), An analysis of motorcyclist injury severity under various traffic control measures at three-legged junctions in the UK Safety Science 45 832–847.

PAI, CHIH-WEI AND SALEH, W. (2008). Modelling motorcyclist injury severity resulting from sideswipe collisions at T-junctions in the United Kingdom: new insights into the effects of manoeuvres, International Journal of Crashworthiness, 13(1), 89-98.

REEDER, A.I., CHALMERS, D.J., LANGLEY, J.D., (1995). Young on-road motorcyclists in New Zealand: age of licensure, unlicensed riding, and motorcycle borrowing. Injury Prevention 1, 103–108.

RTR 2001-2003 Projects, "Motorcycle Accident Investigation: Development of a Common Methodology for Motorcycle Crashes Data Collection", (Chairman of the Technical Expert Group: Mr. Cesari, INRETS, France)

RUTTER, D.R. AND QUINE, L., (1996). Age and experience in motorcycling safety. Accident Analysis and Prevention 28, 15–21.

SAVOLAINEN, P. AND MANNERING F. (2007), Probabilistic models of motorcyclists' injury severities in single- and multi-vehicle crashes, Accident Analysis and Prevention 39, 955–963.

SEXTON, B.; BAUGHAN, C.; ELLIOTT, M.; MAYCOCK, G.: The accident risk of motorcyclists.; TRL Report 607, Crowthorne, Berkshire 2004, 57 S.; 2004.

SHANKAR V., MANNERING F.L. AND BARFIELD W. (1996). Statistical analysis of accident severity on rural freeways, Acc. Anal. Prev. 28(3), 391–401.

SHANKAR, V.; MANNERING, F.; BARFIELD, W.: Effect of roadway geometrics and environmental factors on rural freeway accident frequencies. Accident Analysis & Prevention Vol.27, 1995, S. 371-389.; 1995.

SPORNER (2006): Risiken beim Motorradfahren – Spezielle Einflussgrößen durch Straßenführung und Umfeld [Motor Cycle Accidents – Particular risks due to layout of roads and environment], Institut für Zweiradsicherheit, Forschungsheft Nr. 12, Tagungsband der 6. Internationalen Motorradkonferenz, Essen.

Statens vegvesen (Norwegian Public Roads Administration) (2004). Handbook 245e: MC Safety – Design and Operation of Roads and Traffic Systems.

SWEZEY, R.W., LLANERAS, R.E., 1997. Models in training and instruction. In: Salvendy, G. (Ed.), Handbook of Human Factors and Ergonomics, second ed. John Wiley & Sons, New York.

Ulleberg, Pål Motorcykelsäkerhet - en litteraturstudie och meta-analys (Motorcycle safety- a literature review and meta-analysis). Oslo : Transportökonomisk institutt TÖI report 681, 2003 -the most recent European study on motorcycle accident causations)

Ute Grosse, Helsinki University of technology (2006). Safer restraint systems for motorcyclists, Literature research

4 Road Safety Audit (RSA)

4.1 General

In most European countries, road safety requirements both for planning, construction, and maintenance, as well as operation and equipment are contained in the applicable technical standards, specifications and guidelines. Nevertheless, road construction schemes and measures are often being planned and implemented without fully exploiting the design possibilities for road safety, in accordance with the latest technological and research developments. This can also be a result of balancing the various interests that are involved. Added to this, new scientific findings take some time to find their way into the design process. The suitable tool to deal with the above mentioned issues is the Road Safety Audit (RSA).

The RSA has got a long tradition, especially in the UK. Formalised procedures for RSA have been developed in most European countries (plus overseas). These procedures aim at minimising the occurrence of safety deficits as a result of the road planning and design. They contain general principles, as well as more specific local and national issues, and have already proven to be successful in a number of countries.

The recommendations made here are based on the evaluation of already-existing RSA handbooks and the pilot audits conducted within the PILOT4SAFETY project.

4.1.1 Area of Application

Public roads are categorised according to

- Location (outside or inside built-up areas),
- Means of access from adjacent sites (with or without access) and
- Primary function (connection, access, residence)

and planned, built and operated in accordance with the corresponding technical standards and specifications of the country concerned.

The RSA supplements these standards and specifications and can be applied to all kind of road projects – small and large. Criteria regarding the project (e.g. costs, road category and responsible road authority) could limit the execution of the RSA.

The PILOT4SAFETY project concerns only secondary roads, according to the definition given above. The manual can be applied for new construction, redevelopment and expansion work on secondary roads all over Europe.

4.1.2 Objective and definition of the RSA

There are several definitions of RSA in the literature and national guidelines, which show an overall common understanding of RSA. PIARC 2001 defines it as a formal systematic road safety assessment of the road or road scheme carried out by an independent, qualified auditor or team of auditors who reports on the project accident potential for all kinds of road users. The Directive 2008/96/EC uses the following definition: 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. The objective of the RSA is to design roads for new construction, redevelopment, and expansion work as safely as possible and minimise the risk of accidents as much as possible. The RSA places particular emphasis on the issue of road safety in the entire planning, design, and construction process. RSA covers all stages from planning to early operation.

RSA is one of the elements of the quality assurance process. It should be part of a comprehensive quality management system. The systematic application of RSA should result in the increased safety of all road users (motorists, cyclists, and pedestrians) and avoiding additional black spots on new and reconstructed roads.

4.1.3 Costs and Benefits of RSA

According to SWOV (2007), the benefits of an RSA are mainly the costs saved on crashes that have been prevented by following the audit's recommendations. In addition, there are some qualitative benefits: diminished repair works resulting from crashes, a reduction of the total project costs, a greater awareness of road safety and a higher quality in design processes, better facilities for vulnerable road users and a contribution towards achieving road safety targets, better standards, and comprehensive design guidelines.

The costs of an RSA can vary greatly depending on the size of the project and the phase in which the audit takes place. A distinction can be made between direct and indirect costs. The direct costs are the time spent by auditors and the extra time that designers need to include the recommendations in the design. The earlier in the process an initial RSA is carried out, the lower the relative costs. The experience from the PILOT4SAFETY project shows that an RSA of a "typical"[7] project on a secondary road in one audit phase can be conducted in a team of two auditors over a period of less than one week, so the direct costs of such an RSA are rather low compared to the construction costs.

The indirect costs are the extra costs of construction and reconstruction activities recommended by the auditors. Estimates of experiences abroad are between 1 and 2 % of the total project costs. In smaller projects, the direct and indirect costs of an RSA are relatively greater than in larger projects. Based on a literature study, Macaulay & McInerney (2002) maintain that an RSA is generally cost-effective. According to Elvik (2004), the effects of RSA depend on the application of the proposals made by the auditor. The effectiveness of road safety auditing is a "derived effectiveness" – depending on the effectiveness of the implementation of the proposed measures. The Handbook of Road Safety Measures (2004) mentions the following table of cost-benefit ratios of RSA.

Table 19: B/C ratio of RSA

Selected assessments of road safety audits				B/C-ratio
Safety Audit - Denmark				1.46
Method:	**CBA**	Result:	**acceptable**	
Source: Herrstedt L. (1999); Herrstedt L. (2000)				
Implementation of Road Safety Audits (RSA) in Germany				4-99
Method:	**CBA**	Result:	**excellent**	
Source: BASt (2002)				
Road Safety Audits in Norway				1.34
Method:	**CBA**	Result:	**acceptable**	

[7] Single intersection, new by-pass road, reconstruction of the road section up to 15-20 km.

The RSA has proven its road safety value abroad and it can be concluded that the RSA can contribute to road safety. However, large contributions are not to be expected because usually small alterations of the design are concerned (SWOV, 2007).

4.2 RSA phases

RSA should ideally be integrated in the planning procedure of a project as follows:

- Phase 1: Draft design
- Phase 2: Detailed design
- Phase 3: Pre-opening
- Phase 4: Early operation

These audit phases represent the recommended way to integrate the RSA into the overall procedure. Figure 37 shows the integration of the audit phases into the planning and design procedure for secondary roads. Due to national specifics, the RSA integration into the planning process can be slightly different in each country.

The required number of audit phases depends on the type of project and planning phases. Audit phases 1 and 2 should take place during the design of a road traffic facility, which should generally be before the endorsements, permissions and resolutions regarding the designs are reached. Audit phases 3 and 4 apply to the period when the road is opened; auditing in this case should take place before and after traffic opening.

Audit phases 2 to 4 should also check if the findings of the previous audit phases have been taken into consideration.

The RSA should be conducted in all phases. If this is not possible (e.g. in the cases of some specific projects), the RSA should be carried out as early as possible because the acceptance of findings resulting from RSA is higher during the earlier stages of the project.

Phase 1: Draft design
Alignment Design, Regional Planning Procedure (if necessary), Determination of the Alignment by different Authorities, Approval of Plans, Planning Permit, Disapproval of plans
Phase 2: Detailed Design
Detailed Design, Preparation an Awarding, Approval by Road Authority
Phase 3: Traffic Opening
Traffic legislation, Construction, Acceptance, Chief Supervision of Construction, Local Site Supervision
Phase 4: Early Operation
Traffic legislation, Construction, Acceptance, Local Site Supervision, Accident Structure

Figure 37: Planning and design process

4.3 Audit process

The client, designer and auditor should all participate in the audit process.

- The client: generally the road authority that orders the project from the designer
- The designer: the contractor or organisational unit responsible for planning/designing the project
- The auditor: the independent organisation, person or team who critically reviews the project worked out by the designer.

Usually the client initiates the safety audit and commissions the auditor and all information and reports are distributed via the client (Figure 38).

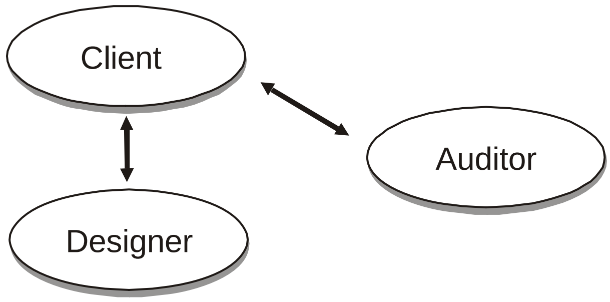


Figure 38: Participants in RSA

The RSA must be an independent process with formalised procedures and, as such, an essential part of the planning process (Figure 39). This is the case whether the audit is carried out externally or internally. The amount of time required for RSA is very small compared to the individual planning stages. Nonetheless, it should be considered well in advance. The client provides the auditor with all the design documents required for the RSA. The auditor carries out the audit independently based on these documents and, usually, a local site visit.

The audit is carried out with the following basic questions in mind:

- Is it safe for all relevant road users to use the traffic facility?
- Is the design that has been selected the best for traffic safety, within the decision framework of the regulations?
- Do new findings concerning traffic safety and road design make a different design seem advisable?

The written audit report lists the safety deficits that have been identified as well as opportunities for improvements and suggestions on how to rectify or implement these. It is not within the auditor's remit to create a new design when carrying out a RSA. The suggestions are written in the form of general and simple recommendations.

The client receives the audit report. It is useful to discuss the audit results between the client, designer and auditor. The client decides if such a discussion is required.

The client determines if, and to what extent, the proposals contained in the audit report will lead to design modifications. Reasons must be given in writing for each rejection and these must be added to the planning documents. The client informs the designer as well as the auditor of his decision. This procedure should be referred to in the contract. This concludes the process for the corresponding audit phase.

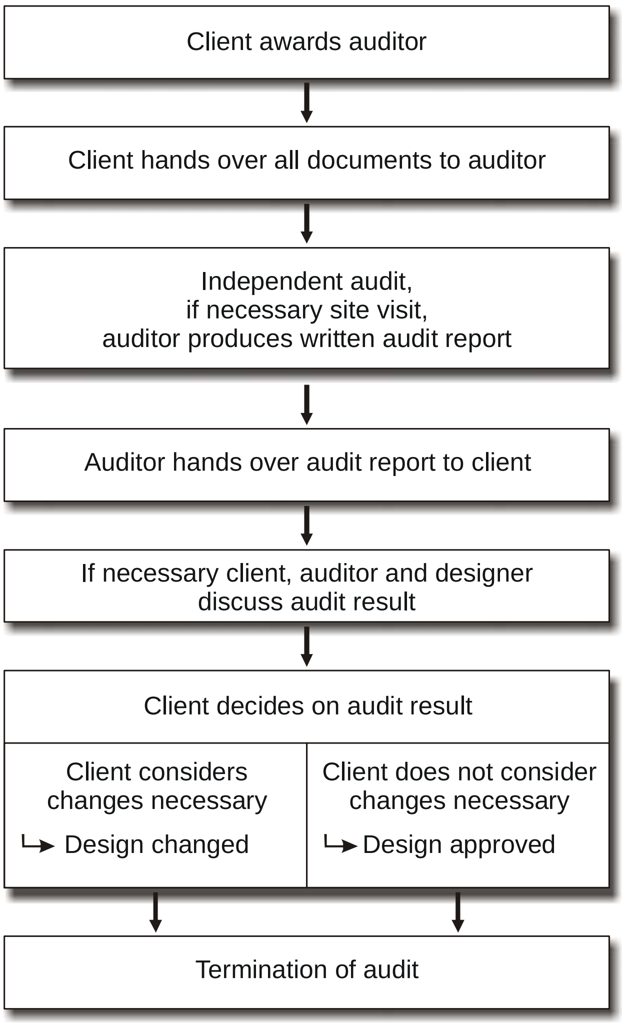


Figure 39: Procedure of safety audit

4.4 Audit implementation

4.4.1 Required documents

The number of documents required increases as the design phases proceed. The auditor should only audit the documents received from the client and not conduct complementary traffic surveys. From the existing documents, the following should be available to the auditor (each audit phase is listed in brackets):

The traffic analysis, including the traffic volume prognosis (draft design) as well as the explanatory report (all audit phases), is required for the audit. The overview map which offers insight into the location of the individual road construction measures in the road network should be available to the auditors (draft design and detailed design).

General vertical and horizontal alignment plans to a suitable scale (scale 1:5,000 to scale 1:10,000) are required in all audit phases. The junction types must be indicated.

The cross sections which also contain details regarding the width of the individual elements of the cross section, any safety devices that are planned as well as the stability of road verges are also needed for the audit (draft design and detailed design).

The vertical and horizontal alignment plans are the most important documents (all audit phases). They must therefore be given to the auditors in a suitable scale (scale 1:250 to scale 1:1,000). It is very important that these plans are clear and legible. The site plans must be in colour.

The site plans for the accompanying landscaping planning (draft design) and the landscape execution planning (detailed design, pre-opening) indicate the exact location of greenery, especially the location of trees; however, they are also used for checking the views.

For a detailed inspection of traffic signage, markings and road equipment, which greatly influence traffic safety, the auditors must have access to the traffic signage and marking plans, the site plans with the road equipment as well as the traffic engineering analysis for planned traffic signals (if required, draft design, detailed design, pre-opening).

All documents required for the individual audit phases are listed in Table 20. Depending on the type and range of the measure, not all listed documents are required.

Table 20: Required audit documents

Draft design	Detailed design	Pre-opening	Early operation
Explanatory report Traffic analysis incl. traffic volume prognosis Overview map Overview site plans with indication of junction types Overview vertical alignment plans	Result of previous audit phase with Client's decision Explanatory report Overview map Cross sections Horizontal alignment Vertical alignment Construction plans	Result of previous audit phase with Client's decision Explanatory report Horizontal alignment Vertical alignment Site plans of landscape detailed planning Signing and marking plans	Result of previous audit phase with Client's decision Explanatory report

Draft design	Detailed design	Pre-opening	Early operation
Cross sections Horizontal alignment Vertical alignment Construction sketches Site plans of accompanying landscape measures Any existing signing and marking plans	Site plans of landscape detailed planning Signing and marking plans Site plans with road equipment Signal installation plans incl. traffic engineering documents for signal planning	Site plans with road equipment Signal installation plans incl. traffic engineering documents for signal planning	

4.4.2 Procedure

Implementation of the RSA depends on the type of project (new construction, redevelopment or expansion), the location of the project in the road network as well as the audit phase.

The auditor should be given sufficient time to carry out an RSA in order to ensure a thorough audit.

The auditor should receive all required documents at the beginning of the RSA. Incomplete documents lead to questions and additional demands, resulting in more time and work being required for the audit.

The auditor should carry out a local site visit for modification or expansion schemes so that he/she is better qualified to judge the effects of the construction scheme based on the existing traffic conditions and surrounding environment. Photographic documentation is considered helpful. A site visit is not always necessary for new construction work.

When auditing in phases 1 to 2, the auditor must place him/herself in the position of the various road users (motorist, cyclist and pedestrian) using the planning documents so that he/she can judge the traffic safety of the scheme from the viewpoint of all road users. The auditor can view the scheme and audit on site only in the third and fourth audit phase. In order to evaluate the traffic facility from the viewpoint of all road users, he/she should drive through the traffic facility in a passenger vehicle, on a bicycle and on foot as a pedestrian (if necessary). It may also be necessary to view the location at different times of the day (e.g. in daylight/darkness or after school finishes).

The auditor carries out an RSA on the basis of his/her personal experience and his/her knowledge of road safety. To ensure that safety aspects have not been overlooked during this experience-based procedure, checklists are recommended to be used. These are usually divided according to different audit stages (see appendix 1).

The checklists are set against the following background:

- Full exploitation of any room for discretion in the technical standards and specifications to optimise road safety
- Findings from local accident investigations
- Results of new research work
- Experience gained from the pilot audits
- Regularly occurring design errors

Realistic depictions of photographic quality from user perspectives, as made possible by modern design programmes, as well as quantitative analysis of the spatial impression of roads can be helpful in drawing up the RSA, as they make it easier to answer some of the checklist questions.

The checklists and photographic depictions as well as the quantitative analysis of the combination of horizontal and vertical alignment cannot replace the comprehensive examination of the design or the completed road by an experienced auditor; simply working through the checklists, therefore, does not make for an authoritative RSA.

4.4.3 Audit report

The auditor produces a written audit report for each audit stage. This audit report lists the safety deficits that have been identified and provides information on how these may be rectified. In the pre-opening and early operation stage, the audit report should be accompanied by photographs.

The client decides on the results of the audit, provides written justification for any rejected proposals and places them on record together with the audit report. The audit report and the decision of the client should be made available to both the designer and the auditor.

