International Transport Forum

Road Infrastructure Safety Management

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International Traffic Safety Data and Analysis Group

Research Report

DECADE OF ACTION FOR ROAD SAFETY 2011-2020

OECD

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INTERNATIONAL TRANSPORT FORUM

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Executive Summary

What we did

Road Infrastructure Safety Management (RISM) refers to a set of procedures that support a road authority in decision-making related to improving the road safety of a road network. This report describes the most consolidated RISM procedures, analyses their use worldwide, identifies possible weaknesses and barriers to their implementation, provides example of good practices and aims to generally contribute to the scientific assessment of RISM procedures. Important parts of this report are based on a survey of road safety authorities in 23 countries on their use of RISM procedures. The report was prepared by a group of 15 experts from Argentina, Austria, Germany, Greece, Italy, Serbia and South Africa. It was reviewed by experts from Norway, the United Kingdom and the United States.

What we found

Road authorities are key players for improving road safety. Road Infrastructure Safety Management (RISM) procedures are effective and efficient tools to help road authorities reduce the number of accidents and casualties, because design standards alone cannot guarantee road safety in all conditions. Yet successful implementation of RISM procedures requires an adequate level of investment, supporting regulation, availability of relevant road safety data and adequate institutional management capacity. Making RISM procedures compulsory is preferable, as awareness of RISM alone is rarely sufficient for success. To identify the best ways of making road infrastructure safer, road authorities also need good road accident data. Road safety performance monitoring with appropriate indicators helps to achieve safety targets.

Tools to support RISM are already available, including guidelines, manuals and software tools. One of the main tools to help drivers to adopt appropriate behaviour are self-explaining roads. Evidence from pilot projects shows that these can reduce road casualties by 30%. Generally, a more pro-active approach to road infrastructure design and management is desirable, with road safety taken into account in all stages of the road life cycle. As each country has specific needs and barriers around implementing RISM, for instance because of potential liability issues, measures need to be adapted to specific conditions. The exchange of experiences with RISM among countries can be highly useful for finding the best solutions.

What we recommend

Benchmark road infrastructure against good practices in other countries

Road conditions can be the single most lethal contributing factor, ahead of speeding, alcohol or non-use of seat belts. There are substantial opportunities, programmes and tools to deliver safety improvements to road infrastructure. While there is no “one size fits all” standard for road safety programmes, comparisons with practices elsewhere help to identify opportunities for the prevention of fatalities and severe injuries.

Implement new minimum safety standards for road infrastructure

Studies show that upgrading road infrastructure to at least a 3-star rating in the Road Assessment Programme (RAP) categorisation can save many lives and generate savings from reduced trauma and fewer injuries. Between 1980 and 2000, infrastructure treatments, combined with speed management measures, reduced the number of deaths of vulnerable road users in Sweden, the Netherlands, and the United Kingdom by around a third. A number of countries including the Netherlands, Sweden, and Malaysia, have announced proposals to upgrade the safety of roads to 3-star standard or better by either 2020 or 2025.

Continue evaluation and research to quantify safety impacts of planning decisions

There is strong evidence that Road Safety Infrastructure Management procedures support improvements in road safety and can be highly cost effective. However, it is not always easy to assess the safety benefits of such procedures, and no clear relationship was found between the general use of these procedures and road safety performance. More analysis and research on RISM procedures is needed to quantify safety impacts of planning decisions on different types of networks, road types and traffic volumes to underpin specific uses in specific contexts.

Implement suitable Road Infrastructure Safety Management procedures for each stage of road development including planning design, pre-opening and full operation

Some road engineers insist that road infrastructure will provide the necessary level of safety if design standards are satisfied. Some studies have shown, however, that design standards alone are not a guarantee of safe roads. It is particularly important to consider safety aspects as thoroughly as possible before the full operation of road infrastructure.

Make Road Infrastructure Safety Management procedures legally binding

Awareness of RISM is a necessary but not a sufficient condition for successful implementation of infrastructure-oriented safety measures. It is therefore recommended to make RISM compulsory. The European Commission, for instance, requires that roads of the Trans European Network undergo safety programmes. Procedures that are not obligatory are easily skipped to save time and reduce cost.

Involve both road and health authorities when developing road accident data bases

Better road safety data can help to prevent accidents and reduce their severity. Involving road authorities at an early stage will help make the most of a database's capabilities. Involving health authorities will help bridge the gap between casualties reported by the police and by health authorities. It will also improve data on serious injuries.

Assure adequate institutional management capacity and investment levels

Important factors for strong institutional management capacity include political commitment to improve safety, adoption ambitious long-term targets for improving safety, good coordination between various governmental levels and agencies, and well-funded road safety measures.

Use existing tools and guidelines; adopt second-best solutions where state-of-the-art solutions are not feasible

A large number of tools to support the implementation of state-of-the-art RISM procedure are available for use, both on national and international level. Steps can be taken to bring current practice closer to the state of the art where optimal RISM procedures are difficult to implement, for instance because of lack of adequate road safety data or in low or middle-income countries.

Identify the Road Safety Infrastructure Management procedures that fit specific needs and understand barriers to implementation

Countries with different safety levels have different needs. Low and middle-income countries must concentrate on procedures that provide maximum impact for low capital expenditure. They are likely to focus on improving existing roads and prioritise e.g. High-Risk Site (HRS) improvement programmes. Countries with better safety records should consider the implementation of more advanced procedures such as Network Safety Ranking (NSR).

Share good practices of Road infrastructure Safety Management procedures and intervention measures

Just as road safety measures can be effectively and efficiently transferred from one country to another with the help of Crash Modification Functions, good Road Infrastructure Safety Management procedures can be effective in different countries and regions. Relevant international organisations should promote good programmes worldwide.

Monitor the safety performance of road infrastructure

The monitoring of road infrastructure's safety performance should be based on relevant indicators and it should be regular. Road authorities should be given full access rights to the data unless this encroaches on personal privacy.

Develop self-explaining roads

Self-explaining roads are roads designed and built to help drivers to adopt appropriate driving behaviour. Empirical evidence indicates that self-explaining roads can significantly reduce the number of casualties from road accidents. In general, planning authorities should adopt a comprehensive, system-wide and pro-active planning approach to road safety.

CHAPTER 1. INTRODUCTION

This introductory chapter looks at recent developments in road safety word wide and sets out the case for a pro-active versus a reactive approach to infrastructure management for improved road safety that takes into account the entire life cycle of road infrastructure. It outlines the objectives of the study underlying this report, sets out the methodology used and provides definitions for key concepts.

Recently, road safety has significantly improved in many developed countries. The Road Safety Annual Report 2013 (OECD/ITF, 2013a) based on the International Road Traffic and Accident Database (IRTAD) shows that the number of fatalities decreased in almost all member countries between 2000 and 2011. Some countries, such as Portugal and Spain, have more than halved their road fatalities. This is remarkable considering that motorisation has been steadily increasing during the same period. There are numerous reasons why this positive result for road safety has been achieved, but in short, the three main factors contributing to road accidents - road users, vehicles and the road environment - have each seen considerable improvements where safety is concerned.

More people are aware of the importance of respecting speed limits, wearing seat belts, and not driving under the influence of alcohol or drugs. Vehicles are equipped with more safety features than ever before. Air bags are no longer special safety options only for luxurious cars. Cars are now commonly fitted with high-tech functions to assist drivers, such as anti-lock braking systems, automatic cruise control and traction control systems. Roads are more generally designed with safety in mind, more investment in road safety facilities can protect road users from serious injury.

It is certain that these developments in road users' behaviour, vehicles and road infrastructure result from positive policy interactions. Putting the emphasis on road safety education, training and publicity has helped to change peoples' perceptions of road safety. Competition among car manufacturers to satisfy customers' demands for safer cars is also a contributing factor in the development of novel and cheaper vehicle safety technologies. A safety improvement programme has been applied to road infrastructure to reduce road sections with high number of fatalities in many countries. All these efforts have substantially contributed towards improving road safety.

However, when looking at road fatality figures in low- and middle-income countries, a different picture emerges. These countries account for 90% of all worldwide road fatalities, yet they hold less than half the world's registered vehicle fleet. Moreover, between 2007 and 2013 the number of road fatalities in most of these countries increased (WHO, 2013).

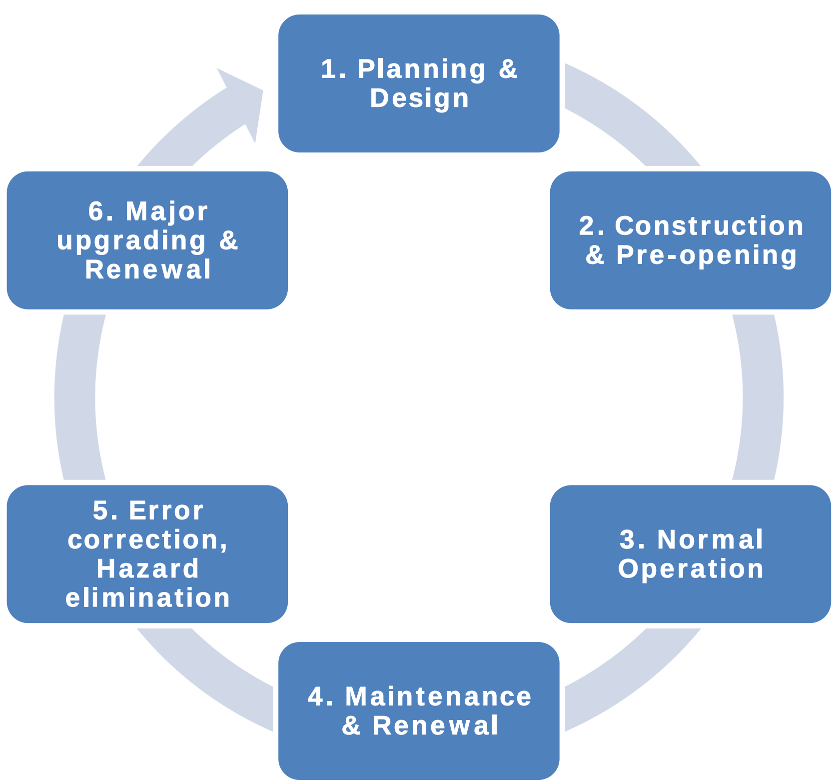
Low- and middle-income countries are experiencing an increasing use of motorised vehicles for transportation. The previously most used transport modes, walking and cycling, continue to remain important means of transport, thus increasing conflicts among these vulnerable road users and motorised traffic. The existing road network in these countries needs to be adapted to the changing traffic environment and national governments need to spend a conspicuous budget in planning and building new roads.

However, in this process of upgrading the road network, it may happen that side effects, especially for vulnerable road users, are overlooked, even if standards are respected. Therefore, in order to improve safety, during operation and maintenance stages road authorities have to find and correct safety issues that cause road accidents. In applying these they take a mainly **reactive approach**, because it relies on accident analysis; a typical example is the high-risk site improvement process. This is not the only approach that a road authority can adopt. New safety improvement procedures that may be applied in the beginning stages (i.e. planning and design stages) have been developed and used over time.

In recent years, in some developed countries like Sweden, the Netherlands and Australia, new road safety approaches have been proposed: *Vision Zero*, *Sustainable Safety* and *Safe System* (OECD/ITF, 2008). These approaches admit that the only acceptable long-term vision for a developed society is a road transport system where no one is killed or seriously injured. Achieving this ambitious target needs to reshape the actual road transport system on the basis of principles like **shared responsibility**, between road users and providers of the elements affecting the safety of system, and **prevention**.

The typical "blame the road user" view is thus replaced by the one that considers providers and enforcers of the road transport system responsible to citizens, guaranteeing their safety in the long term. It is recognised that road users make mistakes and it is important to redesign a road transport system that accommodates human error, making the road environment more **forgiving**[1] and **self-explaining**[2]. A more pro-active approach to road infrastructure design and renewal is desired, where road safety is taken into account in all the stages of a road life cycle.

Figure 1.1. **Life-cycle stages of a road infrastructure**



Source: Elvik, 2010.

Tools and procedures for a pro-active approach to Road Infrastructure Safety Management (RISM) already exist. For example, in the European Union, road infrastructure safety management is legally specified in Directive 2008/96/EC of the European Parliament and of the council – particularly for road infrastructure on the Trans-European road Network (EC, 2008).

It requires Road Safety Impact Assessments, to understand the implications on safety of different planning alternatives of road infrastructure projects. Road Safety Audits should be carried out in planning, design, and early operation stages of road development. Safety Ranking and management of road network in operation are key elements of the directive. Periodic inspections of the road network, management of accident data, and adoption of guidelines are also included. These procedures have been proven to be effective in reducing road accidents and injury risk and can be benchmarked in other road authorities, as long as they wish to find a good way of improving safety in the life cycle of roads including planning, designing, construction and operation.

However, in most countries, RISM is not well defined; certainly not as much as in the European Union for the Trans-European Road Network. Some countries may have a formal safety improvement programme for the operation stage, but they may not have any official safety improvement activity or procedure that can be applied in the early planning stage.

Most of all, budget constraints, particularly in developing countries, can easily force road authorities to sacrifice investment in road safety in favour of an expansion of the road network (OECD/ITF, 2013b). Consequently, it is not easy to introduce some additional safety programmes that incur additional expenditure, even if the expenditure is trivial. Some road authorities try to use only conventional practices on road safety management, simply because they are not familiar with cost-effective safety programmes, or because they do not wish to run the risk of applying new procedures.

There are some low-cost procedures that can effectively reduce fatalities from road accidents particularly for developing countries. For instance, the International Road Assessment Programme (iRAP) has been introduced in many developing countries to identify unsafe road sections and to improve them. It has been particularly effective in developing countries because it allows them to identify hazardous road sections even without a robust accident database, which may not be affordable in those countries.

Even in developed countries, new procedures can be considered after they have been demonstrated as good practice elsewhere. For instance, Germany and Austria use an indicator of potential accident cost savings to manage the safety of the road network. This helps to prioritise road sections for safety improvement. This kind of ranking system at network level can be a useful tool for other countries that do not have a similar one. Or if they have used the number of accidents or rates for performance indicators of road infrastructure, accident cost savings can be a useful measure to introduce because it can provide more tangible information to decision makers in monetary terms. In this respect, sharing of good practices in road infrastructure safety management can be beneficial in most countries.

Objectives

As highlighted, a common problem for all countries is how to prioritise budgets among different needs: maintaining the existing roads and their safety level, rehabilitating them (e.g. increasing roads capacity or their safety level) and building new roads to accommodate the travel demand.

As a matter of fact, governments and road authorities need to identify **affordable** solutions. It is not necessary to implement the perfect road infrastructure but rather an affordable one, meaning the safest available within the available resources. RISM procedures help find safety oriented solutions in a cost effective way during all the life cycle stages of a road infrastructure. If correctly applied, they have the potential to rapidly improve road safety. However, it is not always simple to introduce them as these procedures may require specialised knowledge and skills, extensive road safety data, specific tools and, of course, economic resources.

Over the years several methods and tools have been proposed for the same procedure and more procedures can get to similar results. These aspects may lead to confusion preventing the use of a procedure or relying on simpler and less reliable techniques that do not represent modern best practices. In Europe, some of these procedures are mandatory, but as reported by Elvik (2010), actual use differs country by country. Outside Europe information is lacking about if and how these procedures are applied. Moreover, as found by Elvik (2010), the relationship between the use of RISM procedures and road safety is not clear. A more extensive use of these procedures does not automatically ensure a superior road safety performance in a country. A reason for that is, the recommendations and the results of RISM are not always implemented due to a lack of financial and political commitments.

All these issues can prevent the use of RISM procedures, especially in low- and middle-income countries. Starting from this, the main aim of the study is to encourage a wider use of Road Infrastructure Safety Management (RISM) procedures, providing decision makers with a tool aimed at supporting them in the different stages of a road infrastructure life cycle. Specific objectives of the study are reported below.

Describe the most consolidated RISM procedures

To better understand the main characteristics of RISM procedures, the study will provide descriptions for the ten most consolidated procedures that support improving safety in each stage of road development. The ten procedures selected for consideration are:

- Road Safety Impact Assessment
- Efficiency Assessment Tools
- Road Safety Audit
- Network Operation
- Road Infrastructure Safety Performance Indicators
- Network Safety Ranking
- Road Assessment Programs
- Road Safety Inspection
- High-Risk Sites
- In-Depth Investigation

Essential information about data needed, tools used within the procedure and common practices are given. References for more detailed information about each are also included. These descriptions, and the study as a whole, will help road authorities find the most suitable safety procedure for each stage of road development including planning, designing, pre-operation and full-operation stages. To better understand potential uses and limitations of Road Infrastructure Safety Management procedures, the context of application of an RISM procedure and overlap of RISM procedures will also be investigated.

Analyse worldwide use of RISM and identify weaknesses and barriers

The actual usage level of RISM procedures is not clear, especially outside Europe. Therefore, the study will investigate the current use of RISM procedures in IRTAD countries, examining if and how these procedures are applied. Furthermore, the report will consider obstacles that could prevent the use of an RISM procedure in a country. RISM procedures may require specialised knowledge and extensive data; may have some limitations of use (e.g. due to legislation in force in a country); may be subject to prejudices or need specific requirements to be used, etc. Relevant issues will be investigated and discussed in the study, taking into account results from a survey carried out among IRTAD countries.

Provide examples of good practices

On the basis of the barriers identified within the survey, the study will suggest (affordable) solutions, emphasising good practices of Road Infrastructure Safety Management. It will help road authorities understand the status of road safety compared to others, and will help them find the appropriate activities/programmes to improve their level of Road Infrastructure Safety Management.

Contribute to the scientific assessment of procedures

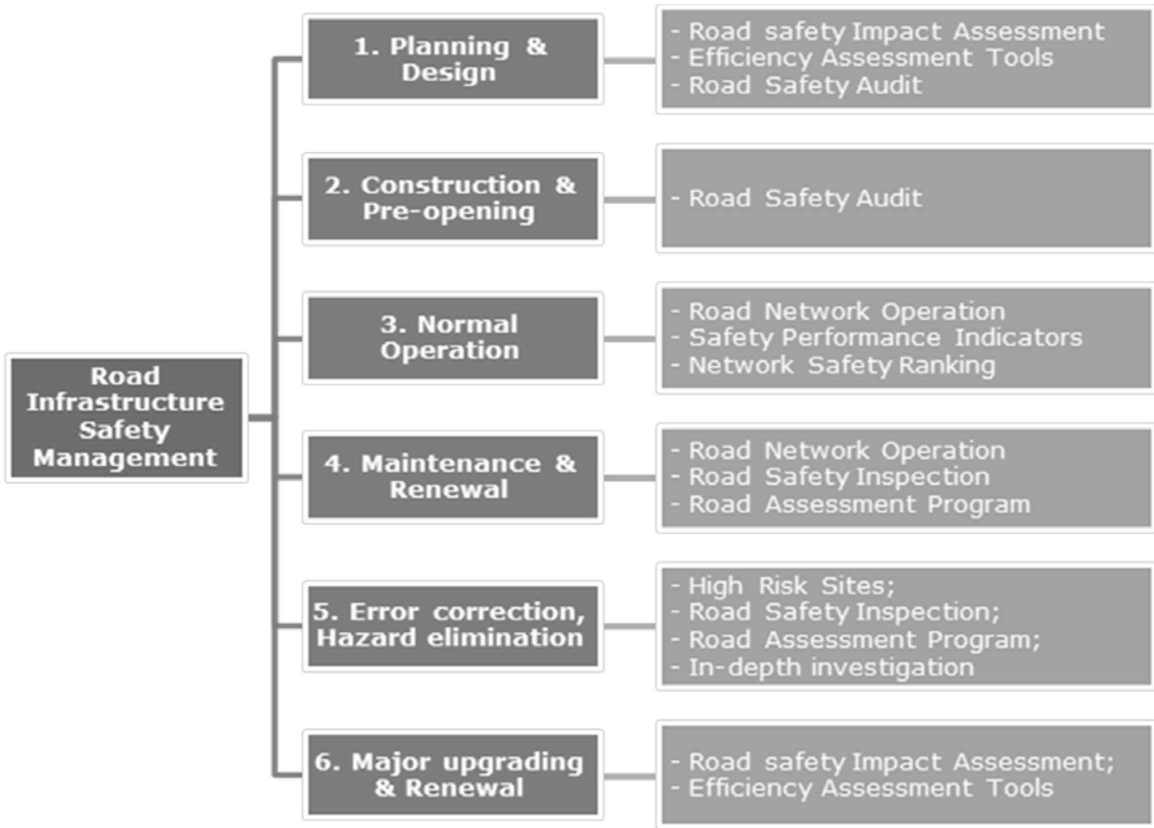
Results from existing studies will be reviewed to summarise the existing knowledge of the relationship between the use of RISM procedures and road safety. Some RISM procedures share similar goals but are based on different approaches and/or data. The study will also investigate the existing relationship among some Road Infrastructure Safety Management procedures to understand whether different approaches lead to the same results or not.

Methodology

As part of its methodology, the study will collect current practices of road infrastructure safety management worldwide for each stage of road development. This collection work will be based on the in-depth review on the existing literature with specific reference to some IRTAD member countries.

Several RISM procedures have been proposed in the last decades, some of them are very popular (e.g. treatment of high-risk sites) and some are less known. In some cases they have similar characteristics. The study focuses on those procedures for which the required data and methods are sufficiently consolidated, paying attention to covering each stage of a road infrastructure life cycle and all area of use (i.e. all road categories). The RISM procedures considered by the report and the stages of road development they are associated with are shown in Figure 1.2.

Figure 1.2. **Road safety procedures in each stage of road development**



Source: adapted from Elvik, 2010

There are a number of other tools and procedures that could be implemented in order to improve road infrastructure safety management; some of them are reported in Elvik (2010). For example, asset management and life-cycle management are management practices that have been implemented in the transportation sector too and which may contribute to the overall improvement of the road networks and subsequently of the level of safety on them. These two practices will be further investigated within the report in Chapter 4. However, other procedures not included in the list, are considered beyond the scope of this study.

A survey of countries was carried out in order to understand to what extent these procedures are applied and what barriers prevent their use. Survey results will be examined with particular reference to barriers to the use of these procedures. Furthermore, a comparison among considered countries with respect to the implementation of a "proactive approach" will be investigated.

Conclusions and policy recommendations derived from this research mainly address road authorities and policymakers.

Some Road Infrastructure Safety Management definitions

This study refers to "Road Infrastructure Safety Management". Other names used in literature for similar concept are "roadway safety management" or "highway safety management". The *Highway Safety Manual* refers to roadway safety management as a "quantitative, systematic process for studying roadway crashes and characteristics of the roadway system and those who use the system, which includes identifying potential improvements, implementation, and the evaluation of the improvements" (AASHTO, 2010). For the purpose of this study RISM can be defined as the sum of all management procedures that support road authorities in prevention and mitigation of future road accidents.

Elvik (2010) defines these procedures as "the analytic tools that help government detect emerging safety problems early, that help in locating the most hazardous parts of the road system, that identify the most important factors contributing to road accidents and injuries and that help to estimate the likely effects of specific road safety measures or a road safety programme consisting of several measures".

The introduction of new perspectives and methodologies in this field and the existing different points of view may have led to several shades of meaning and, in general, a lack of common understanding of these procedures. Road safety impact assessment (RIA), for instance, can be a method of analysis of the predicted variation in safety performance of the road network due to the introduction of a new roadway or a substantial modification to the existing network. However, the scope of RIA can be widened and applied to any road safety measure, not just the construction of new roads or major modifications to existing roads. To this end, Elvik (2007) proposes as definition for RIA "a formal assessment of the expected impacts of proposed road safety measures and integrated road safety programmes".

Notes

1. Forgiving roads are roads designed and built in such a way as to counteract or prevent driving errors and to avoid or mitigate the negative consequences of such errors (Wegman and Aarts, 2006).
2. Self-explaining roads are roads designed and built to elicit correct assessments from road users on appropriate driving behaviour matched to the road environment (Theeuwes and Godthelp, 1995).

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CHAPTER 2. ROAD INFRASTRUCTURE SAFETY MANAGEMENT: AN OVERVIEW

This chapter provides an overview of current Road Infrastructure Safety Management (RISM) procedures. It discusses the context of their application and potential overlap between them. Ten different RISM procedures are then described in detail, with reference to existing tools, data requirements and common practices.

Road Infrastructure Safety Management (RISM) refers to a set of procedures that support a road authority in decision making related to road safety improvement of a road network. These procedures are aimed at enhancing road safety at the different stages of a road infrastructure life cycle. Some of them can be applied to existing infrastructures, thus enabling a more reactive approach (e.g. by fixing the safety issues identified on the infrastructure); while others are used in the early stages (i.e. planning and design) allowing a more proactive approach. A total of ten RISM procedures are considered in the report:

1. *Road Safety Impact Assessment* (RIA). 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. It is carried out at the initial planning stage before the infrastructure project is approved. The purpose is to demonstrate, on a strategic level, the implications on road safety of different planning alternatives of an infrastructure project and these should play an important role when routes are selected.

2. *Efficiency Assessment Tools* (EAT). Budgets for transport in general and for road safety in particular should be spent as optimally as possible. Efficiency assessment tools (e.g. cost-benefits analysis) determine the effects for society of an investment, for instance of an investment in road safety, in order to prioritise investment alternatives.

3. *Road Safety Audit* (RSA). 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, in order to identify and detail unsafe features of a road infrastructure project.

4. *Network Operation* (NO). This relates to daily management of the infrastructure of a road network, with particular reference to maintaining road serviceability and safety.

5. *Road Infrastructure Safety Performance Indicators* (SPIs). Safety performance indicators (SPIs) are seen as any measurement that is causally related to crashes or injuries and is used in addition to the figures of accidents or injuries, in order to indicate safety performance or understand the process that leads to accidents. Road Infrastructure Safety Performance Indicators aim to assess the safety hazards by infrastructure layout and design (e.g. percentage of road network not satisfying safety design standards).

6. *Network Safety Ranking* (NSR). A method for identifying, analysing and classifying parts of the existing road network according to their potential for safety development and accident cost savings.

7. *Road Assessment Programmes* (RAPs). These methods involve the collection of road characteristics data which are then used to identify safety deficits or determine how well the road environment protects the user from death or disabling injury when a crash occurs.

8. *Road Safety Inspection* (RSI). A preventive tool consisting of a regular, systematic, on-site inspection of existing roads. The inspections cover the whole road network and are carried out by trained safety expert teams. They result in in a formal report on road hazards and safety issues found and which require a formal response by the relevant road authority.

9. *High Risk Sites* (HRS). A method to identify, analyse and rank sections of the road network which have been in operation for more than three years and upon which a large number of fatal accidents in proportion to the traffic flow have occurred.

10. *In-depth Investigation*. In-depth Investigation is the acquisition of all relevant information and the identification of one or several of the following: a) the cause (or causes) of the accident; b) injuries, injury mechanisms and injury outcomes; c) how the accident and injuries could have been prevented.

This chapter provides detailed description of these RISM procedures. For each procedure a general description is given followed by information about tools and data needed to carry it out (and how these tools and data are used within the procedure). A detailed technical description of the state of the art of methodologies and tools used within each procedure is beyond the scope of this report. However, useful references are provided to the reader who is looking for more detailed information. Full references are given at the end of the report.

A further objective of this study is the investigation of the existing general barriers to the implementation of a RISM procedure. The use of RISM procedures may be limited (e.g. due to legislation in force in a country) or subject to prejudices or need-specific requirements. Potential barriers to the use of RISM procedures are discussed in Chapter 3.

Context of application

In the Introduction, it has been shown that each investigated procedure may refer to one or more specific stages of a roadway life cycle. In particular, a reactive approach for road safety enhancement makes use of RISM procedures mostly during operation and maintenance stages, focusing on finding safety issues from the analysis of road accidents. While in a proactive approach, procedures are more focused on the beginning stages (i.e. planning and design).

Beyond the application to specific stages, other differences may appear when looking at the type of road, the dimension of the tackled road safety problem (e.g. the entire road network or a single road site) and the specific needs of the country using RISM procedures. RISM procedures can be applied to every type of road, i.e. motorways, rural and urban roads. However, some differences exist relating to "how" a procedure is carried out on a certain type of road network, and the extent of the road network involved in the procedure (e.g. a target site, a group of sites with similar characteristics or an area).

From a functional point of view, roadways are classified according to the type of movements (e.g. transition, distribution and access), trip length and type of road users. Each roadway belongs to a functional class and should be designed with reference to specific technical standards. Therefore, depending on the geometric and traffic characteristics, risk factors present on some roads (e.g. on an urban network) are different from risk factors affecting other types of roads (e.g. motorways). These differences are reflected in the data needed, and in the characteristics of the tools used, in an RISM procedure. Therefore, the type of road affects the characteristics of the RISM procedures to be applied, as the road safety issues encountered differ significantly.

Another aspect to take into account is the dimension of the road safety problem examined – whether one is interested in studying a specific road section or intersection, a road corridor or an entire road network. Some RISM procedures are applied to an entire road network or to a part of it (e.g. Network Safety Ranking and High Risk Sites rank road sections) according to their safety level; therefore they can be used only at network level (at least two road sections). Other procedures, such as Road Safety Inspections, are applied at section or intersection level. The use can be extended also to an entire road network, but proceeding on a per-section basis. Table 2.1 outlines the road category (i.e. the road administration) and extent of application for each RISM procedure.

One last aspect to consider is related to the specific needs of a country, linked mainly to the peculiarities of the roads and their uses in each country. For example, in the UK, roads are designed to be used with left hand driving, therefore tools and data used in RISM procedures need to be adapted to take this into account. This aspect is especially important for developing countries. These countries are exposed to a big increase in population, mainly at the suburban level, leading to urban sprawl. This uncontrolled growth is often accompanied by an inadequately planned road network and mixture of road users in contexts designed only for motor vehicles (e.g. pedestrians crossing motorways).

Country related peculiarities should be considered in order to calibrate RISM procedures to the examined road network.

Table 2.1. **Context of application of RISM procedures**

Procedure	Road Category	Extent
1. Road Safety Impact Assessment	No specific road category	Part of the road network potentially influenced by a measure
2. Efficiency assessment tools	No specific road category	Part of the road network potentially influenced by a measure
3. Road Safety Audit	No specific road category	A designed road infrastructure
4. Network Operation	No specific road category, however some practices are difficult to perform on a urban network	Generally part or an entire road network managed by a road administration
5. Road Infrastructure Safety Performance Indicators	Usually performed on a rural and motorway road network	An entire road network
6. Network Safety Ranking	No specific road category	Generally part or an entire road network managed by a road administration
7. Road Assessment Programs	Usually performed on a rural/ motorway road network	Part or an entire road network.
8. Road safety inspection	No specific road category	Generally part or all road elements belonging to the same road network
9. High-Risk Sites	No specific road category	Generally part or an entire road network managed by a road

Procedure	Road Category	Extent
		administration
10. In-depth Investigation	No specific road category	Limited to the area of intervention (e.g. 30 min from accident investigator's base)

Overlap

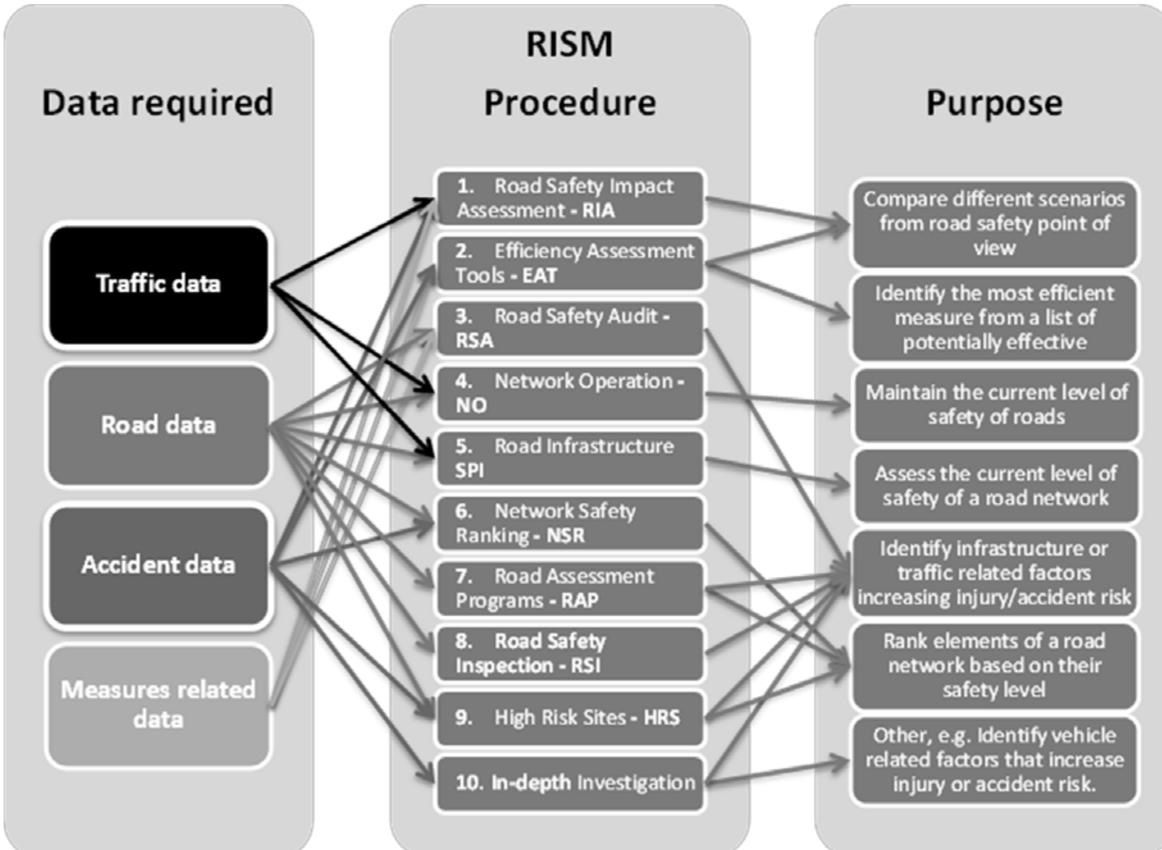
Another point to stress is the overlap of RISM procedures, meaning that in some cases, two different procedures could lead to similar results or have some parts in common. This may happen where some procedures have the same purpose, use the same tools or require similar data (see Figure 2.1).

For example, Road Safety Audits (RSA), Road Assessment Programmes (RAP), Road Safety Inspections (RSI), High-Risk Sites (HRS) and In-depth Accident Investigations have in common a similar purpose: the identification of risk factors related to road design or traffic control that may lead to accidents or make the accidents more severe. The objective is similar but timing, data and methods used are different. RSAs are applied at a design and pre-opening stage, before normal operation of a road, while the other procedures are applied on existing roads. RAPs and RSIs make use of roadway data while HRS and In-depth investigation are based mainly on accident data. RAPs and RSIs are quite similar, as both are aimed at identifying infrastructure deficiencies; however methods used in RAP are focused mainly at classifying and ranking road infrastructure based on their safety level. The analysis of accident data for in-depth investigation is based on the analysis of a large amount of information coming from a singular accident; while HRS methods take into account statistics from 3-5 years of recorded data with a lower level of detail.