The audit report can be structured according to the individual characteristics "cross section, alignment, junction, “and, if necessary, road user groups. An example of an RSA report template based on the PILOT4SAFEETY project experience is shown in appendix 2

4.5 Auditors

4.5.1 Requirements for the auditors

The requirements of the auditor’s professional background and education differ in each country. In general, with regard to their qualifications, auditors must have extensive knowledge and experience both in design and evaluation of the safety of road traffic facilities. As a basic qualification, auditors should have completed a relevant university education or comparable training. Several years’ experience in the field of road design and area of road-related safety examinations is required. The auditors shall undergo initial training resulting in the award of a certificate of competence. Apart from these basic requirements, additional qualifications should be gained by further training. Auditors should have the ability to evaluate the traffic safety of a road for the different road user groups. In addition, auditors should be up to date on the latest safety information relating to the design and operation of roads.

4.5.2 Position of the auditors

Independence of the auditors is important for an impartial and unbiased judgement and evaluation of the audited scheme. Independence in this context means that the audit is carried out by auditors who do not carry responsibility for the project and who are also not involved in producing the design that is to be audited.

With regard to the position of the auditors there are three different options:

(1) The auditors belong to organisational units of the road authority ("internal" auditors), which are not involved in the design process.

(2) The road authority calls in "external" auditors.

(3) The audit is carried out by "internal" and "external" auditors together.

Auditors can also be consulted during the design process as advisers, in order to avoid planning deficits that might affect safety. Auditors who are carrying out the subsequent audit may not, however, have been previously involved in the project in an advisory function.

4.5.3 Audit team

RSA can be carried out either by individual auditors or by audit teams. Audit teams have the advantage, where more complex issues are involved, of having different ways of looking at issues and being able to call on specialist approaches and different backgrounds. In the team, at least one person has to hold a certificate of competence. Less complex measures can be handled by an individual auditor.

4.6 Liability

The client (generally the road administration) is the authority responsible for the decisions at the different planning and design phases. As part of the overall evaluation process, he must take into consideration road safety. The RSA contributes to this overall process.

In this respect, the client carries responsibility for possible damages to third parties. Responsibility for the safety of the road is carried by the person or body in charge of road safety.

The audit, therefore, does not change the boundary conditions pertaining to the liability of the client and designer.

Liability of the auditor can, at the most, exist alongside liability arising from the obligation for traffic safety. The decisive factor with regard to liability is therefore whether internal auditors (employees of the road authority) or external auditors (private third party) are involved.

If the auditor is in the employment of the road authority, liability of the auditor to the road users comes under consideration if auditing is carried out as an official duty. This is, however, difficult to imagine in the normal sense of an audit procedure. Liability of the auditor would only come into question under general recourse regulations, i.e. in case of intent or gross negligence

If the auditor is a private third party, the legal relations of the client and auditor are contractually specified. The contract can also contain liability regulations. This is, however, a question for each individual case. In addition, liability towards the client comes into question as part of the general regulations on defective performance of contractual obligations.

4.7 References

DIRECTIVE 2008/96/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 November 2008 on road infrastructure safety management

Guidelines for Road Safety Audits (ESAS) – Empfehlungen für das Sicherheitsaudit von Straßen (ESAS), FGSV Verlag, Köln, Germany 2003.

Road Safety Audits, PIARC Technical Committee on Road Safety, 2001

Practical road safety auditing, 2nd edition, Belcher, Proctor and Cook, TMS Consultancy 2008

Guidelines for Road Safety Audits - Bezpečnostní audit pozemních komunikací (Metodika provádění), CDV, Brno, The Czech republic 2006

RIPCORD – ISEREST project

PIARC ROAD SAFETY MANUAL

Gadd, M. (1997). Contract reports methods for determining the benefits of safety audit : a scoping study. Transfund New Zealand, Wellington

Surrey County Council (1994). Road Safety Audit: An investigation into casualty savings. Discussion report. Surrey County Council Highways Management Division, Casualy Reducion Group, UK.

Elvik, Vaa (2004): The Handbook of Road Safety Measures.

SWOV Fact sheet (2007) The Road Safety Audit and Road Safety Inspection

5 Road Safety Inspections (RSI)

In chapter 1, a reminder of the definition of RSI as given by the Directive 2008/98/EC was given and a comprehensive definition of RSI has therefore been drafted by the PILOT4SAFETY partners and adopted for the project, to better underline that RSI definitely aims to be a preventive measure and is carried out on the existing road network.

5.1 Why do we need RSIs?

Since 2000, significant progress has been made in Europe. The number of deaths following road accidents is decreasing[8]. The 2010 targets have however not been achieved. Therefore, the new action programme for road safety tried again to halve the number of deaths between 2011 and 2020[9].

An accident is often the result of a combination of multiple unfavourable factors related to the driver (aptitude, behaviour), the state of the infrastructure (degraded friction, sudden change in curve radius, unprotected lateral obstacle, etc.), type and condition of the vehicle. If, as indicated by different sources, human behaviour is the primary road safety factor, infrastructure is part of the complex system and contributes in a significant proportion of cases (as illustrated by Figure 40), to the genesis of an accident or the worsening of its consequences.

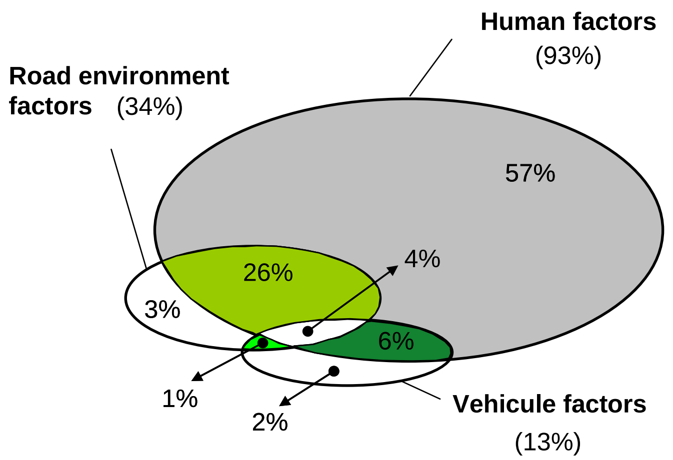


Figure 40: Accident contributing factors -Treat & al (1979)

Road authorities must therefore guarantee adequate levels of safety on existing roads. To reach this goal, an advanced road safety management should consider the whole infrastructure life-cycle itself. As seen in chapter 1, Road Safety Inspections, as a preventive measure, play an important role that is reinforced by the Directive itself: "*Once road sections with a high accident concentration have been treated and remedial measures have been taken, safety inspections as a preventive measure should assume a more important role. Regular inspections are an essential tool for preventing possible dangers for all road users, including vulnerable users, and also in case of road works*".

Black Spot Management (BSM) and Network Safety Management (NSM) (see chapter 1.2.5) are important diagnosis tools, but as other procedures they present some limitations or difficulties:

- Reliance on accident statistics (registration rate? accident localisation?);

[8] *Following the CARE database, the total number of deaths along the European roads (on average for the 27 member states) decreased of around 36% between 2001 and 2009.*

[9] *Road Safety Programme 2011-2020: detailed measures - MEMO/10/343, 20 July 2010*

- Elimination of a black spot does not always solve everything (ad hoc measure <--> shift of the hazard?);
- BSM and NSM concern locations with a higher accident concentration (what about the rest? “Accident dilution” all along the network!);
- Already today, a “relatively small” number of accidents are concentrated on black spots.

Curative procedures like BSM and NSM are therefore not the only steps necessary to achieve a drastic reduction of accidents and traffic fatalities; pro-active safety measures such as RSIs, applied largely on the road network, are necessary.

5.2 Benefits and costs of RSIs

As discussed in chapter 1, the purpose of a RSI is to pro-actively manage safety by identifying and addressing risks associated with road safety deficiencies.

In his guidelines, Elvik (2006) recognises that there are very few studies of the effects on road safety measures known to have been implemented as a result of RSIs. There are, however, many studies on the effectiveness of road safety measures that tend to be proposed in reports from RSI’s. As proposed by Elvik, it is therefore reasonable to assume that the effects of measures introduced following a RSI will be the same as the effects of those measures reported in general in evaluation studies.

Table 21 summarises the effects that can be expected from some main corrective measures being introduced as a result of an RSI.

Table 21: Summary of effects on injury accidents to be expected as a result of road safety inspections – Elvik (2006)

Treatment	**Accidents that are influenced**	**Expected accident reduction (%)**
Removing sight obstacles	All accidents	0-5%
Flattening side slopes	Running-off-the-road	5-25%
Providing clear recovery zones	Running-off-the-road	10-40%
Guardrails along embankments	Running-off-the-road	40-50%
Guardrail end treatments	Vehicles striking guardrail ends	0-10%
Yielding lighting poles	Vehicles striking poles	25-75%
Signing of hazardous curves	Running-off-the-road in curves	0-35%
Correcting erroneous signs	All accidents	5-10%

As can be seen, the table constitutes “low cost measures” which are typically included in a proposal of the RSI report for short and medium-term implementation.

In 2008, the Conference of European Directors of Roads (CEDR) exhaustively reviewed the existing efficiency assessment issues and results for a large number of road safety infrastructure investments (CEDR, 2008), which covered all types of infrastructure (including motorways, rural roads, junctions and urban areas). These investments were ranked in relation to their safety effects and implementation costs and an in-depth analysis of the five most promising investments was carried out in terms of safety effects, other (mobility, environmental, etc.) effects, and implementation costs (Figure 41).

Investment	Sub-investment	Safety effect (%) *		Implementation cost (€)		Benefit / Cost ratio	
		Min	Max	Min	Max	Min	Max
Roadside treatment	Clear zones	-23		*n/a*	*n/a*	< 1:1	*n/a*
	Side slopes	-22	-42	*n/a*	*n/a*	< 1:1	*n/a*
	Safety barriers	-30	-47	130,000 per km	220,000 per km	8.7:1	32:1
Speed limits / reduction of operating speed	Introducing speed limits	-22		300 per km		> 1:1	*n/a*
	Reducing speed limits	-9	-67	300 per km		> 1:1	*n/a*
Junctions layout	Roundabouts	-11	-88	450,000 per junc.	1,300,000 per junc.	2:1	3:1
	Redesigning junctions	-17	-50	1,100,000 per junc.	*n/a*	3:1	
	Channelisation	+16	-57	65,000 per junc.	1,650,000 per junc.	< 1:1	2.5:1
Traffic control at junctions	STOP signs	-19	-45	250 per sign	700 per sign	< 1:1	6.8:1
	Introducing traffic signals	-15	-36	50,000 per junc.	300,000 per junc.	< 1:1	8:1
	Upgrading traffic signals	+60	-37	*n/a*	*n/a*	< 1:1	8.6:1
Traffic calming	Area-wide traffic calming	-8	-50	1,300,000	3,000,000	2:1	4:1

* on target injury accidents
n/a : not available

Figure 41: Cost-effectiveness of the most promising road safety infrastructure investments – CEDR (2008)

With reference to RSI costs, CEDR reported that in the European countries where inspections are carried out on a regular basis, costs can range between 600 and €1,000 per km of motorway.

Some other interesting references focusing on the Cost-Benefit and Cost-Effectiveness Analysis of road safety measures can be consulted (the list is not exhaustive):

- Project ROSEBUD (Road Safety and Environmental Benefit-Cost and Cost-Effectiveness Analysis for Use in Decision-Making) - http://ec.europa.eu/transport/road_safety/pdf/projects/rosebud.pdf
- PIARC Technical Committee 3.1 Road safety (2009). PIARC catalogue of design safety problems and potential countermeasures. Report 2009R07 – www.piarc.org
- SEROES - Best practice safety information expert system - www.seroes.eu
- SWOV (2010). Effectiviteit en kosten van verkeersveiligheidsmaatregelen. Report R-2010-9 - http://www.swov.nl/rapport/R-2010-09.pdf
- Gerlach et al. (2008): Möglichkeiten zur schnelleren Umsetzung und Priorisierung straßenbaulicher Maßnahmen zur Erhöhung der Verkehrssicherheit [Possibilities of faster realization and prioritization of structural measures to improve road safety at black spots], Free download: http://tinyurl.com/35ej63p

Although it is not always easy to quantify precisely the economic benefits of RSI, there is strong evidence that such inspections are highly cost-effective. With the introduction of some typical measures such as the ones mentioned above, it is possible to save lives. Obviously, even saving only one human life per year in an inspected road section, the resulting benefit of the RSI would be much higher than the relevant cost.

Cardoso & al (2005) mention that in an analysis made in Australia of the results obtained with an activity similar to RSI, it was concluded that the majority (78%) of the proposed interventions had cost-benefit ratios greater than 1.0 and that 35% had a cost-benefit ratio greater than 10.

5.3 When should RSI be carried out?

One important feature of RSI is that this activity should cover the whole network. Furthermore, to be fully effective, some regularity in RSI should be defined to ensure that there is a periodic systematic evaluation of safety hazards throughout the entire road network. The following chapters will review the main driving reasons to start an RSI. In some countries, accident data are used as an inspection triggering criteria. Chapter 5.3.1 will therefore come back on that very important topic, which is often a subject of discussion.

5.3.1 RSI and accident data

RSI is considered as a preventive tool because its application to an itinerary or road section is not dependent on knowledge concerning its specific safety level. In fact, neither the decision for the initiation of an RSI nor the procedures for its execution require knowledge on the registered safety record or accident risk of the relevant itinerary. To carry out an RSI, only general knowledge on road hazards, safety issues related to the road environment, and effective infrastructure interventions are needed.
Experts from the PIARC TC Road Safety (PIARC, 2007) support the idea that an RSI does not require accident data and has therefore a big advantage in cases with no reliable accident data. This view is based on the idea that an RSI is a pure preventive approach by giving a systematic review of the safety level of the entire road network, regardless of the number of accidents.

Nevertheless, in some EU countries risk information is used either as inspection-triggering criteria or as complementary information used for setting suitable interventions. Following Cardoso,& al. (2005), this deviance from the mentioned common understanding probably does not seriously affect the application of the RSI concept, provided that the required risk information is readily available and meets quality requirements. However, caution should be taken to ensure that RSI does not become just a part of the safety ranking and management of the road network in operation (NSM and BSM). The RSI and the safety ranking and management of the road network in operation complement each other. While the RSI as the pro-active approach covers the entire network and addresses mainly defects requiring maintenance work, NSM and BSM as the re-active approaches aim at deriving counter-measures for known high-risk road sites. Therefore, when within NSM and BSM site visits (Directive article 5, point 2) are performed similar to RSI, accident data have to be taken into consideration.

Table 22: RSI and accident data following PILOT4SAFETY

On the basis of these opinions and considering their own national experience, the PILOT4SAFETY partners:

- Insist that RSI does not necessarily require accident data;
- Recognise that road authorities may decide to use reliable accident risk information somewhere in the process;
- Want to preserve the principle that the RSI process is systematic and does not only focus on particular high-risk road sections identified by accident data or sometimes only by anecdotal accident or incident information;
- Remind that the aim of RSIis to identify any risk that may lead to accidents in the future, so that remedial measures may be implemented before accidents happen.

5.3.2 Driving reasons to start RSI

There is no unique reason that can lead to the decision to start an RSI on a (section of a) road. It depends mostly on the national safety policy and the network safety management procedures set up by the road authority or operator.

The main reason to start RSI for a road section is the “RSI time schedule” as a periodical task. Additional RSI may be started

- As part of programmes on specific road or road site facilities or specific thematic aspects, e.g. RSI on tunnels, level crossings, trees, motorcyclists, night time etc.;
- When a reconstruction or rehabilitation project is planned by the road administration in the near future; in this case, the RSI can identify the specific needs regarding the road safety (baseline);
- In case of relevant structural changes in the adjacent network or land use, e.g. new motorways with new link roads or the building of a new shopping centre.

5.3.3 Frequency of inspection

Again, there is no "standard" position for this question. The European Directive 2008/96/CE on road infrastructure safety management does not impose any obligation or even give any recommendation; it only mentions "periodic inspections of the road network" and stipulates that "inspections shall be sufficiently frequent to safeguard adequate safety levels". A rapid look at the literature helps to illustrate some European practices.

A survey conducted by Cardoso & al. (2005) within the framework of the RiPCORD-iSEREST project shows that the inspection frequency of a road ranges from two years (in Germany on major roads) to five years (in Portugal and Hungary on the state roads).

In France, the Inter-ministerial Committee for Road Safety (ICRS) decided on 13th February 2008 that RSI will be carried out periodically over the entire national road network starting in 2009 and will be repeated every three years (SETRA, 2008). The frequency of road inspection is likely to depend on the total length of the network that is supposed to be inspected, and is linked to the complexity of the methodology adopted by the road authorities. As an example, the French road authorities adopted a "light and affordable" methodology as each road section is inspected every three years:

- The visit is immediate and concentrates on the safety issue from the user's point of view;
- The inspectors note their impressions or factual events that the road operator will deal with;
- The inspector calls attention to certain situations on the road and its environment without making reference to standards and regulations and without suggesting any corrective measures.

The German guidelines for RSIs ("Merkblatt für die Durchführung von Verkehrsschauen (M DV)") distinguish three causes of RSIs with different corresponding frequencies (FGSV, 2007):

- Regular, periodic inspections performed on all roads, every two years on major roads and every four years on secondary and local roads;
- Special purpose inspections that include night-time RSIs, railway crossing inspections, tunnel inspections, destination sign inspections and inspections of other signs and traffic control devices taking place every four years;
- Ad-hoc RSIs performed as the need arises and that comprise signs and traffic control devices.

This last practice raises another question to be addressed in the next chapter: namely, what is the role of RSIs in regard to routine maintenance?

Following the PIARC TC Road Safety (PIARC, 2007), some road authorities may instigate inspections very intermittently as they may not have the funding for a regular process or the recommended remedial works resulting from the inspection. However, costs can be controlled by being selective in choosing roads for inspections, altering the timing of inspections and prioritising remedial work following an inspection. A literature review also shows that RSIs often lead to the proposition of low-cost measures as remedial works.

While no exact timing is recommended in the literature, an inspection frequency of at least five years should be considered as a minimum.

5.3.4 Inspection and maintenance

Even if the Directive 2008/96/CE stipulates that "safety inspection means an ordinary periodical verification of the characteristics and defects that require maintenance work for reasons of safety"; it must be clear that an RSI is not related to routine maintenance.

Maintenance is a regular process where key infrastructure issues such as overhanging branches, the road surface, potholes and poor quality signage are reviewed and remedied. This can be carried out by people who do not necessarily have road engineering or road safety experience but are simply following a planned process (PIARC, 2007).