HRS, RAP and NSR are procedures providing a classification of road elements (e.g. road intersections and road sections) according to their safety level. However, while HRS and NSR are based mostly on accident data, RAP is based largely on roadway characteristics. Moreover, while NSR offers only a description of the normal variation in safety of roads, HRS – for treatment purposes – aims also at identifying road-related risk factors associated with high accident locations.

A final example is related to RSA, Road Safety Impact Assessment (RIA) and Efficiency Assessment Tools (EAT). RIA estimates the effects of road safety measures on accidents and/or injuries. EAT, like cost-benefit analysis, makes use of the outcome of an impact assessment as an input to carry out the analysis. RSA procedures cover the stages from planning to early operation. While RSA examines the safety aspects within a scheme, RIA considers the safety impact of a scheme on the surrounding road network.

Figure 2.1. **Data required and purposes associated to each procedure**



Road Safety Impact Assessment

Purpose	Compare different implementation scenarios from road safety point of view
When	Generally undertaken at planning stage (stage 1) and before a major upgrading of the infrastructure (stage 6)
Where	Part of the road network potentially influenced by a measure
Data	Roadway related, traffic related, measures related

An RIA is a methodology used at the planning stage to assess changes in the network safety level resulting from the introduction of a modification in the road network configuration or operation. It involves the estimation of the safety level of part of the road network (i.e. the one potentially influenced by the measure) for two or more scenarios. One of these scenarios is the "do-nothing" scenario, for which the current safety level of the road network is estimated. The others represent alternatives to the do-nothing scenario in terms of a modification introduced to the road network configuration or operation.

The purpose of RIAs is to explicitly include road safety consequences in the decision making process during the planning phase, before the beginning of the detailed design phase. For example, according to the European Directive on road infrastructure safety management (2008/96/EC) an RIA is defined as 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, at the initial planning stage before the infrastructure project is approved".

Directive 2008/96/EC refers mainly to infrastructure projects and limits the application of RIAs to: new road infrastructure, such as a new bridge, or a "substantial modification" to the existing network. According to the Directive, an RIA shall provide all relevant information necessary for a cost-benefit analysis of the safety aspects of different options assessed. Therefore, an RIA aids in the selection of the best alternative to implement, by taking into account impacts on road safety performance in addition to, for instance, environmental impacts or traffic demand impacts.

In a more general way an RIA could also be used to assess the impacts of different infrastructure safety policies at a local or national level, for example when developing a Road Safety Plan[1]. As reported in the European project RISMET (Schemers et al., 2011), this type of RIA helps to identify which are the best set of measures to be implemented and to assign a priority level to these measures, supporting decisions concerning the distribution of annual road safety funds. Network wide scenario impacts are analysed in this type of RIA.

The benefits on road safety of carrying out RIAs are not easy to evaluate. RIAs aim at providing better information to policy makers in order to take better decisions for road safety. According to Elvik (Elvik et al, 2009) the research shows that the attitude to a particular traffic safety measure depends on the level of knowledge regarding the effects of the measure. However, the relationship between the supply of professional information and the number of road accidents has still not been evaluated.

Depending on the measure assessed, available data and the scale at which an RIA is applied, tools and procedures used within the assessment methodology may vary. As RIAs should include arguments for selecting specific intervention scenarios, the comparison between different scenarios may be supported through either cost-benefit or cost-effectiveness analysis. More information about efficiency assessment is available in the section on Road Safety Measures Efficiency Assessment Tools below. These values are usually available at the national level and periodically updated.

In the following the definition provided by Directive 2008/96/EC is adopted, and tools and procedures used for this aim will be considered.

Tools and data

The assessment of the impact of road safety measures on the road network requires the prediction of the expected average accident frequency for each road element of the road network potentially affected by a measure for a given time period (i.e. a period when the safety intervention will be realised). This can be obtained by using two types of tools:

- Accident Prediction Models (APMs) (also called Safety Performance Functions)
- Crash Modification Factors (CMFs) also known as Crash Modification Factors (CMFs) or, in term of percentage change in crash frequency, Crash Reduction Factors (CRFs).

If these tools or necessary data are not available, the assessment may involve opinions given by experts.

Accident Prediction Models

An Accident Prediction Model is a mathematical formula describing the relationship between the safety level of existing roads (e.g. numbers of accidents, injuries, fatalities etc.) and variables that explain this level (e.g. road length, width, traffic volume, etc.). An example of an APM (for road segments) is:

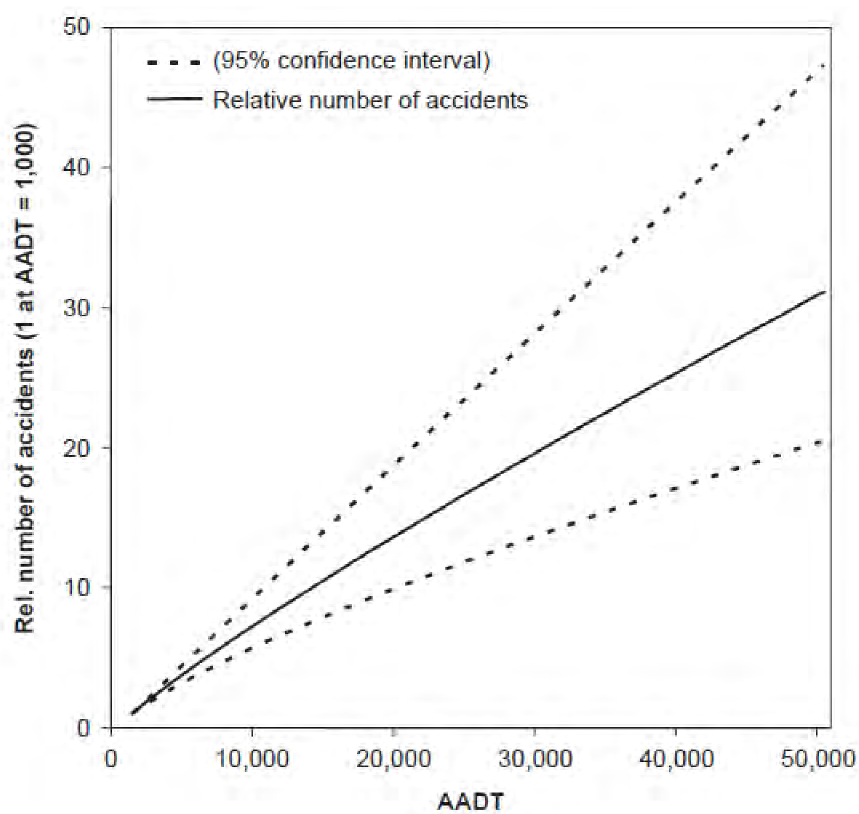
$$N = a \cdot (AADT)^b$$

Where:

- N is the predicted crash frequency over a given time period,
- AADT is the average annual daily traffic volume (vehicles per day) on segment, and
- a and b are calibration parameters.

Figure 2.2 shows on a diagram the estimated relationship between traffic volume and the relative number of road accidents on the basis of a large number of studies (Elvik et al., 2009), assuming one accident at 1 000 vehicles per day.

Figure 2.2. **Relationship between traffic volume (AADT) and the number of accidents, estimated by means of meta-analysis based on 28 studies**



Source: Elvik et al., 2009

The use of accident prediction models allows assessment of the impact on road safety not only in relation to the road elements directly affected by the intervention, but also on all the road elements of the network in which a change in traffic volume (i.e. AADT) is expected. APMs are developed through statistical regression modelling using historic accident data collected over a number of years at sites with similar roadway characteristics. In order to carry out an RIA, a “library” of APMs should be available from which one can identify and apply the most suitable model for each case encountered.

In literature, several APMs have been calibrated for different categories of road elements. However, the use of these functions is usually limited to the reality for which they have been calibrated. APMs developed for a road environment do not provide reliable accident estimates when applied out of the original context, e.g. in another country (Hills et al., 2002). This is because of existing differences in terms of traffic levels and mixture, road standards and road user behaviours.

If a library of APMs is needed, two paths may be followed. One is through the development of an ad hoc APMs library from scratch. The second option is by transferring existing APMs from literature. In the second case, an assessment of the transferability followed by a re-calibration process to suit local needs is needed. Currently, methods exist that may be used to achieve a satisfactory transfer of simple APM from one region to another – see AASHTO (2010) – and even between different countries, as shown by Cardoso et al. (2010).

The development of a library of APMs is a complex process as the reliability of the models is dependent on the quantity and quality of the data used to calibrate and validate the models. For the development of new models the two main steps required are the identification of the variables to be used in the model and the choice about the functional form to be taken for the model. The first step relates to the categories of models to be developed for groups of road elements with similar features (for example, an APM could be developed for roundabouts, rural T intersections, one-way road sections and so on) and the independent variables to be included in the model (e.g. traffic, presence of traffic lights, etc.). As a minimum, models must be developed for intersections and road sections. Regarding the second step, the issues to be covered are the type of function to be used (linear, generalized linear, logarithmic, etc.) and the calibration approach to estimate the model parameters.

Examples of APMs may be found in the *Highway Safety Manual* (AASHTO, 2010) and several research studies.

Crash Modification Factors

Crash Modification Factors (CMF) or Crash Reduction Factors (CRF) are simply different ways of expressing the effectiveness of an intervention. CRFs reflect the percentage reduction (or increase) in road accidents that can be expected after implementing a road safety measure. CMFs are the ratio of the accident frequency of a site under two different conditions: one indicating the presence of an intervention and the other a specified reference condition (all other conditions and site characteristics are assumed to remain constant). Under the reference conditions the value of a CMF is 1.0. A value less than 1.0 indicates a reduction in accident frequency in comparison to the base condition, while CMF values greater than 1.0 indicate an increase in accident frequency.

Several handbooks currently exist that report CRFs or CMFs for various categories of road safety measures. The estimation of these factors is based on evaluation studies, typically before-after observational studies or meta-analysis of studies carried out in several countries. However, the quality of these studies may be affected by poor and/or limited data, and poor evaluation methods used in their development (e.g. simple before-after studies of high risk sites). Therefore, the quality and transferability of CMFs, in term of confidence intervals, must be carefully evaluated before using them in an RIA.

In the prediction methodology proposed in the *Highway Safety Manual* (AASHTO, 2010), the accident frequency predicted by an APM for a site is used in combination with CMFs to account for the difference between site conditions and specified reference conditions. If no change in traffic is expected in the analysis period, or if the effects of the assessed intervention are localised only on the treated sites, CMF may be enough for the assessment.

Expert assessment

When neither APMs nor CMFs are available, the assessment may involve expert opinions. A group of experts with knowledge of the assessed road safety measure and the analysed road network may provide an opinion about the potential safety impact of the measures. Each expert may have a different opinion about the issue. The problem of aggregating different experts' opinions may be solved by applying, for example, the Analytic Hierarchy Process (AHP) method proposed by Saaty (1980). The aim is to develop a weighted average of scores assigned by each expert to each relevant safety aspect and intervention considered in a scenario analysed within an RIA.

Experts should critically take into account the findings of published and unpublished research relevant for the intervention, the conditions under which the measure is implemented and all potential factors that may affect, directly or indirectly, the analysed road network.

Data

Three types of data are needed to develop and apply APMs:

- Site characteristic variables such as the number of lanes, lane width, one-way streets and presence of footways
- Traffic flows on the road elements
- The number and severity of accidents observed on the network elements in a given time period
- Accident type may also be considered (in terms of collision pattern and road user involved), since the type of accident may provide information on possible problems of existing safety.

Depending on data availability, collection of additional data would be needed for the calibration or running of APMs.

Road safety prediction is mostly based on estimated and predicted traffic on the road network. Specific traffic simulation software is used to estimate the flow of traffic on a network in the considered scenarios. These tools are based on traffic modelling techniques, such as traffic assignment models, that from a certain demand for travel (usually expressed as a matrix identifying the number of trips between all possible origins and destinations) estimate traffic on the network by loading trips to the network itself. The end result is a map or a table containing the number and characteristics of flows observed on each road link in the network.

Common practices

RIAs are carried out through the analysis and the comparison of scenarios. A scenario is defined by a road network structured in a number of road elements (e.g. road intersections and road sections) with related features (e.g. area type, length and traffic regulation) and traffic volumes with reference to a specific year.

In general, the main steps required are:

- Definition of scenarios to be assessed (reference scenario and alternative scenarios)

- Road safety assessment of scenarios at a given time period
- Comparison of scenarios

The starting point is “scenario 0”, defined by the safety situation at the current year (year 0). The reference scenario (or the "do nothing" scenario) refers to the road network identified in the scenario 0 with associated the estimated transport demand variation for the year chosen for analysis. This reference year is usually chosen according to the year at which the all interventions considered in all scenarios will be realised.

An alternative scenario is defined through a variation from the reference scenario in terms of geometric design and traffic control features of specific road elements, and in terms of traffic volumes (e.g. Annual Average Daily Traffic, AADT). For example, alternative scenarios from a "do nothing" to a "do everything", where all planned interventions are expected to be realised, scenario may be taken into account.

The distribution of traffic volumes over the network is usually obtained through traffic impact analysis studies, used to predict future traffic levels at different road elements in the network and for different growth scenarios. Accident Prediction Models are then used to estimate the safety levels of roadway elements associated to each scenario. Therefore, before carrying out an RIA, a library of APMs should be developed and all data relevant to the estimation need to be collected. The reference scenario is then compared to the alternative scenarios thus enabling the assessment of the number of accidents and injuries prevented or increased resulting from the implementation of an alternative scenario. The results may be expressed into monetary terms by using values indicating the benefits of a prevented accident or injury.

In general, no specific certificate is required to perform a RIA.

Box 1 - Evaluating the safety performance of design alternatives in the United States

In the United States, the *Highway Safety Manual* proposes a predictive method used for evaluating and comparing the expected accident frequency of:

- existing facilities under current or future (forecast) traffic volumes;
- alternative designs for an existing facility under past or future traffic volumes;
- alternative designs for a new facility under future (forecast) traffic volumes;
- and the estimated effectiveness of countermeasures to an existing facility prior to implementation.

In the predictive method, a facility is divided into individual homogenous sites which consist of intersections and roadway segments. Separate APMs or Safety Performance Functions (SPFs) are provided for the roadway segments and specific intersection configurations for the various road types developed from accident information at several United States locations.

An SPF is based on specific, fixed geometric conditions that serve as a base case. For instance, the base conditions for a rural two-lane two-way segment are as follows:

- 3.65 m (12 feet) lane width
- 1.83m (6 feet) shoulder width
- Roadside Hazard Rating[2] (RHR) = 3
- Driveway density (DD) = 5 driveways/mile
- No horizontal curvature

- No vertical curvature
- Level grade
- No centerline rumble strips
- No passing lanes
- No two-way left-turn lanes
- No lighting
- No automated speed enforcement

To convert specific geometric design and traffic control features from the base condition to those at the study site, the value estimated by the model is multiplied by a Crash Modification Factor (CMF) developed exclusively for the same road type. The predictive model is calibrated to local geographic conditions through a calibration factor.

Using the base condition SPF prediction for road segments and multiplying by the local calibration factor (given) and the Crash Modification Factor for total accidents, the number of predicted accidents for one year is calculated.

An example of calculation is shown below for a 2.9 km (1.8 mile) road segment of two-lane, two-way rural highway with a 3.35 m (11 feet) lane width, an Annual Average Daily Traffic (AADT) of 1 800 vehicles/day and a local calibration factor of 0.9 (example taken from NCHRP Report 715).

Let N spf rs be the number of accidents estimated for the base conditions.

NSPF rs = AADT x Length x 365 x 10-6 x e(-0.312)

NSPF rs = 1 800 x 1.8 x 365 x 10-6 x e(-0.312) =0.865 accidents / year

Calculating the CMF for the 3.35 m lane width condition and an AADT = 1 800 vehicles/day results in a CMF value of approximately 1.05. The 1.05 value is applicable only to a subset of possible accidents referred to as "related accidents" (typically run-off-road accidents). This value can be proportionally adjusted if the analyst is estimating the total number of crashes. In this case, a value of 1.0287 was calculated.

N predicted rs = NSPF rs x C x CMF lane width

N predicted = 0.865 x 0.9 x 1.0287 = 0.80 accidents / year

To estimate total number of accidents based on specific crash severity levels, default percentiles are available in the HSM.

References

NCHRP Report 715, (2012), *Highway Safety Manual Training Materials*.

Road Safety Measures Efficiency Assessment Tools

Purpose	Compare different scenarios from road safety point of view and identify the most efficient measure from a list of potentially effective measures
When	Applied at the planning stage and before a major upgrading of the infrastructure
Where	The part of the road network potentially influenced by a measure
Data	Measures related, accident related

Efficiency Assessment Tools (EAT) can assist policy makers in identifying the most cost-effective road safety measures. Road safety policies based on well-performed efficiency analyses contribute to increase the number of preventable road casualties. (Elvik and Veisten, 2005).

Significant research over the past decades has focused on the identification of measures that are effective for specific situations. The results of such research are important for developing new measures and programmes for improving road safety. The resources available, however, are rarely sufficient for implementing all potentially effective measures. Therefore, a decision must be made about which measures to implement. This decision needs to take account of the nature of the particular road safety problem being addressed, the range of potential measures available, the resources available, and the potential physical or political constraints.

Each measure considered appropriate to address the particular problem is assessed in turn, taking account of its predicted effects (including intended benefits such as casualty reductions but also potential drawbacks such as increased pollution or greater travel time), its possible variation of effects with the passage of time, and the costs of implementation. In the final stage of the assessment process, the benefits and costs of the alternative measures are compared. The alternatives are then ranked according to the ratio of benefits to costs, and the most highly ranked effective measure can be selected. This selection offers the highest overall level of benefit relative to the costs of implementation, and ensures that the available resources are used in the most effective manner (ROSEBUD, 2006b).

In the case of larger-scale measures, efficiency assessment can play an important part in developing the measure. Planning often takes many months if not years, and during this time information can be refined or new options can become available. Once the basic assessment framework has been established, the calculations can be readily updated and the implications assessed. The use of such a structured decision making process has several advantages:

- It is transparent: this is likely to increase public acceptance since the various stages in the process are documented and can be defended against criticism.
- It is comprehensive: all effects that may be predicted are brought together in a single framework.
- It is in accordance with the principles adopted by national governments to ensure the best use of public money.
- The assessments can incorporate the best available knowledge about the effects of road safety measures.
- The assessments incorporate public preferences: they include, for example, the results of surveys which have investigated the public's willingness to pay for improved road safety.

Tools and data

Generally, appropriate data and statistical evaluation methodologies, together with systematic procedures and exchange of assessment results, are considered prerequisites for decision makers to be able to make effective decisions (Hasson et al, 2012).

There are two main categories of efficiency assessment tools: cost-benefit analyses (CBA) and cost-effectiveness analysis (CEA). CEA relates to given road safety targets or road safety budgets and ranks measures according to lowest monetary costs. It is a method for estimating the monetary cost of e.g. one life saved, as a result of a given road safety measure. CBA involves monetary assessment of both costs and benefits of a measure. CBA enables efficiency assessment of both road safety measures and infrastructure investments in which road safety competes with other goals, such as mobility and environment (Elvik and Veisten, 2005). An undesired consequence of the discrepancy between CBA and CEA is that measures which are internationally regarded as cost-effective as well as best practices may in some countries appear as having greater costs than benefits. Two possible ways of handling this are by revising the monetary valuation of accidents and by favouring cost-effectiveness analysis, instead of cost-benefit analysis (Hasson et al, 2012).

The knowledge and data elements which are required in order to perform an efficiency assessment (CBA/ CEA) of a safety-related measure are the following:

- Safety effects: The major source of knowledge on safety effects is evaluation studies of past treatments. The most common form of a safety effect is the percentage reduction of road accidents following the treatment (sometimes called the crash reduction factor). The quality of the efficiency assessment of a safety measure (i.e. a prediction of the crash reduction likely to be attained) depends on the quality of the available values of safety effect.

- Number of road accidents affected by the measures: The number of road accidents affected by a measure multiplied by the value of the safety effect provides for the number of road accidents likely to be prevented by the measure.

- Existing road accident databases: One of the problems which complicate decision making at the international level is an absence of relevant international data on road accidents and traffic.

- Implementation costs of measures: The implementation costs are the social costs of all means of production (labour and capital) that are employed to implement the measure. The implementation costs are generally estimated on an individual basis for each investment project. As for road investment costs, the average cost rates to be used in master plans are measured per junction or per kilometre of road. Road maintenance costs are measured per kilometre of road per year. The typical values of costs are required to perform a CBA/CEA, especially at the preliminary evaluation stage. However, these values are usually not published, which increases the uncertainty of the evaluation results. For efficiency assessment of safety measures at different spatial levels (national, regional, local), there is great interest in implementation costs applied to relevant conditions.

- Side-effects: Road safety measures can produce three kinds of effects: safety, mobility and environmental. The mobility effects comprise changes in travel time and vehicle maintenance expenses. Furthermore, as many road safety measures affect the amount and/or speed of travel, they may also have impacts on emissions and noise.

Figure 2.3. **Categorisation of impacts for use in cost-benefit analyses**

Main impact	Subcategories	Vehicle type, road user etc	Unit of valuation
SAFETY	Road Crashes	All (estimated real cases of injury)	Fatality
			Serious injury
			Slight injury
			Property damage
MOBILITY	Travel time	Pedestrian	Person/hour
		Cyclist	Person/hour
		Car occupant	Person/hour
		Bus passenger	Person/hour
TRAVEL COST	Vehicle Operating Cost	Car	Km/travel
		Single truck	Km/travel
		Truck/trailer	Km/travel
		Bus	Km/travel
ENVIRONMENT	Traffic noise	Small cars	Km/travel
		Heavy cars	Km/travel
	Air pollution	CO	Kg of CO
		NO_x	Kg of NO_x
		VOC	Kg of VOC
		SO_2	Kg of SO_2
		PM_{10}	Kg of PM_{10}
	Global warming	CO_2	1000 kg of CO_2

Source: Elvik and Veisten, 2005

Common practices

Efficiency assessment of road safety measures requires specialised analysis. Specifically, the steps that need to be taken for an accurate assessment include (Yannis, 2010): measuring the implementation, measuring changes in road safety performance, linking measures with road safety performances and establishing good practices and setting priorities

Several barriers have been identified that may prevent either the use of efficiency assessment tools in road safety policy or the implementation of the priorities indicated by efficiency assessment tools. There is a general impression that barriers are usually stronger against CBA than against CEA. However, some barriers are common for both methods (Elvik and Veisten, 2005).

The barriers may involve a fundamental rejection of the principles of efficiency assessment tools or be related to institutional settings, e.g. existing laws, directives or traditions ruling out the use of efficiency assessment tools in decision-making regarding road safety. Furthermore, barriers may be related to technical or methodological aspects of efficiency assessment tools (Elvik and Veisten, 2005). Such barriers concern difficulties in isolating the safety effect of a specific measure; difficulties in aggregating information/data due to high diversification of the measures; and difficulties in comparing information/data between countries (e.g. differences in road traffic environments, differences in the actual investment costs among the countries and differences in methodologies of safety effect calculation) (Yannis, 2010).

Finally, some barriers may be related to the implementation of policies; even if priorities based on efficiency assessment tools are set from earlier stages of the decision-making process these may be partly or fully set aside when the final decisions are made (Elvik and Veisten, 2005). In addition, authorities and other stakeholders may fear that evaluation of measures could prove that important road safety investments had little impact. Moreover, comparisons of the effectiveness of measures between different regions or countries may reveal high discrepancies not only in the unit cost of measures but also in the implementation effort (Yannis, 2010).

Usually, no specific certificate is required to perform EATs.

Road Safety Audit

Purpose	Identify infrastructure or traffic related factors increasing injury or accident risk
When	Undertaken during planning, design, construction, pre-opening and early operation stages
Where	A designed road infrastructure
Data	Roadway related, measures related

A Road Safety Audit (RSA) is commonly defined as a safety check of an infrastructure project, be it a new (section of) road or an intersection, or a substantial modification to the existing network. An RSA is a formal, detailed and systematic process that is to be carried out by an independent and well-trained auditor (or team of auditors). It is imperative that the auditor is independent both from the contracting entity and from the designer of the road scheme.

The result of the RSA is an audit report which reflects on (and is restricted to) the project's potential road safety deficiencies for all road user classes, and provides a detailed list of required enhancements to the project. Experience shows that even when a design has taken full account of all available safety-relevant guidelines of a country, issues are usually identified in an RSA that would have led to a) occurrence of accidents and b) to high costs for treatment if they were fixed only after the opening of the respective section, rather than during construction. Performing RSAs aims to ensure all roads operate with high safety standards, minimising potential road safety deficiencies and avoiding the costs of correcting defective infrastructure.

RSAs are commonly applied to the following various stages of a road project:

- Feasibility stage (before a decision on the definitive routing; interface with RIA)
- Preliminary design (before land acquisition)
- Detailed design (before construction starts)
- Pre-opening (after construction is completed), and
- Early operation (first RSI)

In response to an audit report, the contracting body is required to rectify the identified safety issues or – if unfeasible – to explain the reasons for not doing so in a written response to the report. Only then can the next design stage be entered.

It is not straightforward to assess the safety benefits of an RSA, as classical before-and-after analysis cannot be carried out (since in most audit stages the "before" situation is available in technical drawings only). However, it is possible, for instance, to conduct post hoc audits of newly built, non-audited roads and to estimate the accident reductions that would have resulted from implementing the auditor's recommendations. Such evaluations have shown positive cost-benefit-ratios, ranging from 1.34:1 ("acceptable") to 99:1 ("excellent") (ROSEBUD, 2006a).

The costs of an RSA is normally in the range of less than 5% of the construction costs, and the audit processes are usually not reported to cause significant delays in the work schedule of a scheme. The rates of acceptance of the auditor's recommendations are usually significantly above 50%, and they are higher when carried out in the first audit phases (feasibility, pre-design).

Typical design deficiencies on motorways concentrate on alignment (poor combinations of horizontal and vertical alignment), missing or inadequate road restraints and defective intersection schemes. On rural roads and urban thoroughfares suboptimal signing and marking as well as poor design of cross-sections also come into play.

Tools and data

Detailed checklists have been prepared for different audit phases and road classes by numerous national and international organisations (e.g. by PIARC, see Figure 2.4). They are organised along typical safety-relevant dimensions such as the function of the road, cross section, alignment, intersection design, road restraints, traffic signals, service or resting areas, (access to) public transport, signing, marking and lighting. It is advisable to adapt checklists to specific safety problems and requirements of a country; and not to use these compendia only as tick lists but rather to provide clear and detailed advice to the designer on how to implement improvements to a scheme's safety issues.

Figure 2.4. **Example of a Road Safety Assessment Checklist**

Characteristics	No	Question	Yes / No	Comments
3. Alignment	1	Is the alignment consistent/ coherent?		
	2	Have suitable allowances been made for drainage requirements when planning horizontal and vertical alignments?		
	3	Are horizontal and vertical alignments coordinated?		
	4	Have the design elements been selected to effectively prevent "hidden-dips"?		
	5	Have continuity principles been taken into consideration?		
	6	Have steps been taken to prevent minimum design values for horizontal and vertical alignment elements occurring together?		
	7	Are the curves in lanes and carriageways wide enough?		
	8	Is sight obstructed, for example by safety barriers, plants, fences, traffic signs, landscaping and bridge abutments, etc.?		

Source: PIARC RSA "preliminary design / motorways"

Common practices

Audits should be carried out by well-trained and accredited traffic engineers with at least five years' experience in safety engineering and/or accident investigation. Training, accreditation and further education of auditors should be carried out by an independent institute ("Audit Centre"). It is worth noting that the independence of the auditor team performing the RSA is crucial.

The RSA process is usually carried out in three steps: commissioning, execution, and finalisation. In the European Union (EU), commissioning for an RSA lot is usually initiated by a tender of the contracting (road) authority. Care is to be taken that the bidder provides experience for the type of road scheme, road class and types of road users as well as the specific technicalities the project embraces. The contractor will receive all information required for carrying out the audit, such as all relevant scheme drawings, projected traffic flows and composition, any previous audit reports and – in case of a reconstruction scheme – all available previous traffic, accident and inspection data. Convening a meeting between the designer (or design team) and the auditor (or audit team) before the start of the actual audit is recommended, in order to assure mutual understanding on all issues related to the project, so that the process is not delayed by avoidable glitches in communication.

The execution of the audit usually commences with a thorough analysis of the available information and drawings. Depending on the stage of the audit, site visits are then carried out to improve the understanding and the adequacy of the scheme. In this phase, the use of checklists together with the expert judgement of the auditor will ensure that no safety issues are overlooked (see Figure 2.4). The findings of an audit are then compiled in a detailed audit report, which is to be delivered to the contracting entity. The core of the report is a table that lists all deficiencies identified, together with the exact location (and length) of the issue, the type of deficiency, the safety problem it may cause, and a concrete recommendation for remedial action. Generally, care should be taken to make the report as straightforward as possible in order to avoid misunderstandings and delays (e.g. by identifying and visualising the problems in pictures or drawings).

The core of the finalisation phase is the written response to the audit report by the contracting entity. This formal response may be preceded by a meeting with auditor(s) and designer(s) where open issues can be clarified and potential solutions discussed. The client's report is the key prerequisite to entering the next stages of the project. Where the client rejected audit issues, monitoring after opening to traffic should identify whether safety issues subsequently arise.

Usually, a certificate of competence is required to perform a RSA.

Network Operation

Purpose	Maintain the current level of safety of roads
When	Undertaken during normal operation of a road and during maintenance
Where	No specific road category, however some practices are difficult to be performed on an urban network. Generally part or an entire road network managed by a road administration
Data	Roadway related, traffic related

Once the road is built and open to traffic it is essential that an appropriate level of safety be maintained. Network Operation (NO) manages this need. Ideally Major Project Teams hand over the "maintenance and operation guide" for the new road to Operation Teams.

Road safety is a smart balance between the road that was designed, the way it currently is, the condition of the vehicles and their numbers, the education of the drivers and how they behave in the environment they face. Low- and middle-income countries first face the challenge to build roads up to suitable standards and make sure they are good enough to be opened. Although they may manage to prioritise and get grants for this, it is usually then up to them to maintain the asset. The new road must be reasonably cheap to maintain (a reasonable number of lanes compared to the expected traffic, with reservations ultimately to widen the carriageway if necessary) otherwise it will deteriorate quickly.

A common problem is that, when short of money, a road maintenance team will focus on road renewal problems and let the infrastructure and equipment associated with highways become derelict. But these are essential for road safety. The worst-case scenario is, for example, to have a brand new road layer which favours speeding alongside defective safety fences. At least when a road is in poor condition (e.g. full of potholes) drivers are unable to travel very quickly and will therefore be less likely to injure themselves badly.

Tools and data

NO is mainly based on information about events that may increase the risk level on the road network. These events can be scheduled or unscheduled (e.g. a road accident). Scheduled events are programmed by the road operator, while information about unscheduled events may come from road users, local authorities and emergency services for instance. For each event a triggered procedure is put into effect.

Common practices

Maintaining a road to keep it fit for purpose

In order to maintain a road a maintenance schedule should be designed according to the characteristics of the road and its environment. However, careful ranking of the network is required to prioritise the use of resources (workforce and budgets) against essential features versus those considered “nice to have”. This ranking will usually depend from how important each road is to the economy (traffic counts, links between main cities). Two methods of organisation are possible: sometimes maintenance teams define how often renewals of the various elements of the asset are to be carried out (road markings, road surface, safety fence, signs, lamp columns) but more often they plan regular assessments of the various elements by type and prioritise accordingly.

A minimum annual maintenance is key to road safety, and must include:

- Grass cutting in order to ensure the appropriate road width when two vehicles pass by each other, but also to ensure visibility along bends, summits or road crossings.
- Ditch and gully maintenance to keep the road clear of flooding
- Cutting branches near signs

Operating a road on a daily basis

It is very important to remember that a road open to traffic is a living environment. Its condition can change very quickly from the desired state to a dangerous one due to external factors (weather events, animals, cliff failure, vandalism), the type of traffic (slow moving vehicle, congestion) or planned or unplanned road works: obstacles on road, suspected failure or deteriorated carriageway or road equipment, lack of visibility, etc.

Maintaining road safety in the face of events like these, first means informing drivers of the current condition of the road so that they can change their behaviour and adapt to the current environment. Thereafter, the road must be returned to its desired condition as soon as possible.

The first element is based on gathering information and communicating about the event. It must be determined who will provide the information, to whom and how. For example, hot line number to the road operator can be used to seek feedback from road users, local authorities and emergency services. Alternatively, on-road patrols can be organised on a regular basis to spot defects coming up and include the remedial operations in the maintenance agenda. The frequency will depend on the importance of the network (for example, once or twice a day on a motorway might become once a month on the local network).

Once an event occurs it must also be communicated to drivers, either on the road (using specific signing) or through communication media. This requires organising teams on-call or re-organising the work plans for road operatives during working days. The service level for the response (time and quality) will usually depend on the importance of the road; the service level should be planned and organise the spread of on-call teams accordingly.

The second element, returning the road to normal, will generally be included within the task force planned interventions. If the disruption caused by the event is great (road closure as a result of a cliff failure for instance or a major hole in the carriageway) then remedial works must be planned and delivered as a matter of urgency and may be done out of hours. There is a balance to be found between planned maintenance (which will reduce the number of events related to the road and its equipment) and quick interventions, as these will disrupt the already planned maintenance works.

Accident management

Various roles are involved in accident management. Which stakeholders take charge of each role depends on the country organisation. The roles are:

- Informing: Getting the information on the accident to relevant stakeholders (police forces, emergency services, road operator) with accuracy (location and direction of road traffic, type and number of vehicles and people involved, severity, road damage and remaining risks).

- Dealing with road traffic: both in control room and on site (road operator or police forces). The first goal is to protect the current victims and prevent further accidents on the site. The second goal is to keep the traffic flowing, sometimes through diversion routes.

- Dealing with the victims: emergency services will need time to get to the accident, the provision of a safe working zone on site to use their equipment to the utmost efficiency, and time to get the victims to hospital.

- Gathering on-site information: when the accident is very serious information will need to be gathered, to prepare for an enquiry. Police forces can require a lot of time on site to gather detailed information, which may require road closures.

- Hospital treatment: identification of the right care for patients. It is key to route patients according to the type of injuries. If they are not too serious, local hospitals will be able to treat them and patients do not have to be transported far away. If they have more serious injuries, the requirement for specialised care will mean a transfer to an appropriate trauma hospital. The right selection process will lead the right workload for either type of hospital.