As explained before, RSI is a formal and systematic field study with the focus on road safety; it is targeted at elements known to be risk factors for accident occurrence or injury severity. Therefore, the objective of this procedure exceeds the mission of a maintenance unit. Of course, RSI can identify safety deficiencies that are a result of poor maintenance (for example poor signage and line marking or visibility issues caused by vegetation). Some road characteristics, such as the level of pavement friction, are also sometimes difficult to assess during an RSI. Such questions can be quantified thanks to the equipment used in a routine maintenance inspection.

5.4 Partners in the RSI process: their roles and responsibilities

The Client (usually the road authority or private road operating company) and **the inspector** (or team of inspectors) participate in the inspection process.

The Client is the institution (typical the road administration) which is responsible for the road safety in his network. It is the Client's full responsibility to ensure that inspection demands will be obeyed and will start the proposed improvements as soon as possible. It is also the task of the Client to organise the necessary investments for the implementation of the results of the RSI.

The Inspector is the road safety expert, team or organisation who will conduct the RSI. Ideally, it should be a team with different skills appropriated to the project. One person in the team should be appointed as the team leader to manage the team and process. A list of potential inspectors compiled by the Client can be helpful for the selection process. The expert is responsible for conducting the RSI carefully with the focus on the viewpoint of road safety. With a formal written report, the Inspector shall present the findings, deficiencies and references. The Inspector will use his/her expert knowledge regarding best practise in the evaluation of existing situations. It is crucial that the Inspector has profound experience in road design and construction as well as road safety engineering and accident analysis. To ensure the quality of the RSI, inspectors should undergo initial training in the award of a certificate of competence and take part in further periodic training courses. Where RSIs are undertaken by teams, at least one member of the team should hold a certificate of competence. Sometimes it could also be helpful to have experts from the local traffic police in the inspection team. In Germany, the teams usually consist of at least one member of the traffic and the road authority, and the police.

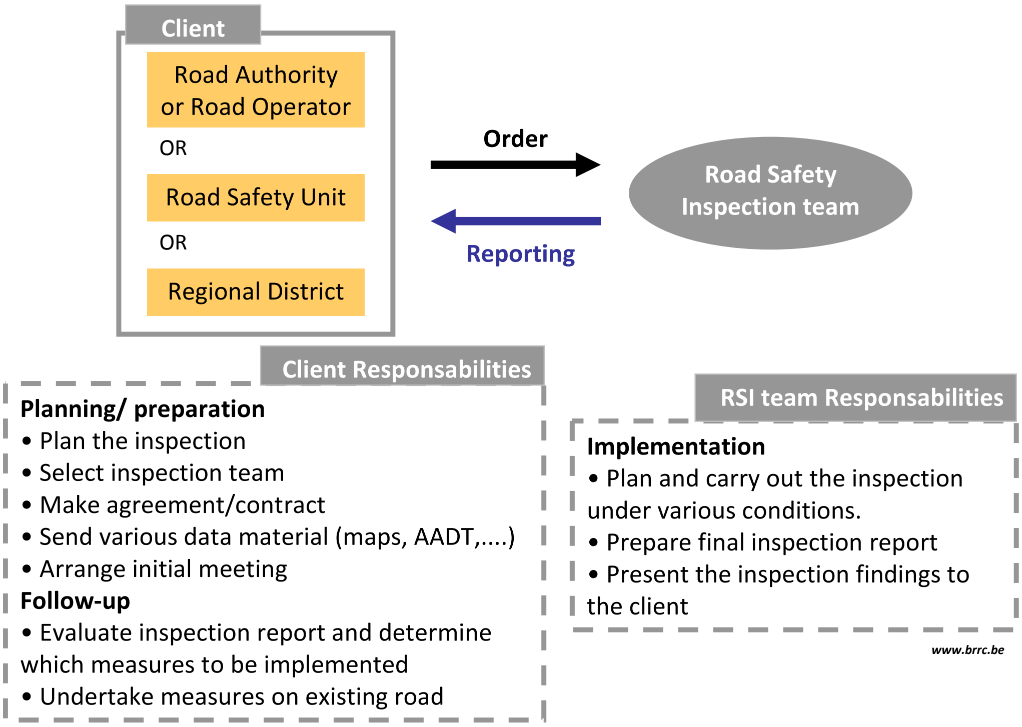


Figure 42: Partners in the RSI process; their role and responsibilities - source BRRC

5.5 Liability issues

Liability issues sometimes argue against the execution of RSI. Following RiPCORD (Cardoso & al., 2005), legislation concerning liability arising from issues related to the influence of road factors in the occurrence of accidents differs from one country to the other.

They point to three possible liability issues resulting from different types of negligence:

- What are the consequences of not having attempted to detect a hazard (no RSI performed)?
  Administrations that routinely carry out RSI demonstrate active concern for improving safety, reducing the credibility of carelessness criticism. This argument supports the interest in having an active RSI programme.

  As reminded by PIARC in its Road Safety Manual, road authorities are duty-bound to care about public safety and are therefore expected to use state-of-the-art methods to identify the road network's safety deficiencies, propose appropriate remedial actions and then apply objective methods to prioritise actions.

- What are the consequences of not having detected a hazard in a performed RSI?

This question stresses the importance of having an active programme for updating the knowledge of a road inspector and regular technical forums for sharing experience among inspectors;

- Which consequences result from not having acted upon a detected hazard?

An intervention on the road should of course follow any hazard detection. However, safety is not the only criterion to be met while managing a road network (funding, land use, social or environmental aspects must also be considered).

In some countries, road administrations are empowered as the discretionary authority to decide how to act upon a detected hazard, according to predefined sets of rules. In these cases, a register of the decisions taken and their rationale is usually kept.
If priorities are decided upon, one important point is to be able to justify how they have been established (PIARC - Road safety manual).

The discussion on the liability issues stresses the need for a thorough appraisal of the legal consequences of RSI prior to its implementation in each country, and for the definition of a suitable legal framework.

5.6 The inspection process

5.6.1 Overview/Introduction

An RSI can be instigated for different reasons, e.g. as part of an overall inspection strategy as part of the safety management of the road network, see also chapter 5.3.2. The first decision is to determine the extent of the inspection by defining its start and end points. Generally, this will be a road from start to finish (i.e. between well-defined intersections), but it could also be a section of a road of a reasonable length.

A (written) agreement must be made between road safety inspectors (inspection leaders) and project owners. Such agreements should contain a description of inspection sections, what should be included in the inspection (i.e. point out traffic safety deficiencies, propose corrective measures), deadline for delivering the inspection report, who is paying for what, timelines and deadlines (Statens vegvesen, 2006).

In the following chapters, a methodology will be presented to explain the more important elements and steps to keep in mind when planning an RSI.

5.6.2 Guidelines for RSI

Before concretely starting the description of the inspection process, it is useful to give a reminder of some important practical rules that should be taken into account for a successful RSI. They concern the four following items:

- Inspection conditions;
- Approach from the perspective of all road users;
- Independent and multi-disciplinary approach;
- Fundamental safety elements.

5.6.2.1 Inspection conditions

To be successful, an RSI has to be done in the most representative conditions; this means considering that the road environmental characteristics and traffic characteristics are subject to daily and seasonal variations. Various time and conditions of inspection are therefore recommended.

Time of inspection
It is strongly recommended that inspections take place both during the day and at night. This is indeed also important so that the inspector can focus on issues that are specific to night. In particular, to check if traffic

signs and road markings are still visible at night time. An analysis of the lighting along a road or at an intersection should also be undertaken to make sure it is suitable for all road users, including pedestrians and cyclists, for example.

Specific issues: frequency of use

Of course, the inspector must always consider in his/her analysis that the traffic (its intensity and the type of users) fluctuates during the day. But there are sometimes other facts he/she must keep in mind; if the road includes a school, for example, the inspection should take place partly when school children are arriving or leaving the school. Similarly, if the road includes a shopping precinct, the inspection should incorporate busy shopping times).

Figure 43: RSI must consider representative road conditions - source BRRC

Different weather conditions

An inspection has to be done under several weather conditions, e.g. the visibility can be different when the sun is shining or when it is raining. The quality of the road surface can change under different weather conditions.

Seasonal variation

The inspector shall take into account in his/her analysis on the field that some elements are also subject to seasonal variations, such as plants and trees (that can introduce some visibility masks, or falling leaves), height of the sun, some agricultural practices all along the inspected itinerary, etc.

5.6.2.2 Approach from the perspective of all road users

The RSI should be conducted taking into consideration the point of view of every kind of road user, e.g. motorists, lorry drivers, public transport users, but also the vulnerable road users such as pedestrians and cyclists, moped riders, etc.

Taking into account the point of view of every kind of road user means that each route (for cyclists, pedestrians, etc.) has to be logical and continuous. It is also important to look at how interactions happen between different type of road users or transport modes.

The inspection team should keep in mind that traffic facilities must give to all drivers a clear picture about the situation of road design, signs, markings etc., and should be assisting them to make the right decisions and actions at the right moment. Following PIARC (2007), all inspections should take into account a range of **human factors** which relate to driver errors that are induced by the road. Issues that should be investigated include <u>strain/workload</u> (either a very low or very high level of “workload” leads to a poor quality of driving, e.g. a changing landscape rather than a monotonous landscape could assist in keeping drivers awake, or multiple signals/signs and events at one location can overwhelm the driver and lead to confusion), perception (illusions can lead to incorrect estimation of speed, direction, curves; see Figure 44) and choice of speed (this is mostly an automatic process that depends on different factors that include the road geometry and surrounds).

Practically, beside an inspection by car it will often be necessary to travel along the road by foot or bicycle.

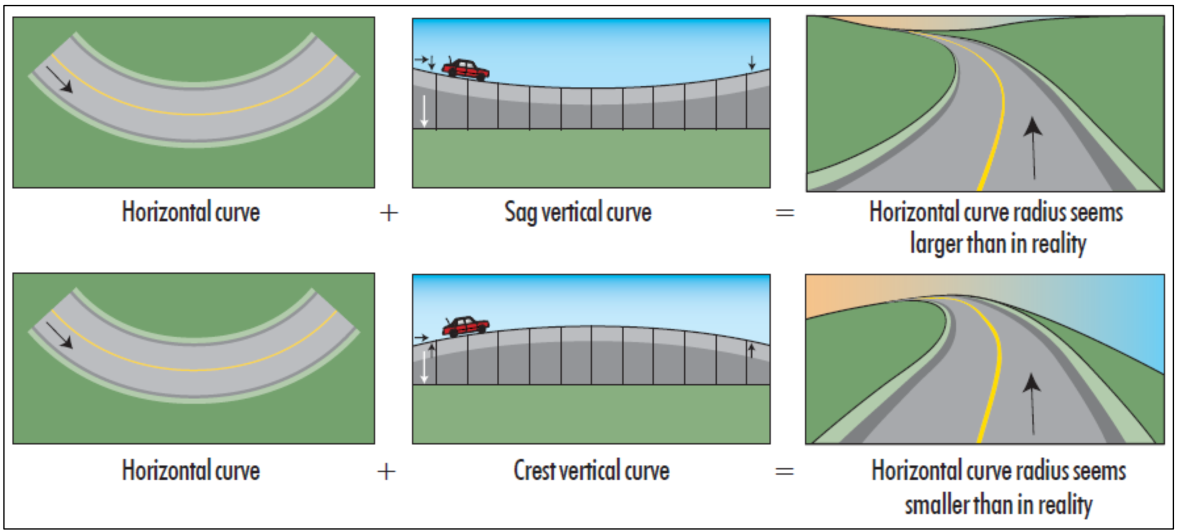


Figure 44: Optical illusion – combination of horizontal and vertical curves – PIARC (2003)

5.6.2.3 Independent and multidisciplinary approach

The question of **independence** of the inspector is one important topic for which there is no standard.

The Directive No. 2008/96 on Road Infrastructure Safety Management handles the question of independence for the road safety auditors (Article 9-4 *"for the purpose of the infrastructure project audited, the auditor shall not at the time of the audit be involved in the conception or operation of the relevant infrastructure project"). But for what concerns the RSI,* the article 6 ("Safety inspections") only stipulates "*Member States shall ensure that periodic inspections are undertaken by the competent entity*".

France adopted an interesting approach concerning independence; in its Methodological Guide on Road Safety Inspections SETRA (2008) writes that "*Inspectors are hierarchically independent of the local road operator and are thus not involved in the maintenance and operation of the road inspected. In addition, it is essential that they do not personally know the network to be visited*".

Within the framework of the RiPCORD-iSEREST project, Cardoso & al (2005) suggested that at least one of the qualified inspectors in the team should be independent of the inspected road's operator to ensure a "fresh" look on current maintenance and infrastructure safety procedures.

There is therefore some variation within practices at European level and it seems difficult at this stage to recommend one specific practice.
However, the PILOT4SAFETY partners support the idea of preserving the objectivity of the RSI, this being easier if the inspection team is not hierarchically dependent of the inspected local road's operator.

Of course, efficiency of RSI depends heavily on the qualification of the performing inspectors.

Concerning **multidisciplinary** and competence, PIARC suggests, through Allan (2006), that the inspection should be led by a trained person (or a team) with a background in traffic engineering and road design who can bring in experts with a knowledge of guidelines and regulations about traffic, signs etc. as necessary.

In their best practice guidelines, Cardoso & al (2005) proposed that background experience requisites may include: a professional degree in road design and maintenance; knowledge in traffic engineering, applied human factors and road safety; familiarity with traffic regulations; and understanding of road design, signalling, signage and marking guidelines.

Issues concerning multi-disciplinary and competence also relate to the composition of the inspection team. It seems reasonable to have several - at least two - inspectors in all but the simplest RSI to ensure that there is a diversity of skills within the team and that discussion of different opinions on the safety issues is possible

5.6.2.4 Fundamental safety elements

The list of elements to be included in RSIs (check lists) should include those that are recognised as important. According to Elvik (2008), the following elements should be included in all RSIs:

- The quality of traffic signs, with respect to the need for them, whether they are correctly placed and whether they are legible in the dark.
- The quality of road markings, in particular whether the road markings are visible and are consistent with traffic signs, also by night.
- The quality of road surface, in particular with respect to friction and evenness.
- Sight distances and the presence of permanent or temporary obstacles that prevent timely observation of the road or other road users.
- Legibility: easy decoding of the infrastructure and its surroundings
- The presence of traffic hazards in the near surroundings of the road, such as trees, exposed rocks, drainage pipes, etc.
- Aspects of traffic operation, in particular if road users adapt their speed sufficiently to local conditions. Consistency of all the elements on the road and surroundings (in relation to all of the above criteria); flow management with the objective of safety (consideration of all users within the context of the entire road environment).

These items will be taken into account during the inspection and consequently will be part of any check list (see appendix) used on the field by the inspectors.

5.6.3 Phased approach

An RSI is a phased approach, in which there are classically four general steps:

- Step 1 – the PREPARATORY OFFICE WORK
- Step 2 – the ON SITE FIELD STUDY
- Step 3 – the RSI REPORT
- Step 4 – the FOLLOW UP

These steps will be discussed in the following five sections (Step 3 being divided into two chapters). It should already be noted that Step 4 may be considered as two separate processes – the first is the implementation of remedial measures, while the follow-up is likely to be some time later to evaluate the impact of the counter-measures.

5.6.3.1 Preparatory work in the office (= step 1)

The objectives of this first step are mainly to well prepare the inspection to be carried out on site, and also to collect enough general data about the road section to be inspected.

Background information about the road should be obtained as a first step, and the following questions will particularly retain the inspector's attention (Allan, 2006):

- About the road function:

    - Describe the function of the road: is it a national, a regional or a local road?
    - What kind of vehicle traffic uses this road?
        - Long or short distance traffic?
        - Mixed traffic?
        - What about heavy vehicle traffic?
        - Is the road a part of a special freight route (e.g. dangerous goods)?
        - Slow-moving vehicles (agricultural areas)?
    - Do vulnerable road users such as pedestrians or cyclists use the road?
    - Describe the surroundings in general
        - Rural, sub-urban or urban area?
        - School area and school bus route?
        - Does the road pass through any towns or villages?
    - Do vulnerable road users, such as pedestrians, bicyclists or powered two wheelers, use the road?

- About the traffic situation, important information for the RSI is related to:

    - Traffic volume;
    - Traffic composition (lorries, buses, vulnerable road users);
    - Any traffic volume prediction for the road.

- About the road standard:

    - Describe the road standard in general and how it relates to the road function, traffic volume, types of junctions and intersections, speed limits, etc.;
    - Analyse the speed limits: are they reasonable for built-up areas, presence of vulnerable road users, especially children, elderly and disabled persons, the alignment of the road, etc.?

The relevant guidelines and regulations need to be available at least for office work. Accident data will sometimes be used in addition; but there are several opinions about using them (or not) (see chapter 5.3.1).

Different equipment or other support documents will also be necessary to carry out the inspection on the field. If possible, reasonably detailed maps or drawings or the usage of aerial views will be made available. Such documents will be helpful during the field study as well as support for the presentation of inspection results (Figure 45).

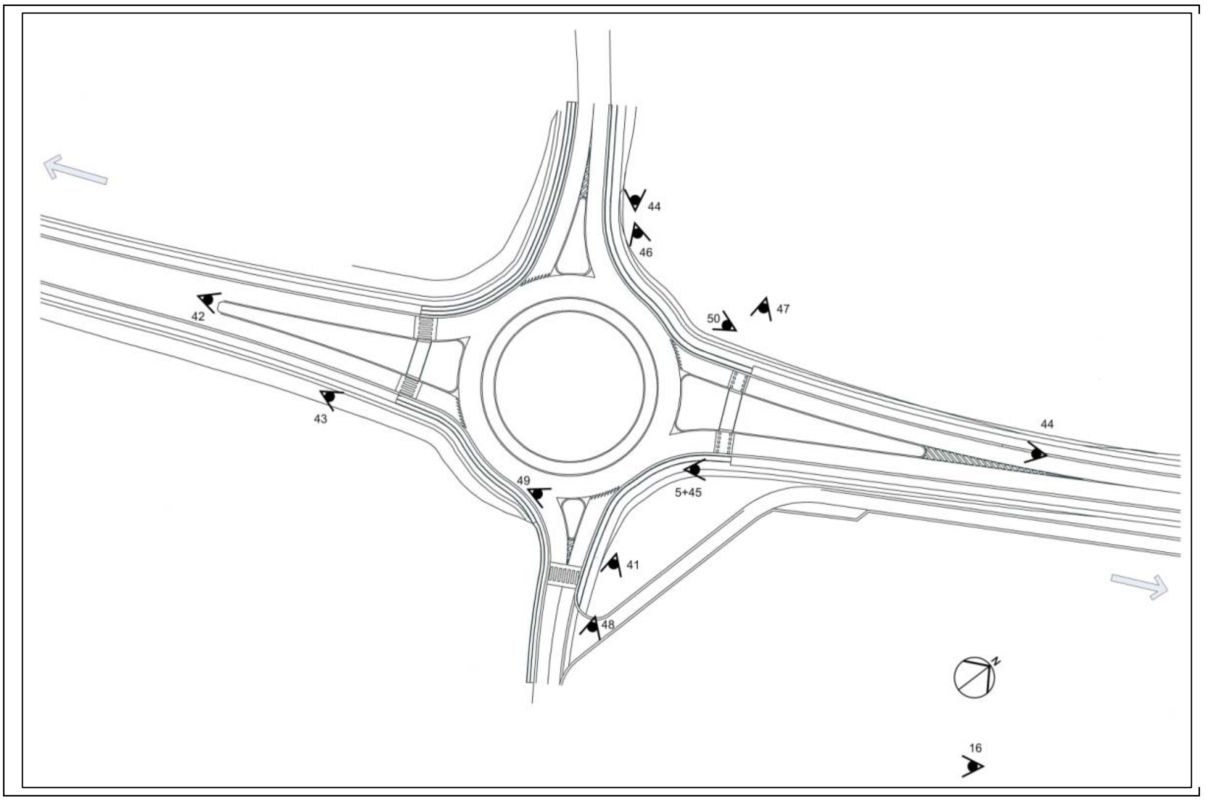


Figure 45: Detailed situation map, here with location of the photos showing some deficiencies - source BRRC

One important part of an RSI is indeed to accurately indicate where particular problems are located along the road to give the right recommendation for remedial measures. The method of identifying concrete locations has to be determined at an early stage. Different methods can be used:

- Coordinates measured by GPS-equipment;
- Mileage from any km-posts;
- Odometer of the car used during the field-study;
- Distance or the coordinates measured on the map or the drawing;
- Easily identified landmarks or reference to video footage.

Figure 46: An odometer used to locate the deficiencies - source BRRC

In addition, <u>digital pictures or films</u> are essential during the reporting and discussion with the Client.

To resume, the following personal and technical equipment should always be organised:

- Maps, drawings;
- Tape measure/measuring wheel;
- Digital camera (for pictures and, on request, short film sequences);
- Some form of recording e.g. portable computer, tape recorder;
- Paper and pencil;
- Check list (see example in appendix 1);
- Warning/safety vest or jacket – to be worn during the inspection so that inspectors are visible to road users;
- Yellow flashing light for cars and flashing torches for inspection at night;

- A letter of comfort is recommended, if officials or residents will be asked.

Depending on the scale or type of RSI, the following technical equipment <u>can be useful</u>:

- Water level to check the cross fall and super elevation, especially in curves;
- Stop watch if recording vehicle speeds, headway gaps and traffic flows;
- Handhold speed gun.

5.6.3.2 Field study (= Step 2)

<u>Safety equipment and safe behaviour</u>
Before conducting the field study, inspectors should clear with the Client and traffic Police which kind of safety equipment is necessary. This of course depends on the kind of road, higher safety standards are necessary for an RSI on high-speed roads. At least the vehicle used to get the inspectors to the site and for use during the inspection should preferably have flashing/warning lights (Figure 47 – left). If team members are from the Road Directorate or traffic police, it could also be helpful to use an official car. Inspectors need to take care, not only wearing a safety vest (Figure 47 – right), but also ensuring they take all necessary precautions such as standing behind a guardrail if it is provided or standing as far away from traffic as possible.

Figure 47: Inspection car with flashing lights and warning triangle (left) – Inspectors with reflecting safety vest (right) - source BRRC

Additional safety equipment is typically necessary on high-speed roads. There could be a need for a temporary closure of one lane. Some sort of warning signage could be placed on the road being inspected and roads that intersect this road. Of course, the inspection team has to follow the traffic rules.

To be able to observe how the traffic flows on some spots (like intersections), it could be necessary to avoid impacting driver behaviour by being too visible (turning off the flashing lights when in a safe area).
<u>How to proceed?</u>
Site inspections should be undertaken under the range of traffic and environmental conditions likely to be encountered. As mentioned before (chapter 5.6.2.1), both nighttime and daytime inspection are essential to appreciate the situation. It may also be necessary to view the location at other times of the day (e.g. after school finishes, during peak hours, weekly road trade market).

The on-site field study will start with the collection of any relevant data about the surrounding road (describe the local situation), environmental conditions and traffic situation at the time of the inspection (complementary to the data collected during the preparatory step.)

For a reliable inspection report, the inspection should be made both by car and on foot (or by bike) where needed and incorporate both sides of the road and roadsides. The road should be driven a number of times if possible and photographs taken of specific issues. An inspector must place him/herself in the position of the various road users (motorist, cyclist and pedestrian) so that he/she can judge the traffic safety of the construction from the viewpoint of all road users (see chapter 5.6.2.2).

When an intersection is included in the road to be inspected, it is necessary to inspect part of the intersecting road as well (at least the approaches).

The road safety inspectors should observe the traffic flow and document traffic incidents which could easily lead to accidents in specific traffic compositions. If there is obviously a problem with speeding, the team could measure the average speed (e.g. with speed guns).

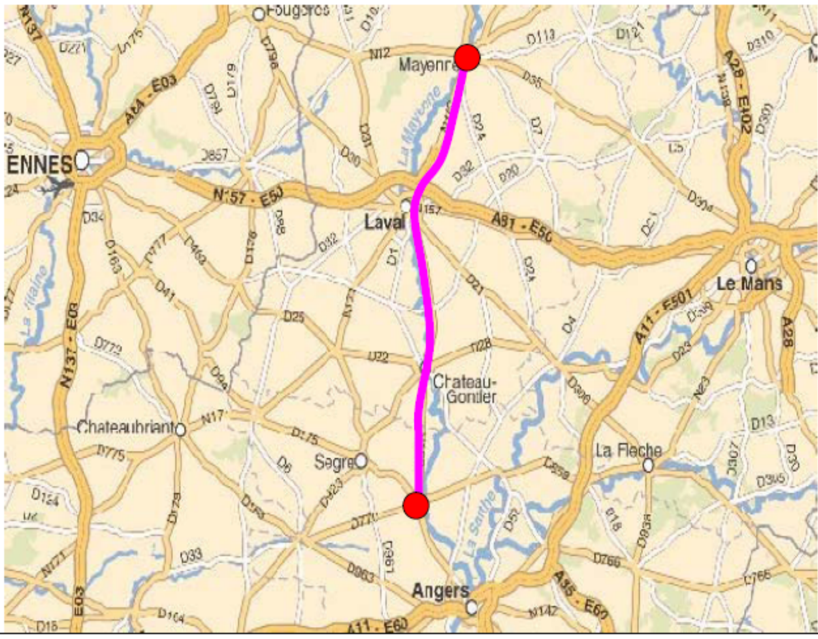
<u>Deficiencies to be noted</u>
In the core part of the RSI, the deficiencies on the road that may cause accidents or could have an influence on the severity of accidents must be detected. The fundamental safety elements that should be included in all RSIs have been listed in the chapter 5.6.2.4. These items are part of any checklists (see appendix) used on the field by the inspectors.

As the inspectors will travel through the road to be inspected (from point A to point B) they will likely identify the deficiencies "chronologically". They will list their remarks on a simple notepad or better on a prepared form.

5.6.3.3 RSI findings and inspection report (= Step 3)

After collecting notes and photographs on the field, the report can be completed by the inspection team (classically by the principal inspector with the help of his/her colleagues). An RSI report is made up of different parts. The report should firstly clearly <u>describe general information</u> about the inspected road section and the inspection team members (Figure 48). One part outlines what the RSI was to encompass, <u>the background data</u> obtained during the preparatory work in the office and gives a description of the activities undertaken.

RN 162 from Mayenne to Lion d'Angers



General data about RSI Visit	
Visit carried out by:	Gérard Dessiaume – SÉTRA – Certification no.: 001 Daniel Lemoine – CERTU – Certification no.: 007
Description of site	2x2; two-way; beltway; agglomerations KM 0+150 to KM 82+867
Date and time	27 July 2007 From 9:15 to 15:30, then from 21:10 to 23:50
Weather conditions	Drizzle for the first hour in the morning
Preparatory work	SÉTRA vehicle, maps with KMs provided by the district

Request	DIR West on June 4, 2007

Documents and equipment used (images/drawing/text)		
Quantity	Description	Type of information
2	Michelin road maps	Geographical reference points
1	Dictaphone	
1	Camera	
1	Note pad	

Figure 48: RSI report - general information about the inspected road section and the inspection team members (example from SETRA, 2008)

A second part describes the shortcomings or deficiencies which were found during the inspection and an assessment of the safety deficiencies (=detected problems). It will contain the completed investigation form and the documentation with pictures (Figure 49).

Road pavement	• Road pavement in poor condition on some places ; longitudinal and transverse joints are open between km 12 and km 16; direction Nxxx.	
	• The cycle way presents the same pavement degradation locally (opening > 2cm) - km 11,5 to km 10,5; direction Nyyy.	

Figure 49: RSI report - (basic) identification and illustration of deficiencies - source BRRC

Following PIARC (2007), it is useful to sort the findings by importance, relevance and kind. Obviously, the road safety deficiencies should be well explained. Moreover, as the report will serve as a decision support element for any further corrective measures, it is also crucial to structure it following the main risk factors presenting a major stake. The fundamental safety elements assessed during an RSI (see chapter 5.6.2.4) are therefore classically organised in the report as follows (Table 22).

Table 22: RSI report – structure proposal to report the deficiencies pointed out on a secondary road (as proposed by Cocu & al, 2011, on the basis of PIARC (2007) recommendations)

1. Function and Road environment
2. Cross Section: geometry; lanes; road sides; pavement; drainage; …
3. Alignment – Road legibility
4. Intersections: type; visibility; three-coloured signals; roundabouts and traffic islands; railway crossings; …
5. Public and private services: service roads; access; rest areas; public transports; …
6. Infrastructure adapted to vulnerable road users (pedestrians, cyclists, persons with impaired mobility, motorcyclists)
7. Road signs, markings and lighting
8. Lateral Obstacles and passive safety equipment

The inspection report should also allow the road authority or road operator (the Client) to determine priorities for corrective treatment; using the report, the Client needs to be able to assess the likely severity of accidents that can potentially result from the deficiencies noted.

However, the circumstances leading to serious accidents are mostly multiple and complex. Try to assign a risk level to a deficiency identified during an RSI is therefore a difficult exercise. At most, is it possible to assess the risk level (classically defined as the product of the accident probability with its potential injury severity). In some countries, the inspection report incorporates the elements of a "risk matrix" (Figure 50), allowing in particular to later link observed deficiencies with a priority list.

Severity			
Consequence → Probability ↓	Minor	Seriously	Very seriously / killed
Low		x	
Medium			
High			

Road Element	Safety related maintenance issues		Safety Issues		
	Description	Severity; Probability	Description	Severity; Probability	Action
Node 1					
Link 1	Ditch obstructed		Possible inconsistent horizontal curve (XXV, XXVII) Safety barrier too short (XXVI) Dangerous obstacles near carriageway (XXVIII)	1 / II 2 / III 2 / II	Check consistency class & signing Lengthen New water inlet
Node 2			Insufficient channelling of allowed traffic movements (VI)	2 / IV	-
Link 2	Holes in pavement surface (8)				
Node 3					
Link 3			Dangerous obstacles near carriageway (XXIV)	2 / II	Soften water inlet
Node 4					
Link 4					
Node 4a			Insufficient channelling of allowed traffic movements (VI)	2 / IV	-

Figure 50: above: risk matrix from a Norwegian inspection report; below: example from a Portuguese inspection report, Ratings: possible harm: 3 = slight; 2 = serious; 1 = very serious; probability of harmful event: IV = rare; III = occasional; II = frequent; I = very frequent (extracts from Cardoso & al., 2005).

These types of elements or matrix seem to be good tools to represent the level of risk and can serve the Client to classify the remedial measures; at least if they are established by well-trained and experienced road safety experts.

A more simple approach is proposed by Cocu & al (2011). It consists on the one hand of trying to provide a detailed description of the risk, referring to the inspectors' experience on safety problems usually found in similar circumstances. And on the other hand, exchanges arguments with the road manager during the presentation of the results (see Figure 51 in next chapter).

To summarise, RSIs may seek to identify all possible risks without distinguishing between major and minor ones, or quantifying the probability of them taking place. But it would be useful if the RSI includes an assessment of the relative significance of any potential safety problem. The benefits of undertaking risk assessment in RSI are that it helps to focus on the priority safety issues, and can assist the client to make appropriate decisions.

Of course this is not an easy task as a risk assessment implies not only identifying hazards, but also evaluating their impact – in terms of the severity of outcome, and the likely frequency of occurrence. Combining severity and frequency is possible by using risk matrices; as shown in the examples above. This matrix should be "benchmarked" to reflect realistic (local) collision situations.

Anyway it is recommended to the road safety Inspectors to carry out an "informal risk assessment" for each problem, assessing both the probability and severity of outcome. Experienced Road Safety Inspectors should have sufficient knowledge of collision type, severity, and frequency to be able to make this risk assessment.

They should try to:

- Provide a detailed description of the risk, referring to the inspectors experience on safety problems usually found in similar circumstances and
- Exchange arguments with the road manager during the presentation of the results (see further).

The post-inspection meeting is a suitable forum for discussing such assessments.

5.6.3.4 Completion of the RSI (= Step 3) – Recommendations and final meeting

Within the French methodology for RSI (SETRA, 2008), the inspector is not in charge of making any recommendations. These inspectors note their impressions or factual events that the road operator will deal with (the inspector calls attention to certain points without suggesting how they should be dealt with) on the basis of his knowledge of the local context.

Following PIARC (2007), the inspection report does not end by giving a list of the detected problems. Following this point of view, another part of the report will contain <u>proposals for counter-measures</u>, from the short to long term.
PIARC recommends an inspection report where the <u>inspectors</u> should make <u>recommendations about step-wise measures to improve the situation</u>. An equal philosophy is given by RiPCORD (Cardoso & al., 2005), where guidelines for RSI are described, e.g. *RSI should state their findings and propose safety measures by means of standardised reports*.

<table>
<tr><th colspan="2">Lateral Obstacles and passive safety equipment</th></tr>
<tr><td><u>Problem 6.1</u> : Unprotected (or insufficiently protected) obstacles

<u>Observations</u> :
▪ Guardrail not high enough (due to vegetation) and too short
▪ All along the curve the guardrail is
▪ The guardrail in interrupted in the second part of the curve to give access to a field. One of the trees is therefore not protected (pictures).

<u>Risk</u> : lack of containment of vehicles in case of run-off the road

<u>Recommendations</u> :
Replace and prolong the guardrail</td><td>
</td></tr>
</table>

Figure 51: Part of an inspection report with recommendations – source BRRC

The recommendations should indicate the nature or direction of a solution, rather than specifying in exact detail how to solve the problem. It is not within the inspector's remit to create a new design when carrying out a safety inspection. The RSI involves one set of professionals checking aspects of the work of other professionals and this calls for diplomacy and respect.

As illustrated by the Figure 52, the inspectors can also choose to group their recommendations into a separate chapter and even classify them following a tentative timetable.

Proposals and recommendations

1. Short term proposals:

The following measures should be done immediately:

- Speed limit concept should be revised (speed limit should be 60 km/h on bought side),
- Regular maintenance (clearing of vegetation along the road and at small intersection, repairing of road surface, improvements of signing and markings)
- Improvements of the guardrails system (general remark: For future projects it is recommended to use consequently the European Guideline EN 1317)

2. Medium term proposals for the project

The following measures will be proposed:

- Changing of the signs (with EU standards),
- Concept of closing the illegal access to the road, organizing of access backwards
- Rehabilitation of the road section (new pavement),

3. Long term measures

- Construction of new motorway will attract traffic from M ... road, and it will be alternative solution for drivers.

Figure 52: Illustration of recommendations on short to long term

Other useful information such as, for example, illustrations, checklists, photographs, other detailed background information, can be collected in the appendix of the RSI report.

In the final step, the report is delivered to the Client. This is accompanied by a presentation during a final meeting. During that meeting, the report will be explained and further appointments can be made. This meeting between the Client and the inspectors could be helpful to discuss the inspection result.

An RSI report template, as proposed by PILOT4SAFETY, is provided in appendix 3.

5.6.3.5 RSI Action plan and Follow up (= Step 4)

Although it could be argued that the actual implementation of remedial measures and evaluation of their effectiveness some time later does not form part of the formal inspection process, they are important steps.

PIARC (2007) mentioned that safety effects of the alternative measures should be estimated. A check must also be made whether the proposed measures can cause any negative effects.

Estimation of costs of the different alternatives of remedial measures should be done. The effects of the remedial measures should be calculated, especially with respect to the number of casualties and the Benefit/Cost Ratio (BCR) should be calculated. A ranking of remedial measures should be made on the basis of the Cost/Effectiveness ratio and the efforts in respect of the time that is needed.

The final decision (how to organise the follow up) has to be made by the Client. Even if the report contains some recommendations about the possible remedial measures (made by the inspection team), it is the responsibility of the Client to decide what the next steps are. He must consider the indicated problems and proposals (given by the inspector team or, if that is not the case, made by the Client himself based on the given problems) and make a decision on how and if he will implement the (proposed) measures.

The follow up of a RSI can be made by an 'action plan'. This action plan will classify action on different levels; the following five levels could be proposed:

- Actions that are part of normal maintenance (for example: removal of vegetation hiding a sign);
- Actions that are part of normal maintenance and that require a very minor commitment within the normal budget (for example: replacement of a damaged sign);
- Actions requiring brief study (for example, signposting bends on the itinerary);
- Actions requiring extensive study and/or specific financing (for example: modification of an junction) and those pertaining to another approach or another road operator or party (territorial authority etc.);
- Finally, the Client may classify observations as without follow-up, depending on the context or the local policy.