- Returning the carriageway to normal: removing the damaged vehicles (on-call vehicle rescue team), fixing road damages (safety fence, road surface), re-opening to traffic.

Speed of communication is essential for a smooth operation of the above steps. Quickly getting the right information about the accident location and accident type allows the appropriate stakeholders to get to the site as soon as possible. This ensures smooth dealing with the victims and prevents further accidents. This fast communication can be done through a clear hot line system, marker posts on the road and stakeholders' joint procedure. It is also essential that the spread of on-call teams for all stakeholders is designed in accordance with the intervention service levels that were agreed, according to the road's importance.

Further key requirements are, a good knowledge of hospital locations, the availability of appropriate vehicles types to the emergency services, traffic management and the fast repair of road damages.

Road Safety Performance Indicators

Purpose	Assess the safety of a road network
When	To help monitor safety performance of the existing road network during normal operation of the infrastructure
Where	Usually performed on a rural and motorway road network
Data	Roadway related, traffic related

Road Safety Performance Indicators (SPIs) are the measures (indicators), reflecting those operational conditions of the road traffic system that influence the system's safety performance (Hakkert et al., 2007). The purpose of SPIs is to: reflect the current safety conditions of a road traffic system; measure the influence of various safety interventions; and enable comparisons between different road traffic systems (e.g. countries, regions, etc.).

According to Hakkert et al. (2007), SPIs are developed for a certain safety domain (e.g. user behaviour, active vehicle safety, road infrastructure) where they should reflect the factors contributing to road accidents/injuries and characterize the scope of the problem identified. Therefore, SPIs might provide a means for monitoring the effectiveness of implemented safety measures. SPIs can give a more complete picture of the level of road safety and can point to the emergence of developing problems at an early stage, before these problems show up in the form of accidents.

In general, the safety of a road transport system strongly depends on the layout and design of the road infrastructure. As highlighted in ETSC (2001), the road network influences the probability of accident occurrence and can help determine the level of injury severity because it determines the conditions under which road users meet. A network with a hierarchy of roads, in which the function of each road is clearly defined, is the preferred situation. Road design should match the function of a road, to enable road users to recognise it immediately and to clarify the expected behaviour of the road users.

According to this, SPIs for road infrastructure aim to assess the safety hazards related to road infrastructure at two levels: the road network level (the right road should be located at the right place from a functional point of view) and road design level (individual roads should be designed in a safe way).

Various road SPIs have been proposed (ETSC**Error! Bookmark not defined.**, 2001), but international comparison is difficult because of differences in road categorisation, safety policy and standards. At the moment there are no consolidated SPIs for road networks. Existing SPIs are concerned almost exclusively with road design. An attempt to propose internationally comparable road SPIs has been promoted within the European research project SafetyNet, specifically with the following two SPIs:

- Road network SPI: This aims to measure whether the right road is in the right location. It is expressed as the percentage of appropriate actual road category length per road category. The traffic demand determines the type of road required. The SPI then measures to what extent the actual roads in a network are appropriate, given the theoretically required roads. This enables a road authority to assess the extent to which a connection complies with the existing demands.

- Road design SPI: This may target a specific design aspect (e.g. percentage of kilometres of roads not protected by traffic barriers per road category) or be comprehensive depending on a number of road characteristics per road category. For example, the European Road Assessment Programme (EuroRAP) developed the Road Protection Score (RPS), a measure used to rate the safety level of a road infrastructure based on road characteristics (see the section on RAPs). The road design SPI may be expressed, for example, as the percentage of road length above a defined safety level threshold per road category.

These SPIs are generally proposed for interurban road networks (e.g. country level road networks), even if these concepts may also be transferred to an urban road network.

Tools and data

Tools and information needed to calculate the road design SPI may vary a lot and are especially dependant on the number of aspects investigated. Road design SPI requires the knowledge of a number of specific data related to each road section of defined length belonging to the road network (or to a representative sample of roads).

A Dutch case-study (available in Hakkert and Gitelman, 2007), demonstrated the possibility of calculating the road design SPI for the road network once the EuroRAP Road Protection Scores (RPS) are available for each road section. If the EuroRAP RPS is used, the information necessary to calculate the road design SPI are related to: EuroRAP Road Protection Score (RPS) per road segment or route, road length and road category per road segment or route of the network.

In New Zealand, Road Infrastructure Safety Assessment (RISA) is used to monitor the safety performance of road authorities (Appleton, 2009). This approach monitors the safety performance of road sections in terms of cross section, alignment, surface, and shows how to average risk of individual road sections to calculate an overall risk of the road network, which comprises different types of roads based on the sampling. For an overview of data and tools needed for the calculation of the EuroRAP RPS scores per road category the reader may refer to the section on RAPs earlier in this chapter.

As highlighted before, the purpose of a road network SPI is to determine whether two centres are connected by an appropriate road. The method proposed within the SafetyNet project and further improved by a recent research study (Yannis et al., 2013) to be used for international comparison, defined the road network SPI as the percentage of appropriate actual road category length per road category.

In order to calculate the road network SPI the following information is needed: a map showing urban areas and inter-urban roads that connect the urban areas, and road categories of actual roads and road lengths. These are required in order to determine the required road categories for the connections between the urban centres and calculate the percentage of actual roads that are of an appropriate category.

For the purposes of international comparison, an internationally harmonised road categorisation should be used. A six categories functional road classification, AAA-C, of rural roads and motorways has been proposed in the SafetyNet project (Hakkert et al. 2007). The classification is based on the following aspects: functional road category (i.e. through road, distributor or access road), separation of opposing directions, lane configuration, obstacle free zone width and type of intersections. These road types are assigned to connections between different combinations of centre sizes.

Furthermore, the actual traffic volume between centres is required to define the theoretically required road category. This can be derived from the estimation of traffic demand between urban areas. Due to the lack of traffic demand data, it is assumed that the number of inhabitants determines the traffic demand between those centres (Yannis et al., 2013). However, there are many factors affecting traffic demand between two centres (e.g. population, business, industry, tourism, culture) and the method can be enhanced with other information such as industrial areas, shopping areas and recreational sites.

Of course, it is better to have all this information digitised in order to manage it with appropriate software. A geographic database representing the road network and the urban areas is useful in order to manage roadway related information. In addition, a Geographical Information System (GIS) application may help in performing some calculation, e.g. the identification of the shortest or fastest route between two centres.

Common practices

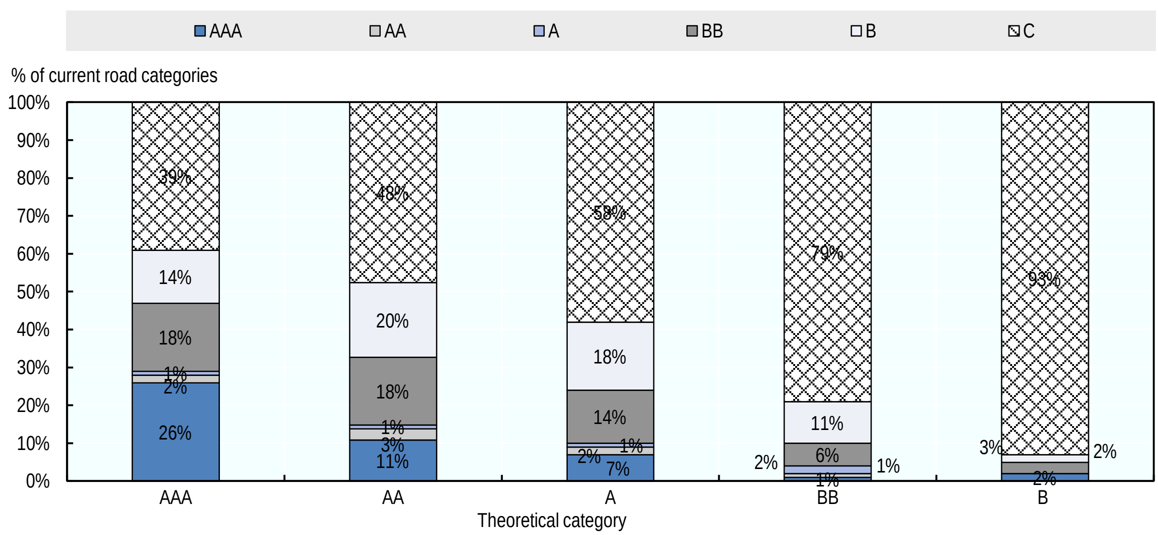
The road design SPI determines the level of safety of the existing roads. As highlighted in the previous chapter, the input for the road design SPI could be the EuroRAP Road Protection Score (RPS) expressed as one to four stars. To obtain an SPI score, the RPS needs to be calculated for each kilometre of network and then converted to a score for each road category (e.g. the six road categories proposed in SafetyNet). For each category, the distribution of the total length over the four star levels is determined.

The road design SPI is the distribution of stars (1-4) per road category (AAA-C). As an example: If there were 10 km of category B roads, with 4 km having 3 stars and 6 km 2 stars, the distribution for road category B would be: 4 stars: 0%, 3 stars: 40%, 2 stars: 60% and 1 star: 0%. Thus, using this method, connections between cities are assessed by comparing the theoretical road categories with the actual road categories.

First, the list of connections that need to be assessed has to be determined. To determine which urban areas or centres should be connected to each other in a given region or country, a method called “circular search areas” can be used, in line with hierarchical graph theory (more information is provided in Yannis et al., 2013). For all identified connections, the road categories they are composed of and the theoretically required road categories between centres need to be determined. Theoretical and actual connections are then matched before calculating the SPI. This step may be quite demanding as, for example, one actual road may serve more than one theoretical connection, or a theoretical connection may not be available at all.

Once the theoretically required road categories for each connection are determined, and the data concerning the length and category of the actual connections are available, the SPI can be calculated. This is made by comparing the theoretically desired and the actual road category and by aggregating the scores for each road category. In this way, for each theoretically required road category, the percentage of actual roads that meets the requirements can be calculated. Figure 2.5 shows for each theoretical road category the distribution of the current road categories in the case study area.

Figure 2.5. **Percentage of road length of appropriate category Case study area.**



Source: Hakkert and Gitelman, 2007

Usually, no specific certificate is required to monitor SPIs.

Network Safety Ranking

Purpose	Rank elements of a road network based on their safety level
When	Generally undertaken during normal operation of the road network
Where	Generally part or an entire road network managed by a road administration
Data	Roadway related, accident related

Network Safety Ranking (NSR) is a systematic road safety ranking and management approach at the level of road networks. According to the EU Directive on Road Infrastructure Safety Management (2008/96/EC) "network safety ranking" means a method for identifying, analysing and classifying parts of the existing road network according to their potential for safety development and accident cost savings."

In times of usually limited safety budgets of road administrations, NSR provides a useful means to identify and rank those sections of the network where investments will bear the highest potential for accident cost reductions. Typically, the bulk of the road death and injury toll occurs on a minor part of a network.

NSR is solely based on the analysis of accidents that have occurred on the network in the past. NSR does usually not involve site visits, video analysis or in-depth analysis. Rather it provides the basis for the decision of which further measures (such as RSI or treatment of high-risk sites) would be appropriate for a specific (set of) problematic road section(s).

Tools and data

Typically, NSR only applies to an existing road network where accident data of certain quality have been available for several years. It is advisable to make use of a Geographic Information System (GIS) and to map all accidents along the road sections in question. The mapping operation requires good quality accident location information from police records. Exposure data including traffic volumes and share of pedestrians, cyclists, motorcyclists and heavy goods vehicles are needed to calculate risk levels for different road users. Road specific data including number of lanes, presence of median, guardrails, and rumble strips as well as speed limits etc. can then be associated with accident and exposure data in order to derive risk levels for various road design and operation features.

A core issue in NSR is the classification of road sections, junctions or ramps for analysis. The general segmentation within a network needs to be carefully designed in order to address safety issues on sections with homogenous characteristics in geometric design, operation, road users, and adjacent environment. Guidance on the desirable length of a road section is not definitive. For matters of manageability, NSR usually divides a road network into road sections of several kilometres (usually less than ten). If section lengths are too short, accident frequencies may show great fluctuation from year to year; if it is too long, the risk values may not represent the spatial distribution of risk adequately for that road section. EuroRAP uses road sections of 20 km with 20 deaths or serious injuries in three years as a reference (www.eurorap.org), but these values need to be adapted according to the spatial requirements in specific countries.

Road sections usually include junctions; and accidents are more likely to occur on junctions than on other parts of roads. Therefore junction density along a stretch of road needs to be taken into account, as well as the density of access roads, such as to private property. Another option, which is also applied in the identification of high-risk sites (black spots), is to analyse road sections and (major) junctions separately.

Various rates and indicators can be used to monitor, analyse and prioritise the risk of road sections on a network level. Typical examples are the number of accidents per kilometre, number of accidents per traffic volume, potential accident savings, accident cost rates, accident risk by road types, equivalent accident number (Equivalent Property Damage Only), and expected average accident frequency with empirical Bayes adjustment (Lynam 2012; ASSHTO, 2010). The decision on which safety performance indicator to use needs to be made in accordance with the availability of the required data. Some rates require fairly sophisticated data, while others can be evaluated with casual data available in most road authorities.

Common practices

Whereas the management of high-risk sites (often called Black Spot Management) is limited to a scope of some hundreds of metres of road sections, or single junctions, NSR typically focuses on parts of the whole network under the jurisdiction of a road authority. It can cover from some hundreds to several thousands of kilometres of roads.

EU Directive 2008/96/EC requires all EU Member States to apply NSR on the Trans-European Road Network (TERN), i.e. to carry out network safety rankings at least every three years and to send expert teams to the site in order to examine remedial treatments (Article 5).

In 2003, the German road and transportation research association issued the ESN (*Empfehlungen für die Sicherheitsanalyse von Straßennetzen*; or "Recommendations for the safety analysis of road networks") and France launched the SURE ("User Safety on the Existing Road Network") process in 2004. The German ESN provides a method to calculate safety potentials for road sections based on costs of various accident types. It also gives some details of how to determine segments or road sections for analysis as well as how to integrate traffic volumes in different sub-sections in a road section. ESN has been applied for both trunk road networks with a national scope and residential road networks at a city level. Whereas the German ESN only recommends a principle for calculation and prioritisation, the SURE method also includes further steps (definition, implementation and evaluation of countermeasures).

The French SURE also ranks road sections according to their potential savings in accident costs and was first applied on 15 pilot routes on the French national road network in 2005. Later it was expanded to 40 routes by 2008. Some EUR 20 million was provided to implement road safety measures (Ganneau and Lemke, 2008). Some technical guidelines for SURE have been summarised by Setra (2006). SURE became mandatory for the national road network in 2014.

Figure 2.6. **Distribution of safety potentials over Germany's motorway network**

Source: Ganneau and Lemke, 2008

In the United States, NSR has recently been applied for "network screening". The *Highway Safety Manual* (2010) provides detailed procedures and methodologies and is, in particular, linked with a computer software tool called SafetyAnalyst (www.safetyanalyst.org). Module 1 of SafetyAnalyst is dedicated to support the application of network screening (FHWA, 2010).

NSR should start from the definition of its main objectives. This can be the identification and treatment of either hazardous sections in general, sections highly prone to certain types of accidents (such as run-off accidents), or sections requiring particular safety measures (e.g. application of median barriers). In a second step, the scope of the network should be determined. Analysis can cover all roads within the jurisdiction of a road authority or only certain types of roads that satisfy specific criteria, e.g. rural single carriageway roads with more than two lanes. Then roads are segmented according to the above general principles.

Depending on the desired safety performance measure, rates or indicators can consecutively be calculated (such as risk levels, accident cost rates and potential accident savings). The *Highway Safety Manual* (AASHTO, 2010) guides how to represent safety levels of a certain road section in three different methods; sliding window method, peak searching method and simple ranking. The first two methods are useful to incorporate variations of risk levels over a road section. The simple ranking method does not consider variations, but uses the average over the whole segment. The priority of road sections can be decided according to the values of safety performance measures evaluated.

Likewise, RISMET (Schemers, 2011) devised a 'Network Screening' method to assess the crash reduction potential of locations in a road network and, based on remedial measures, to prioritise these from locations with the highest to the lowest crash reduction potential.

Usually, no specific certificate is required to perform NSR.

Road Assessment Programme

Purpose	Rank elements of a road network based on road safety and identify infrastructure or traffic related factors increasing injury or accident risk
When	Generally undertaken for identification and correction of errors on the road infrastructure.
Where	Usually applied to a part or an entire rural/motorway network.
Data	Roadway related, traffic related

A Road Assessment Programme (RAP) operates by measuring and raising awareness of risk, encouraging good practice and promoting the innovative implementation of road infrastructure measures known to reduce fatal and serious collisions. An RAP not only concentrates on dangerous roads, where people are dying in large numbers, but also provides a framework to generally upgrade the safety performance of road networks.

The peculiarity of an RAP is the underpinning method used to assign a score to a road section with the aim of identifying those road sections in a network with safety related infrastructure deficiencies. It can be viewed as a form of network screening but it is not only based on road accidents. An RAP can be developed when a screening of the network based on observed accidents is not feasible because it may be affected by the quality or the availability of sufficient accident data. In these cases, alternative methods need to be used. An RAP is based mainly on road infrastructures data and requires site visits and/or photo/video recording.

RAPs are commonly applied on existing roads, both for safety performance monitoring purpose and the identification of infrastructure related risk factors. Existing methods are calibrated to rural and motorway road networks; RAPs are rarely applied to more complex conditions such those that can be found on urban roads. Results from the assessment can be used to support the definition of appropriate road safety measures to be implemented.

Several examples of safety rating systems have been developed in Europe and elsewhere (Cafiso et al., 2007; Perandones and Ramos, 2008; Appleton, 2009), however the best-known system is the international Road Assessment Programme, iRAP, based on the EuroRAP, the European Road Assessment Programme. This approach is described in the following section.

Tools and data

RAPs are based on four standardised protocols that together provide consistent safety ratings of roads across borders. Nationally, they enable the identification of the most dangerous roads, tracking performance over time, and therefore where action is appropriate. Internationally, they enable comparisons of risk within and between countries. Standard protocols for iRAP are[3]:

- Risk Mapping: based on real crash and traffic data, colour-coded maps show a road's safety performance by measuring and mapping the rate at which people are killed or seriously injured. Different maps can be produced depending on the target audience.

- Performance Tracking: identifies whether fewer people are being killed or seriously injured on individual routes or road networks over time, and importantly, through consultation with road authorities, identifies the countermeasures that are most effective.

- Star Rating: using drive-through inspections of routes in specially equipped vehicles. Ratings show the likelihood of a crash occurring and how well the road would protect against death or serious injury in the event of a crash.

- Safer Roads Investment Plans: Following road inspections and coding, in addition to detailed reporting, a Safer Roads Investment Plan can be developed, considering over 70 proven road improvement options.

Common practices

Defining road sections and other criteria

Rules are established to define road sections and to assure comparability among them. A typical road section is about 20 kilometres long with 20 or so deaths or serious injuries over three years. However, this target can be modified as necessary to ensure that roads selected are meaningful and distinct to road users (for example, start and end at identifiable locations), have broadly similar characteristics along their entire length (such as single lane or dual carriageway) and more or less the same level of traffic. Short sections of road (e.g. link roads of less than 5 km), roads with low numbers of crashes (e.g. fewer than seven per three years), or roads with low traffic volumes (e.g. fewer than 2000 vehicles per day) are more likely than others to experience greater year-to-year variation in accident rates. They are therefore also more likely to change risk rating from one period to another. In some cases it is preferable to exclude these links from the analysis.

Frontal accidents, side impact at junctions, run-off and collisions involving vulnerable road users (pedestrian and cyclists) are taken into account, with the aim of identifying ways in which upgrading the infrastructure can reduce the likelihood or severity of accidents.

Data standardisation

RAP protocols can be applied in each country, but benchmarking is important – i.e. identifying and understanding differences in crash risk between countries. RAP Road Risk Mapping within the country may be published using non-adjusted figures, but where results are compared between countries, an adjustment is required, with a clear notation that this is the case.

A standardisation method has been developed to "normalise" the raw data. This is achieved by calculating the ratios for each country between the number of fatal and the number of fatal and serious accidents (or all injury, where these are used). These ratios are calculated from the iRAP network being assessed (rather than the number of these types of accident across the whole country). These 'average ratios for the country' are then applied to the data for each road section.

The method gives a better estimate of the relative long-term crash rate for each section and means that maps are plotted to a scale for each country that, although still described as low, low-medium, medium, medium-high and high risk, have different thresholds for each band depending on how their accident data and iRAP network are defined.

Performance tracking

Performance Tracking uses the data compiled for consecutive risk maps to assess how risk on the network as a whole, or on individual road sections, has changed over time. The EuroRAP process of tracking the performance of road sections over time is carried out in three stages:

- Risk Mapping for consecutive data periods are compared to identify road sections that have shown a statistically significant reduction in the number of fatal and serious accidents over time, and those where there has been little or no change;

- Changes to road network assessed (e.g. change of road class, by-pass): data for individual years is then checked to assess consistency of trends over time. An important part of this stage is in checking any significant changes to the road network between period such as new bypasses or a change to the road class;

- Monitoring results: highway authorities are consulted in order to collate information on specific issues affecting road safety on individual sections, the engineering, enforcement and education measures that have been implemented during the data periods under investigation, and any actions planned for the future.

Road inspection and rating

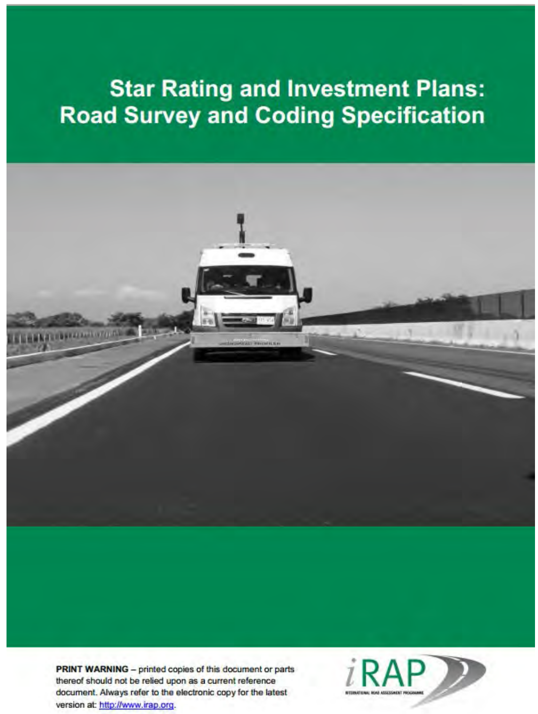
The third protocol in iRAP methodology is the inspection of the road network in order to define the level of safety inherent the road design: five-star roads (green) are the safest, and one-star (black) are the least safe. Star Ratings can be completed without reference to detailed accident data, which is often unavailable in low- and middle-income countries.

Using specially equipped vehicles, software and trained analysts, RAP inspections focus on more than 30 different road design features that are known to influence the likelihood of a crash and its severity. These features include intersection design, road cross-section and markings, roadside hazards, footpaths and bicycle lanes.

Two types of road inspections are available, drive-through inspections and video-based inspections, with video-based inspections being the most common.

Drive-through inspections: drive-through inspections require inspectors to record road design data as they drive along the road using a specialised data tablet. The process is technical and requires accredited RAP inspectors. Drive-through inspections are typically used where the length of the road network being surveyed is short or relatively simple (such as rural roads with no adjacent development). The drive-through inspection equipment includes a video camera, touch-sensitive laptop and GPS antenna. The inspections are followed by a period of data analysis and quality checking.

Figure 2.7. **iRAP guidelines for road survey and coding specification**



Source: irap.org

Video-based inspections: Video-based inspections are undertaken in two stages. Firstly, a specially equipped survey vehicle records images of the road as it travels along. The video is later viewed by analysts, or coders, and assessed according to RAP protocols. The survey vehicle can record digital images of the road (generally at intervals of 5-10 metres) using an array of cameras aligned to pick up panoramic views of the road (forward, left-side and right-side). The main forward view is calibrated to allow measurements such as lane width, shoulder width and distance to roadside hazards. The vehicles can drive along the road at almost normal speed while collecting the information.

Following the completion of the video-based inspection, each relevant design feature is measured and rated according to RAP protocols. The process involves streaming the video images together to form a video of the road network. Coders then undertake desktop inspections by conducting a virtual drive-through of the road network, at posted speed or on a frame-by-frame basis, depending on the complexity of the road. The software used by the coders enables accurate measurements of elements such as lane widths, shoulder widths and distance between the road edge and fixed hazards, such as tress or poles. To support the process a detailed road inspection manual is available. At the completion of the rating process it is possible to produce a detailed condition report of the road that forms the basis for Star Ratings and the Safer Roads Investment Plan.

A colour coded map illustrating the level of safety inherent the road design and features is produced and can be used to make drivers aware of the risk of different roads or networks. A detailed condition of road report is also available, providing information on each examined feature. This can be useful for a first stage of analysis of road conditions.

Usually, trained auditors are required to perform a RAP.

Road Safety Inspection

Purpose	Identify infrastructure or traffic related factors increasing injury or accident risk
When	Generally undertaken during normal operation of a road and may also contribute to error correction and hazard elimination
Where	Part or the entire urban, rural and/or motorway network
Data	Roadway related

A Road Safety Inspection (RSI) is a formalised preventive safety check of existing roads and for new road projects constitutes the RISM tool that follows the last phase of an RSA after the opening of a road. It is to be carried out in a periodic way by independent and well-trained (teams of) experts and involves the assessment of numerous safety-relevant parameters in the course of site visits (driving and walking). The inspection dimensions range from road construction and traffic engineering issues to road user behaviour and perception theory.

The work is usually carried out along standardised checklists. Identified safety deficiencies are compiled in a detailed inspection report, together with concrete recommendations for remedial action. The RSI's client (usually a road authority) has to respond to the report in writing, stating explicitly whether (and when) a recommendation will be implemented, and which issues will be dismissed (and why). RSIs should regularly be carried out along the whole road network under the jurisdiction of an authority.

According to the PIARC's definition (PIARC 2012), RSIs are systematic reviews of selected roads that do not require accident data. Nevertheless, for reasons of sound prioritisation and efficient spending of limited resources, some countries' road authorities have turned to combining preventive and reactive elements under the RSI umbrella, by first inspecting those sections of roads which suffer the highest accident (cost) rates. However, it must be noted that RSIs do not qualify as a replacement for the identification and treatment of high-risk sites, as RSIs are always carried out along whole sections of roads.

If followed up by the implementation of adequate measures, RSI is a powerful tool that contributes to minimising the likelihood of severe accidents on a stretch of road. Evaluation studies have shown favourable impacts of RSI in terms of accident reductions. The cost-benefit-ratio depends on the type of measure implemented (e.g. see Elvik, 2006). It is desirable to monitor the impact of RSI-triggered countermeasures after the first years of implementation.

Tools and data

As for RSA, detailed RSI checklists are available for different road classes, such as for motorways, rural and urban roads. Figure 2.8 shows an extract of the PIARC RSI checklist for interurban roads and highways (PIARC 2012), which also demonstrates that RSIs seamlessly follow the last RSA phase. The checklist is organised along typical safety-relevant dimensions such as the function of a road, cross section, alignment, intersection design, services (rest areas, access control to public services, public transport), needs of vulnerable road users, traffic signing, marking and lighting, as well as roadside features and passive safety installations.

As for RSA, it is advisable to adapt the RSI checklists to specific safety problems and requirements of a country where necessary. Although they are organised as yes/no tick lists they should primarily be used as a memory and decision aid for the inspectors. At the end of the day it is not the number of ticks that count, but a clear and detailed compendium of advice to the road authority on which measures to implement in order to mitigate a road's safety deficiencies.

Figure 2.8. **Example of Road Safety Inspection checklist**

CHECKLIST OF INTERURBAN MAIN ROADS CROSSING BUILT UP AREAS OF TOWNS AND VILLAGES
HIGHWAY N°……… BETWEEN KM …….. AND KM ……. DATE:

Characteristics	No	Question	Yes / No	Comments
1. Function, operating elements and surroundings	0	Have eventual final audit results from previous audit phases been taken into consideration?		
	1	Are there any issues from accident data if available?		
	2	Are there specific traffic composition characteristics to be taken into consideration?		
	3	Are special measures required for particular groups, e.g. for young people, older people, sic k people, physically handicapped, hearing-impaired or blind people?		
	4	Is the design of the road according to its function and hierarchy in the network?		
	5	Are there built-up areas with mixed traffic?		
	6	Is access to abutting properties and agriculture appropriate for road safety?		
	7	Are there any parallel ways to be used by carts and farm equipment?		
	8	Do we realise the change of functions and characteristics early enough? 100 km/h -> 300 m ahead 80 km/h -> 200 m ahead 60 km/h -> 150 m ahead		

Source: Extract from PIARC RSI Checklist "Interurban roads and highways"

Common practices

RSI are usually tendered by a road authority. It is imperative that the inspection team is independent from the ordering entity and in no way involved in the planning, construction or maintenance of the road in question. As for RSA, training, accreditation and further education of inspectors should be carried out by an independent institute.

It is desirable to roll out RSIs according to a master plan that covers the whole network of a road authority in a maximum of ten years. That is, no single road section should be left uninspected after this period, even if no changes in function, surfacing, marking, signing etc. have occurred. In case of structural or functional changes it is recommendable to carry out RSIs that may be restricted to the specific changes in question. Some jurisdictions also initiate unscheduled RSIs on sections with peculiar accident patterns or generally increased crash frequencies, where the classical means of high-risk site management have shown to be insufficient.

A typical RSI involves three major steps. The first step is the **preparatory work** (mostly in the office). This embraces the analysis of design drawings together with information on the function of the road, (growth of) traffic volumes and composition, speed limits and levels, and other important background information. It goes without saying that the team's good grasp of the relevant technical guidelines is a prerequisite for the success of an RSI. Particularities of the road – such as previous safety issues or specific requirements of vulnerable road users at certain locations – can be revealed in discussions with the local road provider and/or by consulting with local residents. As a result of the preparatory work, the inspection team should have a fairly clear first picture of potential safety deficiencies, such as of inconsistencies of horizontal and/or vertical alignment, incompatibilities between design and real speeds or inadequate speed limits at locations of crossing aids for pedestrians.

Next are the **site visits,** which represent the core activity of the inspection. It is recommended to carry out site visits during both the day and night. Care must be taken that the inspecting team and their vehicle(s) do not pose safety dangers while being placed at the roadside. Reflective garments, revolving lights on vehicles as well as warning signs (where deemed appropriate) should therefore be considered standard equipment. For all sub-sections of the road and all dimensions of the above questionnaire, the team should take detailed notes together with appropriate footage (pictures or videos) and the exact locations of issues (best by recording GPS coordinates or the exact offset from kilometre/mile signposts). It may be necessary to carry out measurements on site, e.g. of speed levels, sight distances, cross sections and lane widths. Even if the emphasis of deficiencies may differ between countries (e.g. absence of proper facilities for vulnerable road users and unregulated access to properties in middle- and low-income countries), the key mechanisms of safety problems – and adequate countermeasures – remain the same across the world.

Lastly, the **RSI report** provides a concise description of the inspected road(s), their location, function and specificities as well as details about the inspection itself and the inspecting team. The core of the report is a summary matrix of the deficiencies revealed during preparatory phase and site visits. The matrix typically contains the following for each deficiency;

- The exact location (e.g. "A1, direction North, km 22.4 – 25.7").
- The concrete safety problem (e.g. "median barrier missing").
- One or several options for remedial measures – possibly with different costs and implementation horizons (e.g. "install median barrier, or – as a first step – widened double centre line with rumble strips").
- The intended improvement by the measure(s) (e.g. "reduced likelihood of head-on collisions").
- The recommended time frame for implementation (short/medium/long term) (e.g. "widened double centre line: short term; median barrier: medium term").
- A visualisation (such as a drawing and/or picture and/or map view).

After submission of the report, the client is required to produce a formal reaction in writing, listing for all recommendations agreement or rejection (together with a justification in case of the latter).

Although the implementation of measures does not belong to the core process of an RSI, it is of utmost importance that the accepted recommendations of an RSI are being followed up in a sound way. Only with this step accomplished – together with a monitoring of the safety impacts of the implemented measures – can the intention of the RSI as a central tool of RISM be achieved.

Usually, a certificate of competence is required to perform RSIs.

High-Risk Sites

Purpose	Identify infrastructure or traffic related factors increasing injury or accident risk
When	Identification is undertaken to identify and remove road infrastructure safety issues
Where	Generally part or an entire road network managed by a road administration
Data	Roadway related, crash related

The potential of road accidents exists for any part of the road network. However, in every road network, there are specific sections where the number of accidents is especially high. A basic issue arising is whether this is random or can be explained by specific factors that contribute to the increased number of accidents. The high-risk sites (HRS) approach is based on the idea that, in specific sites of the road network, several factors that lead to many accidents exist simultaneously. These sites are called high-risk sites, and according to the respective approach, it is possible to influence the existing accident contributing factors and in this way treat the high-risk site. Other terms used in the literature for high-risk sites are “hazardous locations”, “hot spots”, “sites with promise” and “black spots”, though the last one is not common anymore.

In Directive 2008/96/EC of the European Parliament and of the Council on road infrastructure safety management, the term “high-risk concentration sections” is used to describe high-risk sites. According to the Directive, Member States should ensure that ranking of high accident concentration sections is carried out on the basis of reviews, at least every three years, of the operation of the road network. ‘Ranking of high accident concentration sections’ means a method to identify, analyse and rank sections of the road network that have been in operation for more than three years and upon which a large number of fatal accidents in proportion to the traffic flow have occurred (European Commission, 2008).

The HRS approach is one of the most traditional reactive approaches for the improvement of road safety. A practical advantage of this approach is that it tackles cost and time limitations as it permits the use of all available means for the sites with the most accidents and allows the setting of priorities concerning the implementation of road safety measures. Furthermore, when effective measures are implemented in areas where many accidents occur these measures are probably cost-effective i.e. the reduction in the number of casualties is in a positive ratio to the costs of the measures (SWOV, 2010).

The approach is appealing and considered effective because unsafe situations are tackled exactly where they occur, at sites with the most accidents. On average, a HRS approach results in an 18% reduction in casualties, and in most cases is cost-effective (Elvik, 1997). Furthermore, the periodical identification and classification of high-risk sites allows for the monitoring of the actual situation in specific sites and the assessment of the measures already implemented.

The HRS approach is probably most effective and straightforward in countries with no prior experience of accident remedial work. Many highway authorities in industrialised countries began their efforts to improve road safety based on such approaches and only later moved on to mass and route action plans as experience increased (World Bank, 2013).