No.	KM	Observations[25]	Comments (in particular with regard to RSS criteria)	RSS[26] Criteria Affected	Photographs Thumbnails	ACTIONS PLANNED
10	8+200	Grade junction with crossing of median on 2x2	Consistency	C		No follow-up (5)
11	10+400	Absence of directional sign for road at right	Risk of hesitation	L, V		Check direction signage on entire itinerary (3)
12	11+400	Junction with left turn forbidden but presence of sign indicating this direction.	At right: toward SACE	C, L		Check direction signage on entire itinerary (3)
13	15+100	Start of discontinuous line before summit of small hill. Presence of building.	Visibility seems reduced	V		Make on-site verification (3)
14	16+200	Abandoned section of road creates false perspective.	Loss of legibility	L		To be studied (4)
15	> 17+100	No possibility of stopping on the 2x2 section except at emergency call box at a distance of around 10 km	Up to ~KM 28	E		Carry out study on entire itinerary (4)

No.	KM	Observations[27]	Comments (in particular with regard to RSS criteria)	RSS[28] Criteria Affected	Photographs Thumbnails	ACTIONS PLANNED
16	19+650	Row of trees closely bordering the road.		G		Plan for installation of restraint systems (3)
17	21+300	Shoulder in poor condition.		E		Check entire itinerary and rank danger levels (1 – 4)
18	23+900	Pedestrians on shoulder in agglomeration.	Non-treated shoulder resembles a traffic lane	F		Contact the mayor and suggest the study of a pedestrian pathway (4)

Figure 53: Actions planed after a road safety inspection in France (from SETRA, 2008)

As already mentioned earlier, it is important to have RSI on a regular basis (periodical RSI). Giving the attention to “safety” is a continuous process and will guarantee an effective way for a serious follow up.

5.7 Typical safety deficiencies – Some concepts

In 2003, the Norwegian Directorate of Public Roads made an evaluation of results and experiences with undertaking RSIs on a total of 56 road sections (dealing with rural roads outside urban areas and with roads inside urban areas) (Statens vegvesen, 2006).

Nearly half of the hazards mentioned along the rural roads were roadside hazards, such as rock cuttings or large trees close to the road, high and steep embankments. Various deficiencies related to traffic signage and guardrails were also often mentioned, i.e. unprotected guardrail ends. The main categories of defects pointed out in the reports dealing with urban roads were different from those identified for rural roads. Characteristics of design of intersections and access drives and the facilities provided for pedestrians and cyclists were the most often mentioned.

It is clear that these important deficiencies can have a critical effect on both number and severity of crashes. The most important proposition for the RSI is - because humans behave like humans and thus make mistakes - to minimise the opportunities for errors in road traffic. And, if mistakes are still made, minimise at least the consequences. This approach is based on the concepts of “Forgiving roads” and “Self-Explaining roads”.

In a nutshell, it can be explained as follows. Traffic facilities must give to all drivers a clear picture of the situation of road design, signage, markings and should help them to make the right decisions and actions at the right moment. Therefore, the following should always be avoided:

- Excessive speed differences
- High absolute speed
- Differences in direction
- Unpredictable situations

And if there are unusual situations or changes regarding the road conditions, drivers have to be warned for it. Surprises and confusion should be avoided, which means the road must follow the expectations and experiences of an average driver. This means a harmonised way of signage in the network and the use of similar solutions for similar situations. A self-explaining road continuously informs the driver how to behave and what to expect. Such a road is designed and constructed to evoke correct expectations from road users, eliciting proper driving behaviour.

Forgiving roads are designed and constructed to avoid and/or mitigate negative consequences of driving errors. So rather than people having to protect themselves from oncoming obstacles in case they have skidded, the obstacles themselves were moved away as far as possible. And obstacles which could not be moved away were made flexible; so as to cause minimum damage.

5.8 References

Allan, P. (2006). PIARC Road Safety Inspections Guidelines. Road Safety Seminar, Lome, October 2006

Cardoso, L. & al. (2005). RiPCORD-iSEREST - Deliverable 5 - Road Safety Inspection - Best Practice Guidelines and Implementation Steps

CEDR (2008). Best practice for cost-effective road safety infrastructure investments. Full report (http://www.cedr.fr)

Cocu, X. & al, (2011). Gestion de la sécurité des infrastructures routières : d'une politique curative à une politique préventive. Synthesis BRRC.

Elvik, R. (2006). Road safety inspections: safety effects and best practice guidelines. TOI Report 850/2006

FGSV, 2007. Merkblatt für die Durchführung von Verkehrsschauen (M DV). Forschungsgesellschaft für Straßen und Verkehrswesen.

PIARC (2003). Road Safety Manual. Technical Committee Road safety

PIARC (2007). Road safety inspection guidelines for safety checks of existing roads. Draft document from the Technical Committee Road safety

SETRA (2008). Road Safety Inspections – Methodological Guide. October 2008.

Statens vegvesen (2006). Road safety audits and inspections. Handbook 222E

Treat, J. & al (1979). Tri-Level Study of the Causes of Traffic Accidents, 1979, Washington DC – Cited in PIARC (2003). Road Safety Manual.

APPENDIX 1: Check lists for RSA and RSI - as proposed by the PIARC Technical Committee Road Safety

	RSA audit phase 1	RSA audit phase 2	RSA audit phase 3	RSA audit phase 4	RSI
1 Function and surrounding					
Do the function of the road and the desired use of the road correspond?	X				
Have the effects of the project on the surrounding road network been considered?	X				
Are there any parallel ways to be used by carts and farm equipment?			X	X	X
Are there build up areas with mixed traffic?			X	X	X
Are there traffic islands and lane shifts at the entrance of villages and towns?			X	X	X
Are transitions installed between different functions?			X	X	X
Do we realize the change of functions early enough? 100 km/h ▸300 m ahead, 80 km/h ▸200 m ahead, 60 km/h ▸150 m ahead			X	X	X
Is access to abutting properties appropriate for road safety?			X	X	X
Is the design of the road according to its function and hierarchy in the network?			X	X	X
Where tractors or carts will access the road is the lay out safe?			X	X	X
2 Design and operating elements					
Have the audit results from the previous audit phase been taken into consideration?		X	X	X	
Have specific traffic composition characteristics been taken into consideration?	X	X	X	X	X
Have previous findings/documents on the accident situation been taken into consideration during the planning phase?	X	X			
Have the design speeds been selected correctly for the intersections?	X				
Is access from abutting properties avoided or of an appropriate design for road safety?	X				
Is restricted use by certain user groups foreseen or appropriate?	X				
Is the design speed suitable for the road category?	X				
2 Design and operating elements					

	RSA				RSI
	audit phase				
	1	2	3	4	
Is access from abutting properties avoided or of appropriate design for road safety?		X			
Are speed limits required and applied in the best way?		X	X	X	X
3 Cross section					
Have the audit results from the previous audit phase been taken into consideration?		X	X	X	
Are parking areas designed in such a way to allow vehicles to enter and exit parking areas safely?	X	X	X	X	X
Are the road verges strong and stable enough? Are they able to carry vehicles and trucks?	X	X	X	X	X
Can road maintenance service vehicles be parked safely?	X	X	X	X	X
Have sufficient measures been taken on cutting slopes to prevent falling material (e.g. falling rocks)?	X	X	X	X	X
Have suitable measures been taken to ensure that speed limits are obeyed?	X	X	X	X	X
Have the needs of public transport and its users been taken into consideration?	X	X	X	X	X
Is a separating strip required between cycle path and parking strip?	X	X	X	X	X
Is narrowing of the carriageway required and, if so, designed in such a way to ensure traffic safety?	X	X	X	X	X
Is stopping sight obstructed, for example by safety barriers, plants?	X	X	X	X	X
Is there sufficient cross fall and longitudinal fall?	X	X	X	X	X
Is there sufficient drainage for the road and surroundings?	X	X	X	X	X
Are fixed obstacles avoidable, set up at sufficient distances or safeguarded?	X	X			
Are lanes and carriageway in curves wide enough?	X	X			
Has the construction standard and, if applicable, the transition area been adapted to the adjacent road sections?	X	X			
Is the transition from a built-up to a rural road or from an illuminated to an unilluminated road of a safe design?	X	X			
Do compensatory measures provide a sufficient degree of safety when deviating from guidelines?	X	X			
3 Cross section					

	RSA audit phase 1	RSA audit phase 2	RSA audit phase 3	RSA audit phase 4	RSI
Are planted trees a sufficient distance away from skidding cars?	X	X			
Have measures been taken to ensure safe access for rescue vehicles/maintenance vehicles/fire service?	X	X			
Are unavoidable bottlenecks of a safe design?	X	X			
Are the cross section dimensions (width, height, and spacing) suitable for the function of the road?	X				
Are parking areas required and, if so, are they large enough to prevent parking on the road?	X				
Has the safest average cross section been selected from the ones that come into question?	X				
Are waiting areas, in particular on the refuges, large enough for waiting pedestrians and cyclists?	X				
Have pedestrian and cyclist requirements been considered (shared foot path and cycle path, separate cycle facilities)	X				
Is there a sufficient division (separation planned) between the traffic lane for motor vehicle traffic and the path for cyclists and pedestrians?	X				
Is there transition of a safer design when cycle paths end on a road?	X				
Are no-stopping zones planned/ required?		X			
Are passive safety devices planned at the required locations and are they suitably designed?		X			
Are refuges large and wide enough for crossing pedestrians and cyclists to stand and wait?		X			
Are speed bumps, lane shifts by use of islands or carriageway narrowing required?		X			
Are the cross section dimensions suitable for the function of the road?		X			
Are the islands clearly visible and of a suitable design?		X			
Have cyclists' requirements been considered (e.g. separate cycle facilities)?		X			
Have pedestrian requirements been considered?		X			
Have the dimensions for speed-damping measures been observed?		X			
Is a sufficient separation planned between motor vehicle lanes and cycle and footpath?		X			
3 Cross section					

	RSA				RSI
	audit phase				
	1	2	3	4	
Is the transition of a safe design when cycle paths end on a road?		X			
Have specific traffic composition characteristics been taken into consideration?		X	X	X	X
Does the road surface provide the required grip over the long term where small radii occur (e.g. also on ramps)?		X	X	X	X
Are the shoulders and the carriageway at the same level?			X	X	X
Are there any bottlenecks? If so, are they properly signed?			X	X	X
Are there any doubts regarding the surface grip because of excess bleeding or polished components?			X	X	X
Are there deep ditches?			X	X	X
Do curves with small radii have an enlarged width of the pavement?			X	X	X
Do the elements of the cross section realize the situation for the road users?			X	X	X
Does the embankment require passive safety installations?			X	X	X
Is slow and non-motorized traffic separated from fast and heavy traffic? Or Have pedestrian and cyclist requirements been considered (e.g. separate cycle facilities)?			X	X	X
Is the cross fall in straight sections constant?			X	X	X
Is the cross section appropriate to the function?			X	X	X
Is the surface even and free from grooves?			X	X	X
Is the surface free from short or long waves?			X	X	X
Is the width of the safety zones sufficient (distance to trees, buildings)? 100 km/h ▸9m, 80 km/h ▸ 6m, 60 km/h ▸ 3m			X	X	X
Is there a median? Does it have a safe design, e. g. safety barrier or sufficient width to prevent turn accidents?			X	X	X
Is there an open drainage system within the safety zone?			X	X	X
What is the medium width of the road shoulders?			X	X	X
4 Alignment					

	RSA				RSI
	audit phase				
	1	2	3	4	
Have the audit results from the previous audit phase been taken into consideration?		X	X	X	
Is right of way clearly defined at points where cyclists come into contact with each other or with motorized traffic?	X	X	X	X	X
Have suitable measures been taken to ensure that speed limits are obeyed?	X	X	X	X	X
Is the transition from a built-up to a rural road or from an illuminated to an unilluminated road appropriately designed (village/town outskirts)?	X	X	X	X	X
Is sight obstructed, for example by safety barriers, fences, road equipment, parking areas, traffic signs, landscaping/greenery, bridge abutments, buildings?	X	X	X	X	X
Are entrances and exits to service and rest areas planned at safe locations?	X	X			
Are further crossing aids required?	X	X			
Are lane reductions correctly designed?	X	X			
Are lane shifts by use of islands or carriageway narrowing required (e.g. when entering towns or villages)?	X	X			
Are lanes and carriageway in curves wide enough?	X	X			
Are there enough possibilities to overtake safely (overtaking sight distances / overtaking lanes)?	X	X			
Do compensatory measures provide a sufficient degree of safety when deviating from guidelines?	X	X			
Has the construction standard and, if applicable, the transition area been adapted to the adjacent road sections?	X	X			
Have pedestrian crossings been appointed in such a way that collective use is guaranteed and the road will not be crossed at other points?	X	X			
Have specific traffic composition characteristics been taken into consideration?	X	X			
Have the critical changes been located correctly for roads of the operational type 2+1 and climbing lanes?	X	X			
Is stopping sight distance guaranteed along the entire section?	X	X			
Is the end of the construction area away from critical points, e.g. summits, downgrades, curves, areas with restricted sight distance or distractions?	X	X			
Is there sufficient cross / diagonal fall?	X	X			
Have continuity principles been taken into consideration?	X				
4 Alignment					

	RSA				RSI
	audit phase				
	1	2	3	4	
Have steps been taken to prevent minimum design values for horizontal and vertical alignment elements occurring together?	X				
Have suitable allowances been made for drainage requirements when planning horizontal and vertical alignment?	X				
Have the design elements been selected to effectively prevent "hidden-dips"?	X				
Is access from abutting properties required and is it appropriate for traffic safety?	X				
Are horizontal and vertical alignments coordinated?	X				
Are there approaches and accesses that can be combined?	X				
Is it possible to guide the pedestrians and cyclists on the existing route network?	X				
Has the transition zone to the adjacent road sections been set up correctly?		X			
Is stopping sight obstructed, for example by safety barriers, plants?		X			
Is there sufficient drainage for the new road?		X			
Does the ambient lighting present any special requirements?		X	X	X	X
Are changes (surprises) indicated by transitions like signing, points of fixation?			X	X	X
Are the insides of curves free from side obstructions?			X	X	X
Are the outside of the curves framed parallel and consistent?			X	X	X
Are there accumulations of changes and critical situations?			X	X	X
Are there hidden dips in the vertical alignment?			X	X	X
Are there lane shifts by use of islands or carriageway narrowing when entering towns and villages?			X	X	X
Are there optical illusions?			X	X	X
Are there sufficient overtaking possibilities			X	X	X
Has the passing lane a sufficient length in order to insure that the vehicles can overtake and return safely?			X	X	X
4 Alignment					

	RSA				RSI
	audit phase				
	1	2	3	4	
Has the passing lane a sufficient length to overtake and return safely?			X	X	X
Has the uphill sector a passing lane for overtaking slow traffic?			X	X	X
Is access to abutting properties appropriate for road safety?			X	X	X
Is sufficient stopping sight distance guaranteed along the entire section? 100 km/h ▸185 m for trucks, 80 km/h ▸ 130 m for trucks, 60 km/h ▸ 85 m for trucks			X	X	X
Is the alignment consistent and easily recognized by the road users? Or full of „surprises“ for the drivers?			X	X	X
Is the existing speed limit adequate for the horizontal and vertical elements of the alignment?			X	X	X
Is the super elevation in curves sufficient?			X	X	X
Is the visibility of the road course assisted by edge delineation?			X	X	X
Is visibility in curves ensured?			X	X	X
Where tractors or carts will access the road, is the lay out safe?			X	X	X
5 Junctions					
Have the audit results from the previous audit phase been taken into consideration?		X	X	X	
Are all approaches equipped with pedestrian and cycle crossings?	X	X	X	X	X
Are further crossing aids required?	X	X	X	X	X
Are special measures required for particular groups or facilities (including hospitals), e.g. for young people, older people, sick people, physically handicapped, hearing-impaired or blind people?	X	X	X	X	X
Are the auxiliary lanes or tapers for turning movements necessary and, if so, is storage length sufficient?	X	X	X	X	X
Are the islands clearly visible and of a suitable design?	X	X	X	X	X
Are the pedestrian crossings located where most required by pedestrian traffic?	X	X	X	X	X
Are there plans to set stop lines for motorists' further back for the benefit of cyclists?	X	X	X	X	X
5 Junctions					

	RSA				RSI
	audit phase				
	1	2	3	4	
Can road maintenance service vehicles be parked safely?	X	X	X	X	X
Does the junction have sufficient drainage?	X	X	X	X	X
Has right of way been specified and clarified at cycle crossings, in particular for cycle paths that are set back?	X	X	X	X	X
Have suitable measures been taken to ensure that speed limits are obeyed? Are traffic signals/ temporary speed monitoring required?	X	X	X	X	X
Is right of way clearly defined at points where cyclists come into contact with each other or with motorized traffic?	X	X	X	X	X
Is stopping sight distance guaranteed on the approach to the junction?	X	X	X	X	X
Is the transition safely designed if footpaths and cycle paths end on a junction or road or are directed across the road?	X	X	X	X	X
Is there sufficient cross fall/ longitudinal fall?	X	X	X	X	X
Is the central island of the roundabout free of fixed obstacles?	X	X	X	X	X
Is pedestrian/cyclist routing at junctions adapted to the actual conditions and clearly marked and signposted?	X	X	X	X	X
Are additional areas for cross-turning movements required and is storage length sufficient?	X	X			
Are areas for waiting pedestrians and cyclists sufficient?	X	X			
Are auxiliary lanes for deceleration, acceleration, and weaving required and, if so, are they appropriately and safely designed?	X	X			
Are public transport stops planned at junctions?	X	X			
Are stops easily accessible to pedestrians?	X	X			
Are the dimensions of the junction sufficient for all necessary vehicle movements (minimum turning radius of design vehicles)?	X	X			
Are there approaches and accesses that are superfluous or that are located at critical points that can be combined?	X	X			
Can turning motorists see past oncoming vehicles?	X	X			
Has it been ensured that, for small roundabouts, the circulatory carriageway can be driven on in single lane only?	X	X			
Has the construction standard and, if applicable, the transition area been adapted to the adjacent road sections?	X	X			
5 Junctions					

	RSA audit phase 1	2	3	4	RSI
Have all approaches for small roundabouts been aligned radial to the centre of the circle?	X	X			
Have pedestrian crossings been appointed in such a way that collective use is guaranteed and the road will not be crossed at other points?	X	X			
Have specific traffic composition characteristics been taken into consideration?	X	X			
Have the requirements of pedestrians and cyclists been considered?	X	X			
Can junctions be recognized in time? Is the junction clearly visible and recognizable in advance from all approaches?	X	X			
Is safe serviceability guaranteed?	X	X			
Is the type and design of the selected junction suitable for the function of the road and the intersecting roads (crossroads, T-junction, roundabout, traffic signals etc.)?	X	X			
Is through visibility effectively stopped by the roundabout?	X	X			
Are lanes and carriageway in curves wide enough?	X				
Are sight lines obstructed/sometimes restricted, for example by safety barriers, fences, road equipment, parking areas, traffic signs, landscaping/greenery, bridge abutments, buildings, traffic jams?	X				
Are the junctions and junction elements designed in such a way that they can be clearly recognized in time?	X				
Are the movements guided clearly and easy to understand?	X				
Do compensatory measures provide a sufficient degree of safety when deviating from guidelines?	X				
Have junction speed and design speed been coordinated?	X				
Have previous findings/documents on accident situations been taken into consideration during the planning phase?	X				
Is the roundabout fully visible and recognizable from all approaches and are the required markings and signs clear and unambiguous?	X				
Is the sequence of the junction elements easily understood?	X				
Have some turning movements been excluded from signal control or from the roundabout? If so, is traffic operation safe?	X				
Is the junction necessary and has the number, spacing and form of the junctions been selected appropriately?	X				
5 Junctions					

	RSA audit phase 1	2	3	4	RSI
Is good visibility ensured at the junctions and, is the required sight triangles clear for all road users?	X				
Are refuges large and wide enough for crossing pedestrians and cyclists to stand and wait?	X		X	X	X
Are cross turning movement included in signal control?		X			
Are lanes and carriageway in junctions wide enough?		X			
Are no-stopping zones planned/ required?		X			
Are suitable measures planned to restrict speeds at the appropriate locations?		X			
Are the green times long enough for cyclists and pedestrians?		X			
Can perspectives that appear to be continuous (passage effect) be prevented/ interrupted by highlighting the nearest signals?		X			
Have any turning movements been excluded from signal control or from the roundabout? If so, is traffic operation safe?		X			
Is access from abutting properties affected and, if necessary, included in signal control?		X			
Is good sight ensured at the junctions? And are the required sight triangles clear?		X			
Is reconcilability guaranteed?		X			
Is traffic signals / stationary speed monitoring required?		X			
Are pedestrian crossings clearly marked? Is each section equipped with signals (including railway structures)?		X	X	X	X
Are sight lines partially obstructed, e.g. by vehicles in lay-bys, by parked vehicles or by queuing traffic?		X	X	X	X
Are the crossings for pedestrians and cyclists provided with low kerbs?		X	X	X	X
Are the movements guided clearly and easily to understand? Are traffic flows guided by markings?		X	X	X	X
Are the type and spacing of different crossing installations coordinated (e.g. railway crossings, traffic signals, zebra crossings)?		X	X	X	X
Does the ambient lighting present any special requirements?		X	X	X	X
Does the obligation to yield right of way need to be reinforced (e.g. using repetition)?		X	X	X	X
5 Junctions					

	RSA audit phase 1	RSA audit phase 2	RSA audit phase 3	RSA audit phase 4	RSI
Is it clear to the motorist whether he is crossing a one-way or two-way cycle path?		X	X	X	X
Is sight obstructed, for example by safety barriers, fences, road equipment, parking areas, traffic signs, landscaping/greenery, bridge abutments, buildings?		X	X	X	X
Is the junction fully visible and recognizable in time from all approaches and are the required markings and signs clear and unambiguous?		X	X	X	X
Is a reduction in speed required in the direction of the junction? And are there transitions for speed reductions on the minor road?		X	X	X	X
Should turns be prohibited (block diversion)?		X	X	X	X
Are there no-stopping zones?			X	X	X
Are all approaches to roundabouts perpendicular and radial to the centre?			X	X	X
Are public transport stops easily accessible to pedestrians?			X	X	X
Are the intersections perpendicular?			X	X	X
Are the islands above the level of the carriageway?			X	X	X
Are the islands made only by markings?			X	X	X
Are type and design of the junctions suitable for the function and traffic volume of the intersecting roads? (Separate answers for each intersection!)			X	X	X
Can pedestrians cross the road in one go? Is the green time sufficient? (see signalization)			X	X	X
Is good visibility ensured at the junctions for different driver eye heights of: Cars, trucks, motorcycles, bicycles, etc., and are the required sight triangles clear?			X	X	X
Is the central island of the roundabout shaped as a hill?			X	X	X
Is the main direction clearly recognizable? And if so, Is the right of way clearly recognizable?			X	X	X
Is the maximum delay reasonable for cyclists? Can cyclists be partially or totally removed from signal control?			X	X	X
Is the stopping line correlated with the traffic signal so that the signal can be seen?			X	X	X
Is the through-visibility effectively stopped by the roundabout and the hill?			X	X	X
5 Junctions					
Is there a danger of underestimating speed and overestimating distance of crossing vehicles?			X	X	X
6 Traffic signals					

	RSA				RSI
	audit phase				
	1	2	3	4	
Have the audit results from the previous audit phase been taken into consideration?		X	X	X	
Have specific traffic composition characteristics been taken into consideration?	X	X	X	X	X
Are all approaches equipped with pedestrian and cycle crossings?	X	X	X	X	X
Are protected phases provided for turning movements or are the fast driven approaches signalled separately?	X	X			
Are the auxiliary lanes or tapers for turning movements necessary and, if so, is storage length sufficient?	X	X			
Is reconcilability guaranteed?	X		X	X	X
Is access from abutting properties affected and, if necessary, included in signal control?	X		X	X	X
Are areas for waiting pedestrians and cyclists sufficient?	X				
Are the pedestrian crossings located where most required by the pedestrian traffic?	X				
Are the traffic signals clearly recognizable?	X				
Are there plans to set to stop lines for motorists' further back for the benefit of cyclists?	X				
Have cyclist and pedestrian requirements been considered (e.g. route through junction)?	X				
Is the type and design of the selected junction suitable for the function of the road and the intersecting roads?	X				
Have some turning movements been excluded from signal control? If so, is traffic operation safe?		X			
Are exclusive green phases provided for pedestrians and cyclists where necessary?		X			
Are exclusive green phases required for pedestrians and cyclists?		X			
Are secondary signals provided as necessary?		X			
Are high intensity signals and/or contrast louvres required if the signals are affected at dawn/dusk by direct sunlight?		X			
6 Traffic signals					
Are there any additional signs correlated with the traffic signals to show the direction to which that traffic signal is referring to?		X			
Can pedestrians cross the road in one go? Is the green time sufficient?		X			

	RSA audit phase				RSI
	1	2	3	4	
Does the existing road lighting lead to conflicts in recognizing the yellow indication (sodium discharge lamps)?		X			
Are the signals are affected at dawn/dusk by direct sunlight?		X			
Have cyclists' requirements been considered (e.g. route through the junction)?		X			
Have right-turning movements been excluded from signal control? If so, are markings clear for right-turning motorists?		X			
Should specific turns be prohibited (block diversion)?		X			
Are secondary signals required in the vicinity?		X	X	X	X
Are perspectives that appear to be continuous (passage effect) interrupted by highlighting the nearest signals?		X	X	X	X
Are longer and/or additional green times planned for road users with restricted mobility?		X	X	X	X
Are signals covered/ obstructed (e.g. by traffic signs, lighting masts, plants, traffic jams)?		X	X	X	X
Are traffic signals easily recognizable?		X	X	X	X
Can perspectives that appear to be continuous (passage effect) be prevented/interrupted by highlighting the nearest signals?		X	X	X	X
Have right-turning movements been excluded from signal control? If so, is traffic management safe?		X	X	X	X
Have the locations for the signals been selected correctly (additional signals, overhead signals, etc.)?		X	X	X	X
If there is no exclusive pedestrian phase, is a leading pedestrian interval provided?		X	X	X	X
Is the maximum delay reasonable for cyclists? Can cyclists be partially or totally removed from signal control?		X	X	X	X
Are the traffic signals properly situated so that they can be distinguished by each particular traffic flow?		X	X	X	X
Are pedestrian crossings clearly marked? Is each section equipped with signals (including railway structures)?			X	X	X
Are advanced warnings planned for traffic signals that cannot be seen in time?			X	X	X
6 Traffic signals					
Are advanced warnings provided for traffic signals that cannot be seen in time?			X	X	X
Are phase offsets required for pedestrians and cyclists within the cycle?			X	X	X

	RSA				RSI
	audit phase				
	1	2	3	4	
Are separate signals provided for cyclists? (Are the signal aspects correctly located for the cyclists? Estimate clearance times for cyclists? Avoid protected turn phases/ risk of cyclists crossing on red.)			X	X	X
Are special measures required for particular groups or facilities (including hospitals), e.g. for young people, older people, sick people, physically handicapped, hearing-impaired or blind people?			X	X	X
Are stop lines for motorists' further back for the benefit of cyclists?			X	X	X
Are the traffic signals co-ordinated with other traffic signals within the road segment or the network?			X	X	X
Are the type and spacing of different crossing installations coordinated (e.g. railway crossings, traffic signals, zebra crossings)?			X	X	X
For the protection of pedestrians, is it possible to set up an all-way red phase for vehicle traffic?			X	X	X
Have any turning movements been excluded from signal control? If so, is traffic management safe?			X	X	X
Is the stopping line correlated with the traffic signal so that the signal can be seen?			X	X	X
Is the visibility of the traffic signal ensured on a sunny day?			X	X	X
7 Service and rest areas					
Have the audit results from the previous audit phase been taken into consideration?		X	X	X	
Is the layout of the service or rest area appropriate for the different traffic movements? And if so, Is layout suitable in access areas to and from property?	X	X	X	X	X
Are the dimensions of the parking areas sufficient for parking for passenger vehicles, trucks and buses?	X	X	X	X	X
Have measures been taken to ensure safe access for rescue vehicles/maintenance vehicles/fire service?	X	X	X	X	X
Are pedestrian facilities of a safe design?	X	X			
Are entrances and exits for rest and service areas planned at points with good overall visibility?	X				
Are rest areas easily accessible and do they provide sufficient manoeuvring space?	X				
7 Service and rest areas					
Are stopping facilities planned at points with interesting views?	X				
Are there service and rest areas on both sides of the road in cases of two lane roads to avoid turning manoeuvres?	X				

	RSA audit phase 1	RSA audit phase 2	RSA audit phase 3	RSA audit phase 4	RSI
Are there sufficient parking areas to prevent parking on the entrances and exits and/or carriageways?	X				
Is there a sufficient distance to the adjacent junctions?	X				
Are no-stopping zones to be planned?		X			
Are parking areas easily accessible and do they provide sufficient manoeuvring space?		X	X	X	X
Are service and rest areas and parking facilities on both sides of the road? In case not, are there turning lanes?			X	X	X
Are the road markings clear and recognizable?			X	X	X
Are there any pedestrian facilities? And if so, are they of a safe design?			X	X	X
Are these areas physically separated from the carriageway (guardrail, kerb, green area etc.)?			X	X	X
Do users feel safe and secure?			X	X	X
Is access from abutting properties appropriate for road safety or are the accesses and exits of a safe design and easy to see?			X	X	X
Are no-stopping zones provided as necessary?			X	X	X
Is the layout in such a way, that vehicles are running at the appropriate speed?			X	X	X
8 Railway crossings					
Have the audit results from the previous audit phase been taken into consideration?		X	X	X	
Are traffic control devices required and optimally set up with regard to future traffic developments?	X	X	X	X	X
Does the ambient lighting present any special requirements?	X	X	X	X	X
Is good visibility guaranteed?	X	X	X	X	X
Are particular safeguards required as a result of seasonal use of the railway crossing?	X	X			
8 Railway crossings					
Are prohibition of overtaking and speed limits planned?	X	X			
Are the clearance areas behind the railway crossing long enough?	X	X			

	RSA audit phase 1	2	3	4	RSI
Are the road widths before and after the railway crossing as well as the width of the railway crossing sufficient for all necessary vehicle movements (vehicles meeting each other, minimum turning radius of design vehicles)?	X	X			
Is lighting required and, if so, appropriately designed?	X	X			
Are the railway crossings clearly recognizable?	X				
Is a railway crossing at-grade avoidable?	X				
Vehicle movements (vehicles meeting each other, minimum turning radius of design vehicles)?	X				
Are planned safety barriers for pedestrians or other barriers appropriately designed (beginning and end of the barriers, barrier posts, distance between stanchions, stability, depth of stanchions, combination with guard rails)?		X			
Is reconcilability guaranteed?		X	X	X	X
Are passive safety devices at the required locations?			X	X	X
Are prohibition of overtaking and speed limits in place as necessary?			X	X	X
Are safeguards in place if required as a result of seasonal use of the railway crossing?			X	X	X
Are the traffic signs correlated with the type of railway crossing?			X	X	X
If the railway crossing is situated in a curve are the traffic signs doubled on the other side of the road?			X	X	X
Is lighting required and appropriately installed?			X	X	X
Is the type of the railway crossing according with the traffic volume?			X	X	X
Is the visibility of the traffic signal ensured on a sunny day?			X	X	X
9 Traffic signing					
Have the audit results from the previous audit phase been taken into consideration?			X	X	
9 Traffic signing					
Are signs located in such a way as to avoid restricting sight from approaches or intersecting roads?		X	X	X	X
Are the installations shared by pedestrians and cyclists, including underpasses and bridges, properly signposted?		X	X	X	X

	RSA				RSI
	audit phase				
	1	2	3	4	
Can the signs be clearly recognized and read (size of signs)? And do the signs conform to the conventions of Vienna and Geneva?		X	X	X	X
Could greenery lead to safety problems if the vegetation grows (e.g. as a result of covered road signs)?		X	X	X	X
Do all signs and markings correspond without any contradictions?		X	X	X	X
Have old signs/markings (phantom markings) and protruding foundations been completely removed? Are there more than 2 different traffic signs at one place?		X	X	X	X
Is it clear to the motorist whether he is crossing a one-way or two-way cycle path?		X	X	X	X
Is pedestrian/cyclist routing at junctions adapted to the actual conditions and clearly signposted?		X	X	X	X
Is right of way clearly defined at points where cyclists come into contact with each other or with motorized traffic?		X	X	X	X
Is signing for service and rest areas clear?		X	X	X	X
Are advanced warnings planned for traffic signals that cannot be seen in time?		X			
Are no-stopping zones to be planned (service and rest areas)?		X			
Does the obligation to yield right of way need to be reinforced (e.g. using repetition)?		X			
Have appropriate speed limits been planned (start, end, height, location)?		X			
Is prohibition of overtaking for trucks, buses etc. required and, if so, is it set up at suitable locations?		X			
Is sight obstructed by traffic and direction signing?		X			
Is the junction fully visible and recognizable from all approaches and are the required markings and signs clear and unambiguous?		X			
Have variable direction signing or traffic control systems been taken into consideration?		X			
Is signing logical and consistent?		X			
Are advanced warnings in place for features that cannot be seen in time?			X	X	X
9 Traffic signing					
Are signs retro reflecting or are they illuminated at night? In daylight and darkness, are signs satisfactory regarding visibility?			X	X	X
Are the additional information panels uniform?			X	X	X

	RSA				RSI
	audit phase				
	1	2	3	4	
Are the sign masts and foundations sufficiently protected against collisions?			X	X	X
Are the signs at a uniform position, compared to the pavement?			X	X	X
Are the signs provided with protective edges?			X	X	X
Are there misunderstanding or misguiding traffic signs or additional information panels?			X	X	X
Are there speed limitations of 70/60 km/h ahead of intersections and build up areas?			X	X	X
Do delineators have a break away structure?			X	X	X
Do the signs have a dimension according to the type of road?			X	X	X
Do the traffic signs including their supports have a sufficient passive safety by: low mass or/and? Break away structure or/and? Are they beyond the safety zone? Passive safety installations?			X	X	X
Have appropriate speed limits been signed appropriately (start, end, height, location)?			X	X	X
Is prohibition of overtaking for trucks, buses, etc. appropriately designed and located? Are there warning signs ahead of the junction prohibiting overtaking?			X	X	X
Is readability ensured at the required distance? Are there background problems?			X	X	X
Have variable direction signing or traffic control systems been installed and are they fully functional?			X	X	X
Is a reduction in speed when approaching the junction assigned to the correct place and properly designed?			X	X	X
Is sight obstructed traffic or by the signs?			X	X	X
Is signing logical and consistent? Does it show the right of way clearly?			X	X	X
Is the roundabout fully visible and recognizable from all approaches and are the markings and signs clear and unambiguous?			X	X	X
Is the vertical signing properly emplaced and complete?			X	X	X
9 Traffic signing					
Where needed have signs been located above the carriageway?			X	X	X
10 Markings					
Have the audit results from the previous audit phase been taken into consideration?		X	X	X	

	RSA				RSI
	audit phase				
	1	2	3	4	
Are the road markings clear, recognizable and appropriate?	X	X	X	X	X
Is pedestrian/cyclist routing at junctions adapted to the actual conditions and clearly marked?	X				
Is the transition safely designed if cycle paths end on a road or are directed across the road?	X	X			
Do all signs and markings correspond without any contradictions?		X			
Have old markings been removed?		X			
Have turning movements been excluded from signal control? If so, are markings clear for turning motorists?		X			
Is the junction fully visible and recognizable from all approaches and are the required markings and signs clear and unambiguous?		X			
Are there plans to set stop lines for motorists' further back for the benefit of cyclists?		X	X	X	X
Is it clear to the motorist whether he is crossing a one-way or two-way cycle path?		X	X	X	X
Is pedestrian/cyclist routing at junctions adapted to the actual conditions and clearly marked and signposted?		X	X	X	X
Is reconcilability guaranteed?		X	X	X	X
Is right of way clearly defined at points where cyclists come into contact with each other or with motorized traffic?		X	X	X	X
Is the transition from a built-up to a rural road or from an illuminated to an unilluminated road appropriately designed?		X	X	X	X
Have old markings/signs been completely removed (phantom markings)?			X	X	X
Have any turning movements been excluded from signal control? If so, are markings clear for turning motorists?			X	X	X
Are the markings according to the pedestrian/cyclist traffic flow?			X	X	X
Are the markings appropriate for the function and category of the road?			X	X	X
10 Markings					
Are the markings in a parallel line to the edge of the road surface?			X	X	X
Are the markings likely to be effective under all expected conditions (day, night, wet, dry, fog, rising and setting sun)?			X	X	X
Are the markings visible on the entire sector?			X	X	X
Is the obligation to yield right of way enforced by markings according to the one enforced by signing?			X	X	X
Is the roundabout fully visible and recognizable from all approaches and are the required markings clear and unambiguous?			X	X	X
11 Lighting					
Have the audit results from the previous audit phase been taken into consideration?		X	X	X	