Tools and data

In order to implement the HRS approach reliably and effectively, a set of high quality data describing accidents and the locations where they have occurred is required. Such information is necessary for the identification of common features that contribute to accidents. The number of accidents at a particular site usually varies widely from year to year, even if there are no changes in traffic or in the road layout. In statistical terms, road accidents at individual sites are rare, random, multifactor events. This means that the examination of accident numbers at specific sites must refer to a fixed time period, usually one year. Furthermore, a single year's data will be subject to considerable statistical variation. Ideally, several years' data are required, from which a mean, annual accident rate can be calculated. Three years is generally regarded as a practicable minimum period for which a reasonably reliable annual average rate can be calculated (World Bank, 2013). This is also the period determined by the EU for the ranking of high accident concentration sections on the basis of reviews (European Commission, 2008).

Although the annual number of accidents at a particular site is adequate and relatively easy to obtain, there are cases, such as links in the highway network, for which accident density is more appropriate for the identification of HRS. On a road network, accidents may happen at locations with specific characteristics, for example an unexpected, sharp bend, but also at locations without any obvious single feature to which accidents may be attributed. In such cases, accident density along a particular link, meaning the number of accidents per kilometre, is a more appropriate unit of measurement for identifying of high-risk sites. In other cases, where the target is the improvement of safety of specific road user groups or the limitation of a specific type of accidents, the actual number of the respective accidents may be used instead of the total accident number.

Common practices

There are three main phases in the HRS approach. During the first phase, the identification of HRS takes place. The simplest method is to locate road accidents recorded within a specific area and spot the sites with the highest accident numbers. The second phase concerns the analysis of accident patterns and the identification of common characteristics, which may reveal the causes of the accidents. In the last phase, the most effective measures are determined based on the results of the previous analysis. The implementation and the assessment of measures are not included in the high-risk sites approach, but are normally expected after a HRS study.

During the first phase, in order to identify high-risk sites, a limit of accidents per period of time or per kilometre is determined. There are two main methods to identify high-risk sites: the numerical and the statistical methods. Numerical methods are those based solely on historical road accident data; two examples are the number of recorded accidents in a given period or the number of accidents that occur during a certain time period at a given site in relation to a measure of exposure like the average daily traffic. Statistical methods are those using statistical distributions for describing the risk at specific sites, or the probability of an accident occurring at the specific site. In every case, a site with a number of accidents higher than the specified limit is characterised as a high-risk site. It is important that the criterion of at least X accidents in a period of Y years (or per kilometre) is chosen with great care.

According to Directive 2008/96/EC, the identification of road sections with a high accident concentration takes into account at least the number of fatal accidents that have occurred in previous years per unit of road length in relation to the volume of traffic and, in case of intersections, the number of such accidents per location of intersections (European Commission, 2008).

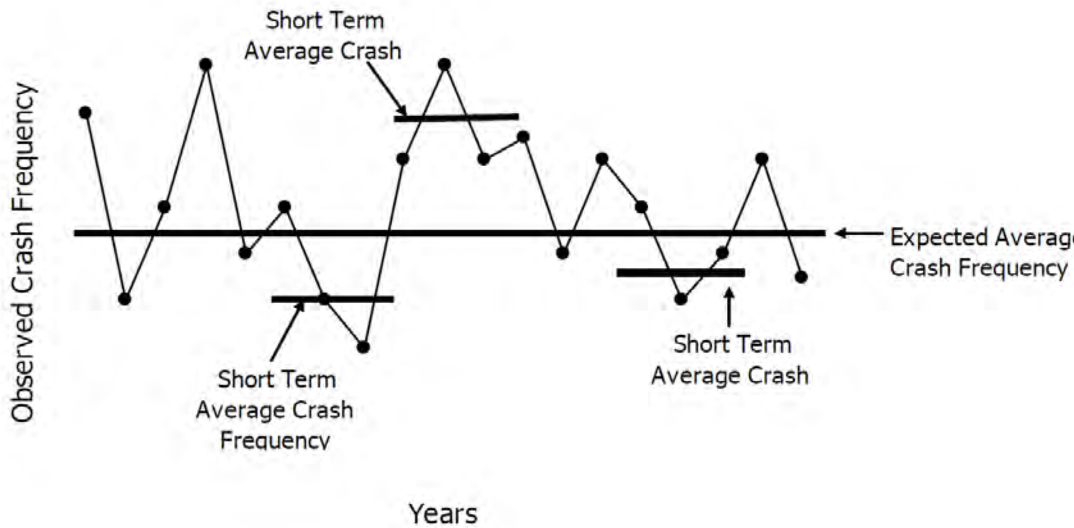
The severity of accidents is an issue that should also be taken into account when determining the limits for high-risk sites because it is related to the social and economic cost of accidents. Availability of data on cost of different types and with different severity will also permit their weighting in relation to their cost. In this way, the comparison of sites is possible and priority can be given to those sites where remedial action will be most effective.

If traffic flow data are available, it can also be helpful to compare sites in terms of accidents per unit of traffic. Such accident rates are often expressed as accidents per million vehicles entering an intersection or accidents per million vehicle kilometres on a link. If such data are available, sites can be compared in terms of these rates that give an indication of their relative safety, given their traffic volumes.

As expressed in previous research (Hauer, 1996) HRS that will be treated should not be selected based solely on the number of accidents or respective indicators but also based on the potential they have to be improved. The implementation of measures that are not cost-effective has no practical meaning. On this direction, three criteria for the appropriate HRS to be treated have been identified. The first one is financial performance, meaning that those HRSs where the implementation of measures will result in the maximum benefit for road safety should be selected. The second one is professional and institutional liability, meaning that measures should be taken at sites where increased risk is caused by errors in the design, the construction or the maintenance of the network. The last criterion concerns objectivity towards the user, meaning sites that show an objectively high risk for users are selected for treatment.

In any case, when HRSs are explored some confounding factors should also be taken into account. Confounding factors are all factors that weaken the basis for inferring a causal relationship between HRS treatment and changes in road safety. Confounding factors represent alternative interpretations to the findings and ought ideally to be eliminated. Such confounding factors are: changes in traffic volume, general trends in the number of accidents, regression to the mean and accident migration (Elvik, 1997). More specifically, changes in traffic volume affect the number of accidents. These can be corrected for by assuming that the number of road accidents increases with the number of passing vehicles. A correction for the general trend can be made by comparing road safety developments in a control area or at comparable locations, assuming that these developments would also have happened in the high-risk locations without the measure having been taken. This development must then be compared with the effect found at the location.

Figure 2.9. **Variation in short-term observed crash frequency**



Source: AASHTO, 2010

The expression "regression to the mean" refers to the phenomenon that locations with an extra high number of road accidents during a particular period will often have a lower number in the following period, even if no measure has been taken (Figure 2.9). An acceptable correction method is to examine developments that occur for a group of similar "dangerous" locations where no measure has been taken.

Migration is the phenomenon in which the number of road accidents in the immediate vicinity (also called the influence area) increases as a result of the measure at the dangerous location or in the area dealt with; in other words, road accidents move to somewhere else. This can, wholly or partially, counteract the benefit from the measure taken. The effects within any influence area should therefore also be taken into account in the evaluation (SWOV, 2010).

Usually, no specific certificate is required to perform HRS.

In-Depth Investigation

Purpose	Identify infrastructure or traffic related factors increasing injury or accident risk
When	Undertaken to identify and remove safety issues emerging from the interaction between human factors and infrastructure
Where	No specific road category: limited to the area of intervention of the investigator teams (e.g. 30 min from accident investigators' base)
Data	Crash related

Road accident data can be collected, classified and analysed in various ways depending on the specific issues treated and the objectives pursued. While police accident data may be adequate for aggregate analyses of road accidents occurring on the road network in general, they tend to lack detail about factors that contribute to the causation and consequences of accidents. At an in-depth level, there are multiple uses for data, from the analysis of accident causes, to research and to the study of consequences and the monitoring of effects of a road safety measure.

In-Depth Investigation is a methodology consisting of data gathering and analysis of a conspicuous amount of data related to a single road accident. Generally data gathering is carried out directly on the accident scene by a team of accident investigators. Investigators register a predefined set of accident data by examining involved vehicles, the road environment and by interviewing persons involved in the accident (drivers, passengers and pedestrians), witnesses and emergency service personnel present on the accident scene. In a second stage, all gathered information is analysed, taking into account the objectives of the accident investigation. Objectives, data gathering procedures and analysis methods are usually specified within a research study or an accident investigation programme.

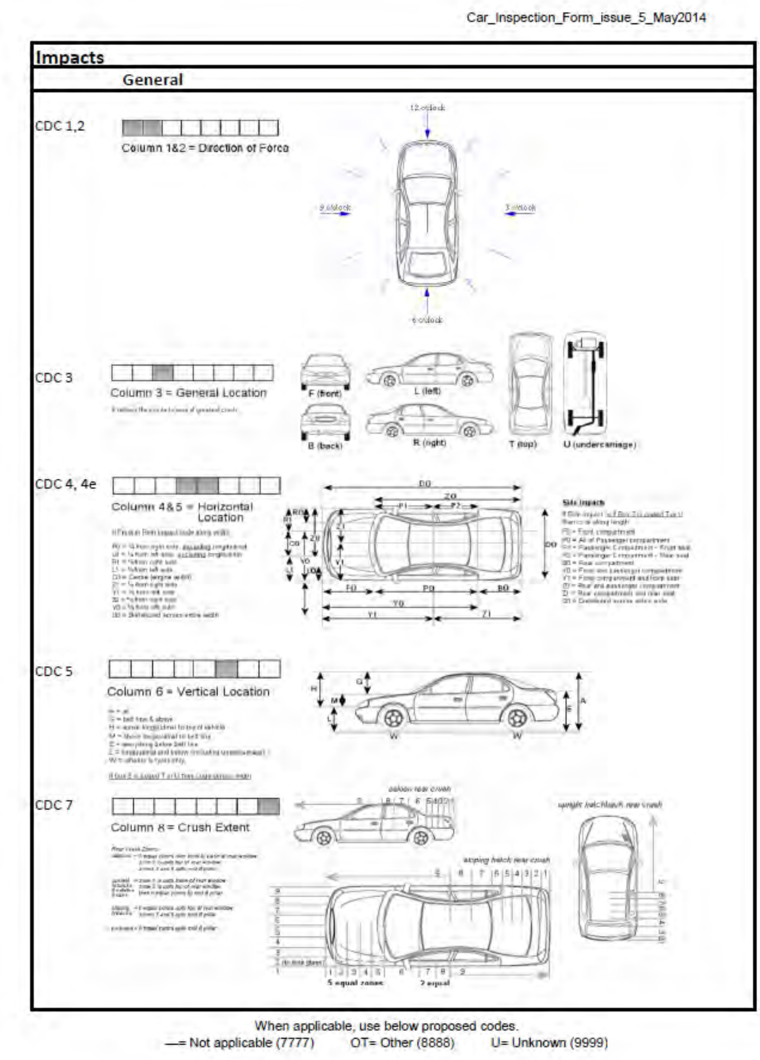
Usually, In-Depth Investigations are conducted for specific types or very serious types of accidents. Several projects, mostly US- and EU-funded projects, include the in-depth analysis of various samples of accidents; e.g. MAIDS[4] (powered two wheelers), ETAC[5] (trucks), LTCCS[6] (trucks), PENDANT[7] (passive safety), SafetyNet (active safety). In general the purpose of these projects is to get a more in-depth knowledge of accident and injury causation. For example, objectives of MAIDS are "to gain a better understanding of the effects of human, vehicle and highway factors on the causes of accidents and injury outcomes" (ACEM, 2004).

In-depth data can aid in the identification of localised problem sites or traffic systems. Benefit is provided by the added detail about accidents occurring on the road network, which ordinarily would not be reported in the national reporting system.

Tools and data

The investigation of an accident usually entails two main phases: a first phase of accident data collection and a second phase where collected data are analysed. The tools and data used in the two phases are different. The instrumentation and the equipment needed for the accident data collection phase may vary widely, depending on the type of investigation to be carried out and the precision that is required. In general, the main tools for accident data collection are: a camera (preferably a digital one), a video camera, a measuring tape, a levelling rod, a voice recorder, chalk, and a notebook with pens and markers. Other more specific measurement instruments to get better precision may be added to the list: an inclinometer, an anemometer, a laser scanner, pressure gauge, etc.[8].

Figure 2.10. **Car inspection form**



Source: DaCoTa on-line manual: http://dacota-investigation-manual.eu/pmwiki.php

When all information is available, the accident investigator proceeds with the analysis. Investigation material is processed and a reconstruction of the accident dynamic is carried out, followed by specification of consequences and causes. Sometimes recommendations for accident prevention may be made and an accident report is produced.

Usually, behind the analysis method, especially when analysis of accident causes is involved, there is an "accident model" able to explain how the system behaves, the possible interactions among the elements of the system (e.g. the vehicles) and possible factors that may contribute to a system "failure" or to a crash. Various accident models have been proposed in literature, from domino or "sequential" models to epidemiologic models (Huang et al. 2004). An example of an accident model is the one proposed within the European research projects SafetyNet, first, and then DaCoTa. The accident model is derived from a systemic approach used firstly in manufacturing. This approach focuses mainly on the relationships among each element of the system rather than on each single element. Within this approach, accidents are mainly due to a failure in the interaction of the system components, namely, technological, human and organisational components. On the basis of this accident model it has been developed a method of analysis of the causes called DREAM 3.0 (Driving Reliability and Error Analysis Method)[9].

The results from the investigation analyses should be recorded both in a report and in a dedicated accident database, in order to facilitate their processing in aggregate analyses. The accident report should contain at least (SafetyNet, 2008):

- The method of investigation and the evidence to support the conclusions made.
- The identified accident causes and the factors that may have contributed to increase the severity of the accident.
- Recommendations designed to prevent the analysed accident.

The database should be able to record all useful information for the investigation purposes. Data should not be public; in particular sensitive data should be adequately protected with a restricted access.

Common practices

The types of In-Depth Investigation (in reference to the data collection phase and length of time between the accident and the intervention of the investigators) may be classified as:

- **On scene:** the investigation team arrives at the scene of the accident when the parties involved are still present;
- **Nearly in-time:** the investigation team arrives at the scene of the accident the same day when the accident occurred but cannot perform the investigation On scene;
- **Retrospective***:* the investigation team arrives at the scene of the accident in the days following the accident.

With respect to this classification, on scene investigation is preferred as it allows collection of "volatile" data, which can be found just a few minutes after the accident, and that may be lost once the scene of the accident is cleared.

Road accident investigations are currently conducted by a number of organisations and take different forms. In European research project SafetyNet (SafetyNet 2008), recommendations are proposed for the establishment, in all Member States of the European Union, of a body ensuring an "independent" and "transparent" accident investigation. In particular a “Safety oriented road accident investigation” process is proposed (SafetyNet, 2008). This process is defined as:

- Including the acquisition of all relevant information and the identification of (one or several of the following): the cause or causes of the accident, injuries, injury mechanisms and injury outcomes, and how the accident and injuries could have been prevented
- Being conducted by one or several investigators with specialised knowledge in accident investigation and other fields of knowledge, relevant for the purposes of the investigation;

- Being aimed at preventing future accidents and injuries through the development of countermeasures; and

- Not contributing to any judicial enquiry or take a stand on responsibilities.

According to EU SafetyNet project, the aspects that should be defined when implementing an In-Depth Investigation process are:

- characteristics of the body in charge of the In-Depth Investigation (structural relationships, financial and functional with other organisations, freedom of inquiry in the field of multidisciplinary investigative teams that make up the organ, etc.);

- operating procedures (notification of the accident, sampling, orientation of the surveys, systematic procedures for investigation, etc.); and

- analysis reports, countermeasures and data dissemination (extended availability of the results of the survey, transparency of the process of dissemination of the results, using the results to develop countermeasures, etc.).

A second necessary element is the establishment of a structure composed of one or more investigation teams, in relation to the extension of the area and the probability of occurrence of accidents, which provide for action in the event of an accident. The investigation team should be composed of figures with different expertise in various accidentology fields and road safety. A multidisciplinary team allows the organisation of data collection on site in relation to the different elements characterising a road accident: the state of the vehicles; of road infrastructure; road users' behaviour; and physical and mental condition of those involved. References about roles and responsibilities of investigators can be found, for example, in the UK Road Death Investigation Manual (ACPO, 2004) and in the methodology developed by Finnish insurance companies VALT.

Before beginning the investigation, appropriate safety procedures should be followed in collaboration with emergency services present on the scene in order to ensure the safety and security of the people and vehicles in transit. One of the main issues for an In-Depth Investigation study is getting a representative sample of road accidents in the study area. It is important to precisely define the area of investigation and a sampling protocol for road accidents. Investigators should be notified of accidents and allowed to access the accident scene. It is important to ensure that the accident notification process adequately identifies all accidents that meet the sampling criteria. If legislation does not allow this, an agreement should attempt to be made with police forces and emergency services, highlighting the research purposes in order to gain co-operation and support (e.g. access to information gathered and permission to interview people involved).Types of inspections and the sequence in which they take place may vary from accident to accident. These variables depend mostly on the objectives of the study, the subjects involved and the transient nature of some information. Data collection usually includes: descriptive surveys, measurements (e.g. of road layout), interviews, taking photographs and video recording. The most important phase is the collection of all relevant information for the reconstruction of the dynamics and the analysis of the causes of the accident.

Usually, no specific certificate is required to perform in-depth accident investigation.

Notes

1. In the RIPCORD-ISEREST European project Road safety Impact Assessment is described as a methodology to assess at the planning phase the impact of traffic schemes on road safety (Eenik et al., 2007).