	RSA				RSI
	audit phase				
	1	2	3	4	
Is the road sufficiently illuminated?	X	X	X	X	X
Is the transition from a built-up to a rural road or from an illuminated to an unilluminated road appropriately designed (village/town outskirts)?	X	X	X	X	X
Is the lighting of special situations (transition zones, changes in cross section) required and, if so, suitably designed?	X	X	X	X	X
Are fixed obstacles avoidable, set up at sufficient distances or safeguarded (masts)?	X	X			
Is stationary lighting required at junctions/ service and rest areas and, if required, of an appropriate design?	X	X			
Does stationary lighting need to be changed so that crossing pedestrians are clearly visible?		X			
Is stationary lighting of the sections, junctions, service and rest areas foreseen, in relation to the ambient lighting?		X			
Does the ambient lighting present any special requirements?		X	X	X	X
Does the existing road lighting lead to conflicts in recognizing the yellow indication (sodium discharge lamps)?		X	X	X	X
Is contrast lighting required at the junction?		X	X	X	X
Are the lighting masts situated outside of the safety zone or properly protected?			X	X	X
Can the stationary lighting cause problems in recognizing the traffic signs or the alignment of the road?			X	X	X
Do remaining unlit areas present potential problems?			X	X	X
11 Lighting					
Does lighting need to be changed so that crossing pedestrians are clearly visible?			X	X	X
Have fixed obstacles been sufficiently safeguarded?			X	X	X
In the areas where is no stationary lighting, are there any potential dangers?			X	X	X
Is stationary lighting at junctions/service and rest areas properly situated?			X	X	X
Is the stationary lighting appropriate?			X	X	X
12 Other road equipment					
Have the audit results from the previous audit phase been taken into consideration?		X	X	X	

	RSA audit phase 1	2	3	4	RSI
Are antidazzle screens provided as required?	X	X	X	X	X
Are the emergency telephones in appropriate and safe positions with regard to traffic?	X	X	X	X	X
Are game fences required?	X	X			
Is suitable road equipment (fog warning signs, automatic sprinklers for de-icing agents, snow fences etc.) required and/or planned based on particular weather requirements?	X	X			
Is there a risk of pedestrian underpasses and bridges being bypassed? Are suitable measures (e.g. fences) planned?	X	X			
Is sight obstructed, for example by game/screens/snow fences?	X				
Are special measures required for particular groups or facilities e.g. for young people, older people, sick people, physically handicapped, hearing-impaired or blind people?		X			
Have sufficient measures been taken on cutting slopes to prevent falling material (e.g. falling rocks)?		X	X	X	X
Is sight obstructed, for example by safety barriers, fences, road equipment, advertising billboards and traffic signs?		X	X	X	X
Has suitable road equipment (fog warning signs, automatic sprinklers for de-icing agents, snow fences etc.) been installed and is it fully functional?			X	X	X
Is the beginning and end of game fencing correctly determined?			X	X	X
13 Planting					
Have the audit results from the previous audit phase been taken into consideration?		X	X	X	
13 Planting					
Does the greenery and type of planting preclude irritations to the road users (e.g. alignment)?	X	X	X	X	X
Is visual contact motorist-pedestrian-cyclist restricted by greenery?	X	X	X	X	X
Is good visibility ensured at the junctions? Or Is sight obstructed by the planting?	X	X			
Will growth of greenery lead to future safety problems, (e.g. as a result of obstructed sight, expected trunk diameter greater than 8 cm, hidden road signs, light and shadow effects, leaves falling on the road)?	X	X			
Are existing and planted trees a sufficient distance away from the road or out of reach of skidding cars?	X				
Are roundabouts fully visible and recognizable from all approaches?		X			

	RSA audit phase 1	2	3	4	RSI
Is sight obstructed by the planting? Is good visibility ensured at the junction?		X	X	X	X
Is the transition from a built-up to a rural road or from an illuminated to an unilluminated road appropriately designed (village/town outskirts)?		X	X	X	X
Are all existing and planted trees without the safety zone? 100 km/h ▸9m 80 km/h ▸ 6m 60 km/h ▸ 3m (away from skidding cars?)		X	X	X	X
Are planted trees a sufficient distance away from the road?			X	X	X
Are there bushes within the safety zone?			X	X	X
Are tree trunks free of scars from accidents?			X	X	X
Does it obstruct the visibility on the road course?			X	X	X
Does road side vegetation guide the drivers in curves continuously?			X	X	X
Does the greenery impede the drainage of the road?			X	X	X
Does the greenery or will the growth of greenery lead to future safety problems?			X	X	X
Does vegetation protect the road from natural disasters like landslides etc.?			X	X	X
Is the junction fully visible and recognizable from all approaches and are the required markings and signs clear and unambiguous?			X	X	X
Is the vegetation along the road old and could lead to safety problems?			X	X	X
13 Planting					
Is the vegetation monotonous? Or does it help to avoid a monotonous character of the road?			X	X	X
Is there any vegetation along the road?			X	X	X
14 Civil engineering structures					
Have the audit results from the previous audit phase been taken into consideration?		X	X	X	
Can road maintenance service vehicles be parked safely?	X	X	X	X	X
Does the structure have sufficient drainage?	X	X	X	X	X
Have measures been taken to ensure safe access for rescue vehicles/maintenance vehicles/fire service?	X	X	X	X	X
Is reconcilability guaranteed?	X	X	X	X	X

	RSA				RSI
	audit phase				
	1	2	3	4	
Have pedestrian and cyclist requirements been considered (e.g. layout of pedestrian and cycle paths)?	X	X			
Have specific traffic composition characteristics been taken into consideration?	X	X			
Are passive safety devices planned at the required locations and are they suitably designed?	X	X			
Is sight obstructed e.g. by bridge abutments?	X	X			
Is there a risk of pedestrian underpasses and bridges being bypassed? Are suitable measures (e.g. fences) planned?	X	X			
Are parapets and overpasses at a safe distance from the road?	X		X	X	X
Have masts, abutments, supporting walls, bridge railings etc. been set up at sufficient distances or safeguarded?	X		X	X	X
Are parapets and overpasses, masts, abutments, supporting walls, bridge railings etc. been set up at sufficient distances or safeguarded or at a safe distance from the road?		X			
Is lighting required and, if so, appropriately designed?		X			
Are passive safety installations set up at the required locations?			X	X	X
Are the constructions of culverts obstacle like?			X	X	X
Are the light poles to be considered as an obstacle (steel, concrete construction)?			X	X	X
14 Civil engineering structures					
Are there unprotected advertisement boards in the obstacle-free zone?			X	X	X
Are there unprotected supports for other cables than lighting in the obstacle-free zone?			X	X	X
Are traffic signs (other than road directional signs) to be considered as dangerous obstacles?			X	X	X
Have cyclists' requirements been considered (e.g. separate cycle facilities)?			X	X	X
Is lighting appropriately designed?			X	X	X
Is the drainage system a linear obstacle?			X	X	X
Is there a risk of pedestrian underpasses and bridges being bypassed? Are suitable measures in place?			X	X	X
Is there loose material with more than 0,4 kg each element in the „obstacle-free“ zone?			X	X	X
What is the distance of the road directional signing to the pavement?			X	X	X
15 Passive safety installations					
Have the audit results from the previous audit phase been taken into consideration?		X	X	X	
Are fixed obstacles avoidable, set up at sufficient distances or safeguarded (masts, abutments, supporting walls, bridge railings, trees etc.)?	X	X	X	X	X

	RSA				RSI
	audit phase				
	1	2	3	4	
Are passive safety installations set up at the required facilities/locations?	X				
Are areas for waiting pedestrians and cyclists sufficient?		X			
Are passive safety devices planned at the required locations and appropriately designed (beginning and end of the barriers, barrier posts, distance between stanchions, stability, depth of stanchions, combination with guard rails)?		X			
Is reconcilability guaranteed?		X			
Is sight obstructed, for example by safety barriers, fences, road equipment, parking areas, traffic signs, landscaping/greenery, bridge abutments, buildings?		X			
Is there a risk of pedestrian underpasses and bridges being bypassed? Are suitable measures planned?		X			
Are all necessary medium barriers in place and properly signed or delineated?			X	X	X
Are all road safety barriers in place and safely located so that they are not obstacles themselves?			X	X	X
15 Passive safety installations					
Are barriers placed so that they don’t restrict visibility?			X	X	X
Are dangerous windows of guardrails avoided?			X	X	X
Have passive safety installations been set up at the required locations?			X	X	X
Is the guardrail correctly installed, regarding: - End treatments: - Anchorages, - Post spacing, - Post depth, - Rail overlap?			X	X	X
Is the length of any guardrail adequate?			X	X	X
Is there a risk of pedestrian underpasses and bridges being bypassed? Are suitable measures in place?			X	X	X
16 Public transport stops					
Have the audit results from the previous audit phase been taken into consideration?			X	X	
Are public transport stops easily recognizable?	X				
Are public transport stops planned at (behind!) junctions? Are stops easily accessible to passengers?	X				
Are public transport stops clear of critical areas?	X				
Have the requirements of pedestrians and cyclists been considered?	X				
Is lighting required and, if so, appropriately designed?	X				

	RSA audit phase 1	2	3	4	RSI
Are areas for waiting pedestrians and cyclists sufficient?	X				
Are further crossing aids required to reach the public transport stops?	X		X	X	X
Are special measures required for particular groups, e.g. for young people, older people, sick people, physically handicapped, hearing-impaired or blind people?	X		X	X	X
Have the needs of public transport and its users been taken into consideration?	X		X	X	X
Is cyclist routing safely designed in the area near public transport stops?	X		X	X	X
Is sight obstructed, for example by safety barriers, fences, road equipment, parking areas, traffic signs, landscaping/greenery, bridge abutments, buildings?	X		X	X	X
Are areas for waiting pedestrians and large enough?			X	X	X
16 Public transport stops					
Are public transport stops designed in such a way that they are easily accessible to passengers?			X	X	X
Are stops easily and safe accessible to pedestrians?			X	X	X
Are the bus stops signposted and detectable by the drivers? Is reconcilability guaranteed?			X	X	X
Are the bus stops situated outside of the carriageway where appropriate?			X	X	X
Are the queuing areas for waiting passengers sufficient?			X	X	X
17 Pedestrians and Cyclists needs					
Have the audit results from the previous audit phase been taken into consideration?		X	X	X	X
Are all approaches equipped with pedestrian and cycle crossings?	X	X	X	X	X
Are areas for waiting pedestrians and cyclists sufficient? / Are refuges large and wide enough for crossing pedestrians and cyclists to stand and wait?	X	X	X	X	X
Are crossings over special railway structures of a safe design?	X	X	X	X	X
Are further crossing aids required?	X	X	X	X	X
Are special measures required for particular groups or facilities (including hospitals), e.g. for young people, older people, sick people, physically handicapped, hearing-impaired or blind people?	X	X	X	X	X
Are the pedestrian crossings located where most required by pedestrian traffic?	X	X	X	X	X
Have cyclists' requirements been considered (e.g. route across central refuges, bottlenecks)?	X	X	X	X	X
Have pedestrian crossings been appointed in such a way that collective use is guaranteed and the road will not be crossed at other points?	X	X	X	X	X
Is there a risk of pedestrian underpasses and bridges being bypassed? Are suitable measures in place?	X	X	X	X	X
Is two-way visual contact ensured between pedestrians and motorists?	X	X	X	X	X

	RSA				RSI
	audit phase				
	1	2	3	4	
Are crossings plausible and safe?	X	X			
Are the islands clearly visible and of a suitable design?	X	X			
Is lighting required and, if so, appropriately designed?	X	X			
17 Pedestrians and Cyclists needs					
Will growth of plants lead to safety problems in the future?	X	X			
Have the needs of horse riders been taken into consideration?	X				
Is sight obstructed/ partially obstructed, for example by safety fences, safety barriers, road equipment, parking areas, traffic signs, plants, buildings, by vehicles in lay-bys, or by queuing traffic?	X				
Is the entire junction regulated by traffic signals?	X				
Is the transition safely designed if footpaths and cycle paths end on a road or are directed across the road?	X				
Are sight lines partially obstructed, e.g. by vehicles in lay-bys, by parked vehicles or by queuing traffic?		X			
Are the crossings for pedestrians and cyclists provided with low kerbs?		X			
Does lighting need to be changed so that crossing pedestrians are clearly visible?		X			
Does the ambient lighting present any special requirements?		X			
Is it clear to the motorist whether he is crossing a one-way or two-way cycle path?		X			
Is reconcilability guaranteed?		X			
Is the transition safely designed if cycle paths end on a road or are directed across the road?		X			
Are refuges large and wide enough for crossing pedestrians and cyclists to stand and wait?		X	X	X	X
Have specific traffic composition characteristics been taken into consideration?		X	X	X	X
Are parked vehicles obstructing the visibility of the road users regarding cyclists?			X	X	X
Are points where cyclists cross intersecting roads provided with low kerbstones?			X	X	X
Is lighting provided where necessary?			X	X	X
Are sight lines partially obstructed or obstructed, e.g. by safety fences, by safety barriers, by road equipment, traffic signs, by plants, by buildings, by vehicles in lay-bys, by parked vehicles or by queuing traffic?			X	X	X
Are the islands clearly visible and properly placed?			X	X	X
17 Pedestrians and Cyclists needs					

	RSA				RSI
	audit phase				
	1	2	3	4	
Are the pedestrian crossings signposted and detectable by the drivers?			X	X	X
Are the pedestrian ways physically separated by kerb stones, barriers or greenery?			X	X	X
Are there small obstacles (obstacles not dangerous for motorised traffic) or rough pavement on roads where bicycles share the pavement with other traffic or at specific pedestrian/cyclist facilities)?			X	X	X
Are there traffic islands at the entrances of these areas?			X	X	X
Do traffic signs within the clearance for cyclists have protected edges?			X	X	X
Has priority been given to cyclists over other traffic where necessary?			X	X	X
Is the visibility for motorised traffic adequate to see cyclists along the road?			X	X	X
Is there a speed limit? And if so, is it respected by the drivers?			X	X	X
18 Motorcyclists' requirements					
Are all poles, pots, and devices necessary? (If so, is shielding an option)?			X	X	X
Are motorbikes a remarkable percentage of the traffic?			X	X	X
Have barrier kerbs been avoided in high speed areas?			X	X	X
Have devices or objects that might destabilize a motorcycle been avoided on the road surface?			X	X	X
In areas more likely to have motorcyclists run off the road is the roadside forgiving or safety shielded?			X	X	X
Is the road side clear of obstructions where motorcyclists may lean into curves?			X	X	X
Will warning or delineation be adequate for motorbikes?			X	X	X
19 Parking, loading, deliveries					
Have the audit results from the previous audit phase been taken into consideration?		X	X	X	X
Are loading areas provided next to the road?	X	X	X	X	X
Are sufficient parking areas provided to minimize illegal parking on footpaths, cycle facilities, and on the carriageway with the corresponding hazards or have corresponding preventative measures been taken?	X	X	X	X	X
19 Parking, loading, deliveries					

	RSA				RSI
	audit phase				
	1	2	3	4	
Are parking areas easily accessible or Is it possible to enter and leave parking areas safely?	X				
Are parking areas easily accessible?		X			
Have specific traffic composition characteristics been taken into consideration?		X			
Is it possible to enter and leave parking areas safely?		X	X	X	X
Is sight obstructed by parking areas?		X	X	X	X
Are sight lines partially obstructed by illegally parked vehicles, e.g. in lay-bys, on footpaths?			X	X	X

APPENDIX 2: RSA Report Template

This appendix contains the example of the template for RSA report. Such a template was used within the PILOT4SSAFETY project and, on the basis of experience from practical examinations of RSA (sees Deliverable D5) it is recommended to be used when conducting RSA on secondary roads. This example shows basic parts of the report describing a RSA conducted in the Czech Republic. The structure of the report is:

1. Title page

2. Introduction – One page showing the RSA stage, name of the project, members of audit team, dates and other information about RSA

3. Specific project details – One page or more (according to the extent of the project) with description and main traffic engineering characteristics of the project.

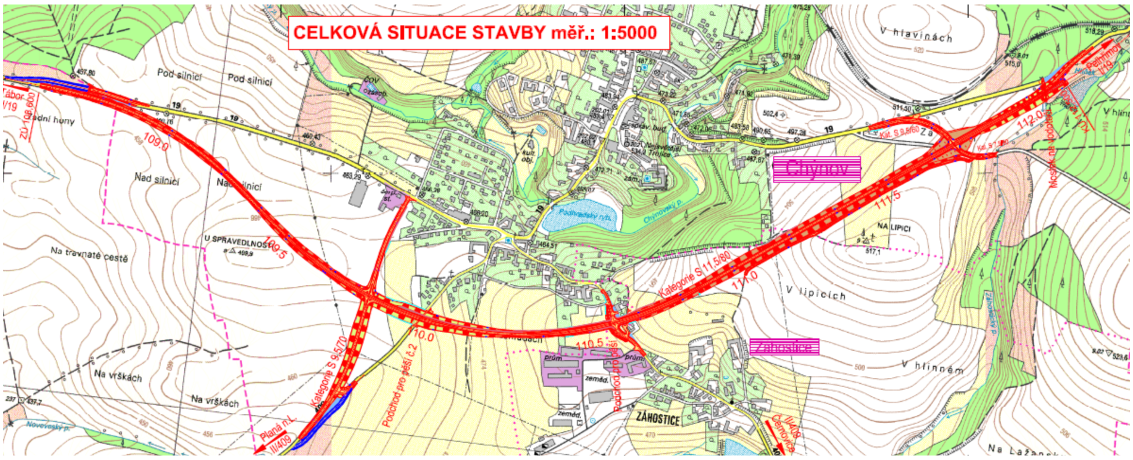
4. Items resulting from the audit – This is the core part of the report. It describes the road safety deficiencies identified within RSA; the potential risks of each deficiency and recommended solutions. It should be accurate and brief, with only general recommendations. The aim is not to redesign the project, but to provide suggestions for the designer, how to improve road safety. The deficiencies are divided into the following groups:

- General problems
- Cross section
- Alignment
- Intersections/Junctions
- Service and rest areas
- Passive safety installations
- Traffic Signage
- Road markings
- Traffic signals
- Lighting
- Other road equipment
- Planting
- Civil engineering structures
- Railway crossings
- Public transport stops
- Vulnerable road users issues
- Parking

5. Audit team statement – This page contains the final statement and signatures of members of RSA team.

Road Safety Audit Report Template

Region of South Bohemia, Czech republic
By-pass road I/19 around town Chýnov
ROAD SAFETY AUDIT STAGE 2 - detailed design



Report date: 7. September 2011
(Lead) auditor name: Jonatan Calafi (Generalitat de Catalunya)

Figure 54: Example of title page

INTRODUCTION

This report describes a Stage 2 (detailed design) Road Safety Audit carried out on project By-pass road I/19 around town Chýnov on behalf of Czech national highway and motorway authority.

Audit team members
Martin Lipl, Traffic Engineer, CDV
Jonatan Calafi, Civil Engineer, Generalitat de Catalunya

Dates
Audit Brief reception: August 2011
Inception meeting: 5th September 2011
Auditing Date (or Period): 5-7th September 2011

Data and documentation:
- Design brief
- Location plans
- Scheme drawings
- Traffic data

Site visit(s):
The site was visited by the Audit Team on 06/09/2011 in the morning. The weather was sunny. The traffic conditions were usual for the working day.

Comments:
The site visit was done by two auditors, one observer and three members of Road Directorate.

Appendix:
None

Figure 55: Example of Introduction page

Specific project details:

Description: The project of by-pass road I/19 of town Chynov aims at improving the living conditions in the town. The current through-pass is very busy with all negative effects on local life. The horizontal alignment of current road is insufficient according to technical standards. The by-pass will be beneficial also for transit transport – new road will be faster and more comfortable. The road I/19 connects western Bohemia (region around city Pilsner) with eastern part of Bohemia. It is also connected to the most important national motorway D1. The construction of the proposed by-pass will start in July 2012 and should be finished in 2014. By-pass goes mainly in not-built-up area in agricultural landscape.

Main characteristics of the by-pass

Road I/19 si 1.class road with two traffic lanes without any median barrier. The speed limit is 90 km/h. The by-pass has total length of 3,512 km.

Maximal radius of horizontal curve: 1050 m
Minimal radius of horizontal curve: 1000 m
Maximal longitudinal grade: 3,0%
Minimal longitudinal grade: 0,5%
Maximal and minimal radius of crest curve: 37 000m
Maximal (minimal) radius of crest curve: 54 000m (3000m)
Maximal cross section grade: 3,0%

There are 3 one-level intersection along the by-pass

1) with road II/409 direction Planá nad Lužnicí (Give-a-way sign)
2) with road II/409 direction Černovice (Stop-sign)
3) with road III/01915 direction Lazany (Give-a-way sign)

There are two pedestrian (cycle) underpasses under the proposed by-pass, 3 meters wide and 2,5 metres high.

Type of project: new by-pass scheme, detailed design
Length: The by-pass has total length of 3,512 km. It starts at western part of the town and goes southern from the town in the fields
Cross section: the total width of the road is 11,5 m with design speed 80 km/h. It is two-lane road with traffic lane 3,50 m wide + 0,25 m dividing marking lane + 1,50 m hard shoulder + 0,50 m soft shoulder
Traffic Volume: According to the national survey conducted in 2010, the traffic volume on road I/19 near town Chynov is 8 115 vehicles in both directions in 24 hours, with 24 % share of heavy vehicles.
Road Category: Secondary road in rural area, road category S11,5/80
Design Speed: 80 km/h

Figure 56: Example of Specific project details page

ITEMS RESULTING FROM THE AUDIT

General problems / problems at multiple locations

Problem 1.1: *Too many connections to Chynov village.*

Observations :

There is few distance between those connections. The maximum legal speed it´s 90 km/h but all connections are at grade.

Risk

Collateral collisions, speeding, poor visibility of un-coming cars.

Recommendations

Re-evaluate the need of so many intersections to connect to the village.
Study the possibility of roundabouts or at different grade intersections (on the main flow movements).

Problem 1.2: *Connections between existing road and by pass.*

Observations :

There is poor consistence between the existing road and the new by pass. Existing road is about 7 or 8 meters width and new road is 11.5 meters width (carriageway plus shoulders).
The existing road has no shoulders.
The existing road has vertical and horizontal parameters insufficient for a 90 km/h speed, spatially on the train underpass (recommended speed 30 or 40 km/h).
Inconsistent speed from the new by pass and existing road on direction from west to east.

Risk

Confusing drivers behaviour
Speeding up before the railway underpass.
Run off.

Recommendations

Use transitions zones and inform drivers that the existing road changes the comfort and alignment parameters. Change the road width to ensure equal speeds.

Figure 57: Example of Items resulting from the audit page

AUDIT TEAM STATEMENT

We certify that we have examined the drawing and other information listed in Appendix. This examination has been carried out with the sole purpose of identifying and features of the design that could be removed or modified to improve the safety of the scheme. The problems that we have identified have been noted in the report, together with suggestions for improvement which we recommend should be studied for implementation.

Signed: Martin Lipl

Date 7/9/2011

Figure 58: Example of Audit team statement page

APPENDIX 3: RSI Report Template

This appendix contains the example of the template for RSI report. Such template was used within the PILOT4SAFETY project and, according to good experience from practical examinations of RSI (see Deliverable D6), can be recommended to be used when conducting RSI on secondary roads. This example shows basic parts of the reports describing RSI conducted in Catalonia, Spain and in Denmark. The structure of the report is:

1. **Title page**

2. **Introduction** – One page showing the name of the project, members of inspection team, dates and other information about RSI (date of site visit, data and documentation)

3. **Specific project details** – One page or more (according to the extent of the project) with description and main traffic engineering characteristics of the inspected road. (If available: Basic accident figures)

4. **Item resulting from the inspection** – This is the core part of the report. It describes the road safety deficiencies identified within RSI; the potential risks of each deficiency and recommended solutions if necessary. There should be a picture with a detailed description of each identified deficiencies enclosed. The recommendations should be accurate and brief, with only general statements. The aim is to provide suggestions to the road authority, how to improve road safety. The deficiencies are divided into the following groups:

- General problems
- Cross section
- Alignment
- Intersections/Junctions
- Service and rest areas
- Passive safety installations
- Traffic Signage
- Road markings
- Traffic signals
- Lighting
- Other road equipment
- Planting
- Civil engineering structures
- Railway crossings
- Public transport stops
- Vulnerable road users issues
- Parking

5. **Inspection team statement** – This page contains the final statement and signatures of members of RSI team.

6. **Problems location map** – It is recommended to create an overview map, showing the location of each deficiency. The location of deficiency should be marked with the GPS coordinates.

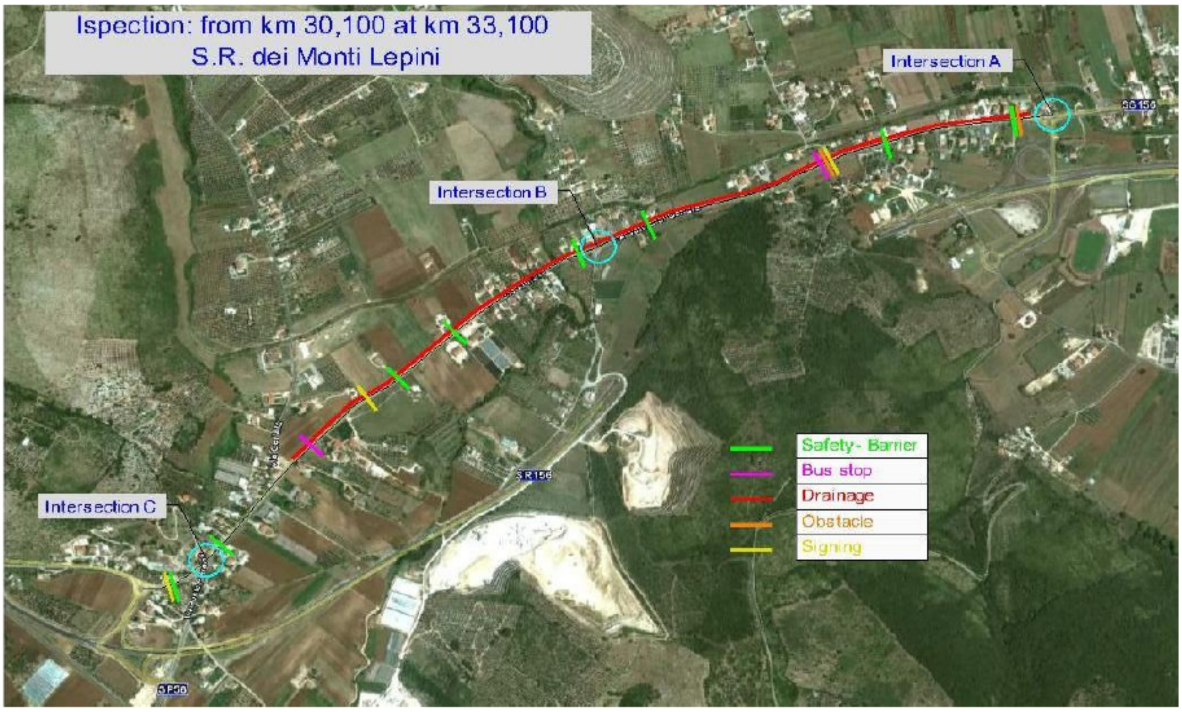


Figure 59: Example of problems location map from Italy

ROAD C155 (KM 0-KM 15,535)
FROM SABADELL TO LLICA DE VALL
BARCELONA, CATALONIA SPAIN.

Report date: 29.09.2011
(Lead) inspector name: Henrik Kaldahl and Lluis Lacruz

Figure 60: Example of title page

ROAD C155(KM 0-KM 15,535)
FROM SABADELL TO LLICA DE VALL
BARCELONA, CATALONIA SPAIN.

INTRODUCTION

This report describes the Road Safety Inspection carried out on road C155 going from Sabadell to Llica de Vall in Barcelona, Catalonia Spain.

Inspection team members
Henrik Kaldahl
Civil Engenieer
The Municipality of Randers, Denmark

Lluis Lacruz
Civil Engenieer
Responsible "Generalitat's Roads of Tarragona, Spain"

Dates
Inspection Brief reception: 15.09.2011
Initial meeting: 28.09.2011
Inspection Date (or Period): 28.09.2011

Data and documentation:
Materials given out on meetings on the 28.09.2011 and on 29.09.2011

Site visit(s):
The site was visited by the Inspection Team on 28.09.2011. The weather was sunny. The road was inspected in daytime and in nighttime

Appendix:
Responsibles of the road service gave out materials on the first meeting on the 28.09.2011 and accident statistics was given out on meeting on the 29.90.2011.
During the year 2004 there was constructed a roundabout in km 12+230 and complementary works between km 11+873 to km 13+293 at the village of Llica de Vall.
During the year 2002 there was constructed two roundabouts between km 12+570 and km 13+810.

Figure 61: Example of Introduction page

SPECIFIC PROJECT DETAILS

Description : The road is going from Sabadell to Parrets Del Valles in Barcelona, Catalonia Spain. The general width of the platfor is 8,20 meters.

Length : The length of the Road C155 is 15,535 kilometers

Traffic volume :
At km 2+700 the traffic volume in 2010 was 8607 with 2,27 % heavy vehicles.
At km 9+600 the traffic volume in 2010 was 9478 with 7,9 % heavy vehicles.

Road category : The category of the road is secondary road.

Design speed : The design speed on the road is 90 km/hour with various local speed recommendations going from 30 km/h to 70 km/h.

Figure 62: Example of Specific project details page

3. Alignment

Problem 3.1: *No sight distance when crossing the road (km 1+820)*

Observations

Risk

High

Recommendations

We recommend to cut the vegetation and dig the cut to improve the sight distance

Figure 63: Example of Items resulting from the inspection page (Spain)

5. Markings

Problem 8.1: *Partly visible markings on the road – low night time visibility*

Observations

In same places the marking on the road was missing/poor/interrupted because of damaged shoulders.

Risk

Drivers can run-off the road because of poor visibility and confusing road marking.

Recommendations

Reinstall the road marking.

Figure 64: Example of Items resulting from the inspection page (Denmark)

APPENDIX 4: Audit Response Template

Cover Page

LOCATION
SCHEME NAME
ROAD SAFETY AUDIT STAGE Xxxx

RSA report reference: …
RSA report date: …
(Lead) auditor name: …

Audit Response reference: …
Audit Response date: …
Author(s): …

Introduction Page

LOCATION
SCHEME NAME
ROAD SAFETY AUDIT STAGE Xxxx

INTRODUCTION

This Audit Response refers to the Road Safety Audit carried out on project *Yyyy*, on behalf of *Zzzz*.
It constitutes a formal answer to questions and recommendations addresses by the RSA team in its report dated from *dd/mm/aaaa* (reference *rrrr*).

Author(s) of the Audit Response
Name
title, name of organisation.

name
title, name of organisation.

Dates
RSA report meeting: …
RSA report: …

Data and documentation:
…
…

Comments:
…

Appendix:
Drawings and other information examined.
…

Reporting Page

Specific project details:

Description :

Type of project:

Length:

Cross section:

(traffic Volume):

Road Category:

Design Speed:

ITEMS RESULTING FROM THE AUDIT & ANSWERS FORMULATED: Content

1. **General problems / problems at multiple locations** **165**
2. **Cross Section** .... Error! Bookmark not defined.
3. **Alignment** .... Error! Bookmark not defined.
4. **Junctions** .... Error! Bookmark not defined.
5. **Service and rest areas** .... Error! Bookmark not defined.
6. **Passive safety installations** .... Error! Bookmark not defined.
7. **Traffic Signing** .... Error! Bookmark not defined.
8. **Markings** .... Error! Bookmark not defined.
9. **Traffic Signals** .... Error! Bookmark not defined.
10. **Lighting** .... Error! Bookmark not defined.
11. **Other Road Equipment** .... Error! Bookmark not defined.
12. **Planting** .... Error! Bookmark not defined.
13. **Civil Engineering Structures** .... Error! Bookmark not defined.
14. **Railway Crossings** .... Error! Bookmark not defined.
15. **Public Transport Stops** .... Error! Bookmark not defined.
16. **Pedestrian and cycle crossings** .... Error! Bookmark not defined.
17. **Parking** .... Error! Bookmark not defined.

Reporting Pages (continued)

ITEMS RESULTING FROM THE AUDIT

General problems / problems at multiple locations

Problem 1.1: *Formulation of the problem* ***To be copied from the RSA report***

Observations
Observation relating to this problem (+ illustrations)

Risk
Nature of the risks incurred for the road safety

Recommendations
Corrective measure(s) recommended by the audit team
(Highly Recommended, Potential High Impact, Suggestions to Consider,)

Observations / Answers formulated by the Road owner and/or the Design Team
…
…

Corrective measure or complementary action decided
…
…

The Audit Response should continue following this template and the content structure taken from the RSA report

Signed ……………………………………………………………………………………………………..

Date ………………………………………………………………………………………………………

Signed ……………………………………………………………………………………………………..

Date ………………………………………………………………………………………………………

PROBLEMS LOCATION MAP

APPENDIX

APPENDIX 5: Guidelines for the national/local versions of this Manual

This Manual can be freely translated in the local languages and some specific additional parts dealing with the national or local needs can be added, according to the following *compulsory* guidelines:

1. Leave the cover (page 3 in this version) as it is, just by translating the text in your language; you can add a second cover with your logo, names and other data according to your needs

2. Add your local introduction after the general one: you may continue the existing test or add a sub-section "1.1.1". Resume *in less than one page* the main differences of your manual respect to the international one; if you need to give more detailed explanations, you may use Appendix 7. Remember that the introduction will be in your local language, while Appendix 7 will be in English

3. Tables, text in the figures, references, check lists and appendixes should not be translated. You may add a legend for the tables and figures; your own check lists can be added in a separate file or printed document.

4. Do not change the structure of the manual: just add your local parts at the end of each chapter/section, according to your needs.

5. Do not delete any part of the manual. If you do not want some parts in your local version, leave the text in red English with a bar, ~~like in this example~~, adding a line of justification in your local language, e.g. " *the suggested solution xxxx doesn't comply with our regional rules"*)

6. Provide an Appendix 7 with the list of the additional parts and the eventual detailed explanations

7. Add the Directive in your local language (available on the European Commission web site) in Appendix 6

8. Send a printed copy to FEHRL

APPENDIX 6: Directive 2008/96/CE on road infrastructure safety management *(click to open document)*

29.11.2008 EN Official Journal of the European Union L 319/59

DIRECTIVES

DIRECTIVE 2008/96/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 19 November 2008

on road infrastructure safety management

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community, and in particular Article 71(1)(c) thereof,

Having regard to the proposal from the Commission,

Having regard to the opinion of the European Economic and Social Committee [1],

After consulting the Committee of the Regions,

Acting in accordance with the procedure laid down in Article 251 of the Treaty [2],

Whereas:

(1) The trans-European road network defined in Decision No 1692/96/EC of the European Parliament and of the Council of 23 July 1996 on Community guidelines for the development of the trans-European transport network [3], is of paramount importance in supporting European integration and cohesion as well as ensuring a high level of well-being. In particular, a high level of safety should be guaranteed.

(2) In its White Paper of 12 September 2001 'European transport policy for 2010: time to decide' the Commission expressed the need to carry out safety impact assessments and road safety audits, in order to identify and manage high accident concentration sections within the Community. It also set the target of halving the number of deaths on the roads within the European Union between 2001 and 2010.

(3) In its Communication of 2 June 2003 'European Road Safety Action Programme. Halving the number of road accident victims in the European Union by 2010: A shared responsibility' the Commission identified road infrastructure as the third pillar of road safety policy, which should make an important contribution to the Community's accident reduction target.

(4) In recent years, major advances have been made in vehicle design (safety measures and the development and application of new technologies) which have helped to reduce the number of people killed or injured in road accidents. If the target set for 2010 is to be achieved, action must be taken in other areas too. Managing the safety of road infrastructure offers plenty of scope for improvement, which must be used to advantage.

(5) The setting up of appropriate procedures is an essential tool for improving the safety of road infrastructure within the trans-European road network. Road safety impact assessments should demonstrate, on a strategic level, the implications on road safety of different planning alternatives of an infrastructure project and they should play an important role when routes are being selected. The results of road safety impact assessments may be set out in a number of documents. Moreover, road safety audits should identify, in a detailed way, unsafe features of a road infrastructure project. It therefore makes sense to develop procedures to be followed in those two fields with the aim of increasing safety of road infrastructures on the trans-European road network, whilst at the same time excluding road tunnels which are covered by Directive 2004/54/EC of the European Parliament and of the Council of 29 April 2004 on minimum safety requirements for tunnels in the trans-European road network [4].

(6) Several Member States already possess well functioning road infrastructure safety management systems. These countries should be permitted to continue using their existing methods, in so far as they are consistent with the aims of this Directive.

(7) Research is vital to improving safety on the roads within the European Union. Developing and demonstrating components, measures and methods (including telematics) and disseminating research results play an important part in increasing the safety of road infrastructure.

[1] OJ C 168, 20.7.2007, p. 71.
[2] Opinion of the European Parliament of 19 June 2008 (not yet published in the Official Journal), and Council Decision of 20 October 2008.
[3] OJ L 228, 9.9.1996, p. 1.
[4] OJ L 167, 30.4.2004, p. 39.