2. A roadside hazard rating system was developed by Zegeer, et al, 1988 to characterize the accident potential for roadside designs found on two-lane highways. According to this system, the rating values indicate the accident likelihood and damage severity expected to be sustained by errant vehicles on a scale from 1 (low likelihood of an off-roadway collision or overturn) to 7 (high likelihood of an accident resulting in a fatality or severe injury).

3. It must be highlighted that iRAP denotes not only score assignment, over time the iRAP has become more comprehensive in scope by adding more tools and protocols as described in the following.

4. Motorcycle Accidents In Depth Study – MAIDS.

5. European Truck Accident Causation – ETAC.

6. Large Truck Crash Causation Study – LTCCS.

7. Pan-European Co-ordinated Accident and Injury Database – PENDANT.

8. A more detailed list can be found at http://dacota-investigation-manual.eu/.

9. The method originates from an existing method called DREAM (Driving Reliability and Error Analysis Method) (Ljung, 2002).

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CHAPTER 3. ROAD INFRASTRUCTURE SAFETY MANAGEMENT WORLDWIDE

This chapter presents the results of a survey among 23 countries regarding their experiences with Road Infrastructure Safety Management (RISM) procedures. The responses provide insights into the application of RISM procedures around the world and highlight barriers that hinder their use. The chapter aggregates the survey information around five topics and also provides country comparisons.

One of the aims of the study is to understand to what extent RISM procedures are applied and what barriers exist that prevent their use. This has been accomplished through a survey of 23 member countries of the International Traffic Safety Data and Analysis Group (IRTAD). Of these countries, 15 from Europe, five from the Americas, two from Asia and one from Africa. The responding countries were: Argentina, Austria, Canada, Colombia, Czech Republic, France, Germany, Greece, Hungary, Ireland, Italy, Jamaica, Japan, Korea, Lithuania, Luxemburg, the Netherlands, Portugal, Slovenia, South Africa, Sweden, Switzerland, and the United States.

The survey, carried out in 2013, aimed to capture the diffusion of different RISM procedures and the main difficulties in their application. The questionnaire was organised to cover eight of the ten RISM procedures described in Chapter 2. Road Network Safety Ranking and Network Operation were considered in a second phase and were therefore not included in the survey.

The five topics included in the questionnaire for each RISM procedure were:

- Presence of a national law regulating an RISM procedure.
- Road network coverage (extent of road network interested).
- Responsible party.
- Tools supporting the application of an RISM procedure, e.g. availability of technical guidelines detailing the RISM procedure, the use of software tools supporting the application of the RISM procedure.
- Adequacy of available tools and main barriers to the implementation of an RISM procedure.

Detailed data at country level are reported in tables in Annex 6. For each RISM procedure examined within the survey, coded information about the questionnaire answers for the investigated countries is reported.

Results by topic

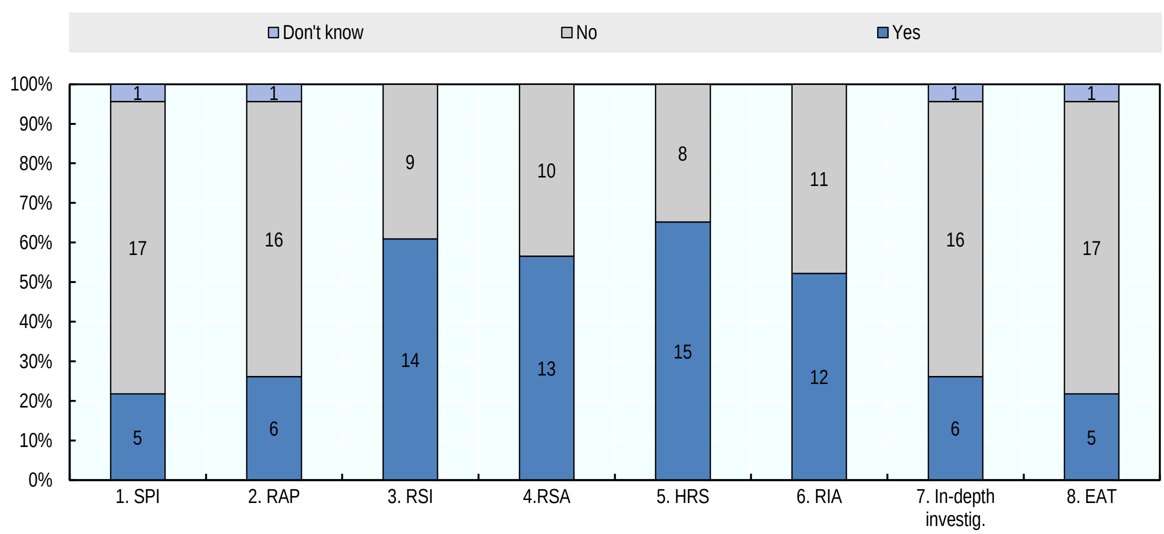
An analysis of the five survey topics allows to better understand the use of the different RISM procedures worldwide. Country data have been aggregated and analysed per questionnaire topic in order to get an overview of the use of these practices for all the investigated countries.

National law regulation

According to the survey results, none of the eight RISM procedures examined are regulated by law in each of the 23 countries investigated (Figure 3.1). Four RISM procedures are present in national regulations in 55-65% of the 23 examined countries In particular: RSI appears in law in 64% of the countries, RSA in 59%, HRS in 68% and RIA in 55%. All eight RISM procedures are regulated by law in only one country, Switzerland, while there is a national law for 7 of the 8 RISM procedures in both Ireland and the Netherlands.

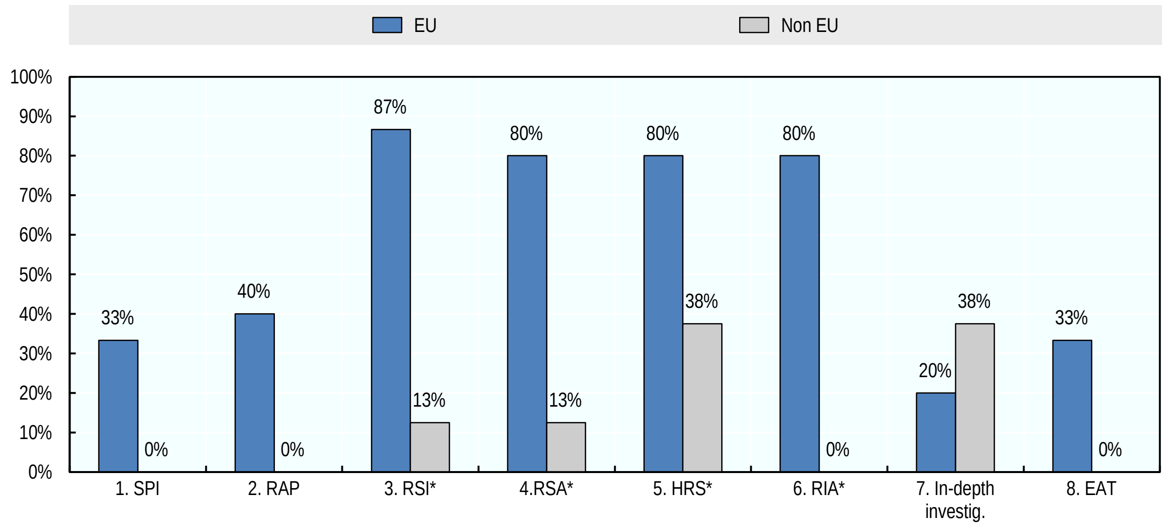
Within the responding countries, the percentage of countries with a law regulating an RISM procedure is higher in the European Union than elsewhere. This is especially the case for the four procedures addressed by the EU Directive on Road Infrastructure Safety Management (2008/96/EC): RSI, RSA, HRS and RIA. For these procedures the percentage of European countries absorbing the Directive reach values of some 80-87% (Figure 3.2). This is mainly due to the fact that the EU Directive 2008/96/EC requests Member States to "bring into force the laws, regulations and administrative provisions necessary to comply with the Directive by 19 December 2010".

Figure 3.1. **Road Safety Infrastructure Management procedures regulated by national law**



Source: Based on a survey of IRTAD Members.

Figure 3.2. **Availability of national law in selected EU and non-EU countries**



* RISM covered by Directive

Source: Based on data from a survey of IRTAD Members.

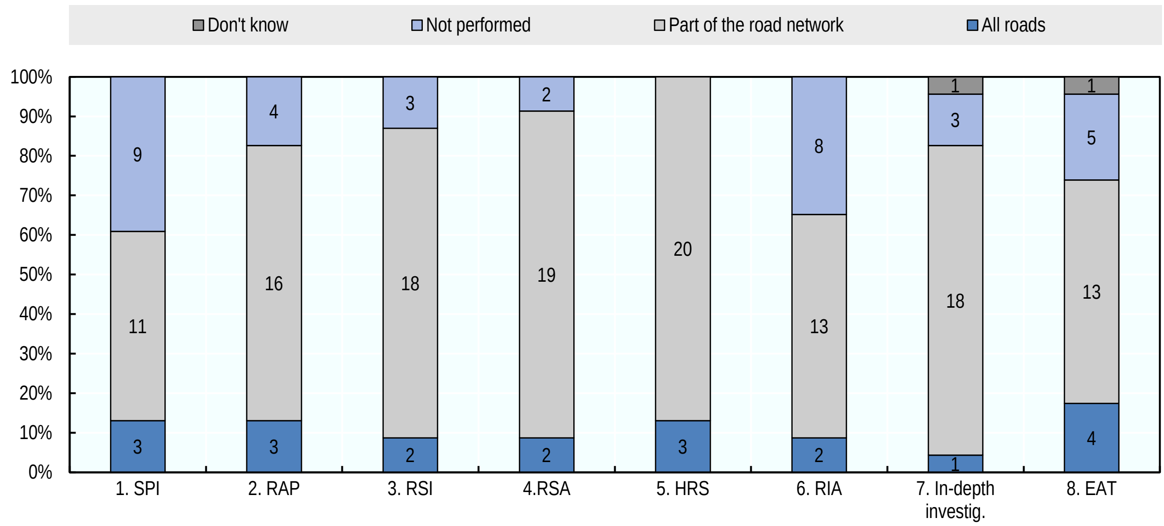
Road network coverage

The extent of road network interested by a given RISM procedure varies a lot country by country. Survey results show that even if an RISM procedure is not regulated by law, the number of countries where it is applied anyway on a part of the road network is much higher (Figure 3.3). For example, some countries, like Lithuania, perform Road Safety Inspections regularly on national level roads. In the United States, RSAs are not mandatory but currently there are 15 States that have formal RSA programmes across State, local, Tribal, and Federal Lands roads. In South Africa and Argentina, RSAs are performed on a voluntary basis on a limited part of the road network.

While, according to the Directive 2008/96/EC RSAs and RSIs are mandatory on all roads of the trans-European road network, some European countries (e.g. Austria, the Netherlands, the Czech Republic) also implemented them on a voluntary basis on other roads, e.g. national roads. Only a few countries (such as Switzerland) apply RISM procedures on the entire road network. The majority of countries only apply a given procedure on certain sub-sections of the road network, usually national roads (main highways) or motorways.

In some countries, like France and Greece, even where RIAs are required by law, it seems that RIAs are still not performed over the whole network.

Figure 3.3. **Application of RISM procedures on national road network**



Source: Based on a survey of IRTAD Members

Responsible party

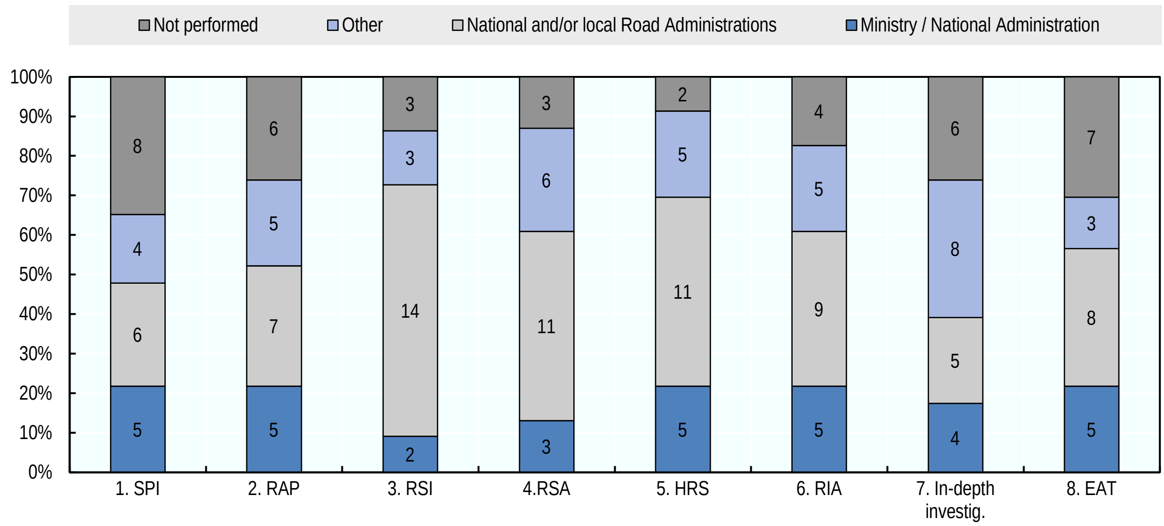
Responsibility for an RISM procedure may change from country to country, and it can depend on the political framework of a country and the part of the road network selected. For example, countries organised as a federation, like the United States, Canada and Germany, may delegate the responsibility to local States.

Depending on the scale of implementation of an RISM procedure in a country (e.g. national roads or national and local roads) the parties involved may be different at the various levels. Usually, the responsibility is assigned to the road owner or to the road administrator. Most of the time, the Ministry of Transport or the National Road Agency (or equivalents) are responsible for primary roads (i.e. national level roads). At the local level, on the other hand, RISM procedures are usually managed by local government or by the local road administration.

However, there can be some exceptions. In case of RISM procedures carried out during the road planning or design stage (e.g. for a new infrastructure or a major modification of the existing one, like RSA, RIA and EAT) the responsibility for taking care of the procedure can be taken by a road contractor (e.g. in Hungary, France) or by certified road safety auditors working for the responsible state agency (e.g. in Greece).

RAPs are usually managed by national and local road administrations, and in five cases (22% of the survey group) they are managed by Automobile Associations or private organisations (in Austria, UNITED STATES, Korea, Italy, Czech Republic). In five cases, HRS are also undertaken by third parties like: consultants (France, Portugal), groups of experts with certified auditors (Greece), private organisations (Colombia), local accident commissions covering police, road building authorities and traffic authorities (Germany). In addition to the national and local road administrations, In-Depth Investigations are also carried out by research centres and universities (e.g. in Germany, Colombia, Czech Republic) and by public prosecutors or the police (e.g. in Hungary, Ireland, Luxemburg, Portugal).

Figure 3.4. **Institutions responsible for RISM procedures**



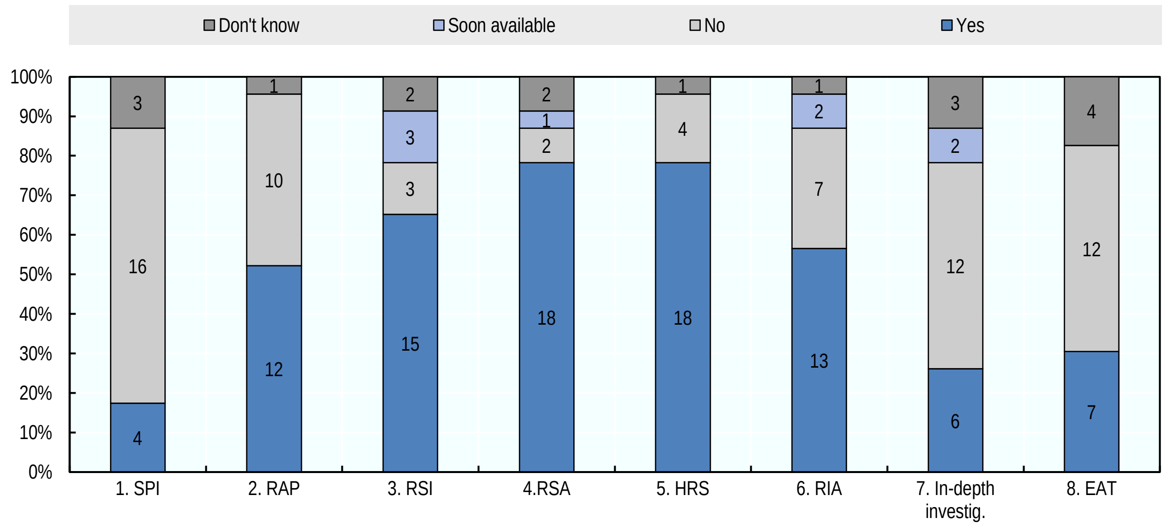
Source: Based on data from a survey of IRTAD Members

Tools supporting the application of an RISM procedure

The kind of tools investigated by the survey are documents providing references and technical guidelines for practitioners undertaking a specific RISM procedure and, eventually, software available to support practitioners, e.g. in recording, managing and analysing data needed within the application of an RISM procedure. Survey results indicate that technical guidelines are widespread among respondent countries for the following procedures: RSIs (65%), RSAs (78%) and HRS procedures (78%). Guidelines for performing RAPs (53%) and RIAs (57%) seem to be available in over 50% of the investigated countries. Technical guidelines for SPIs, In-Depth Investigations and EATs are less common (below 30% of countries).

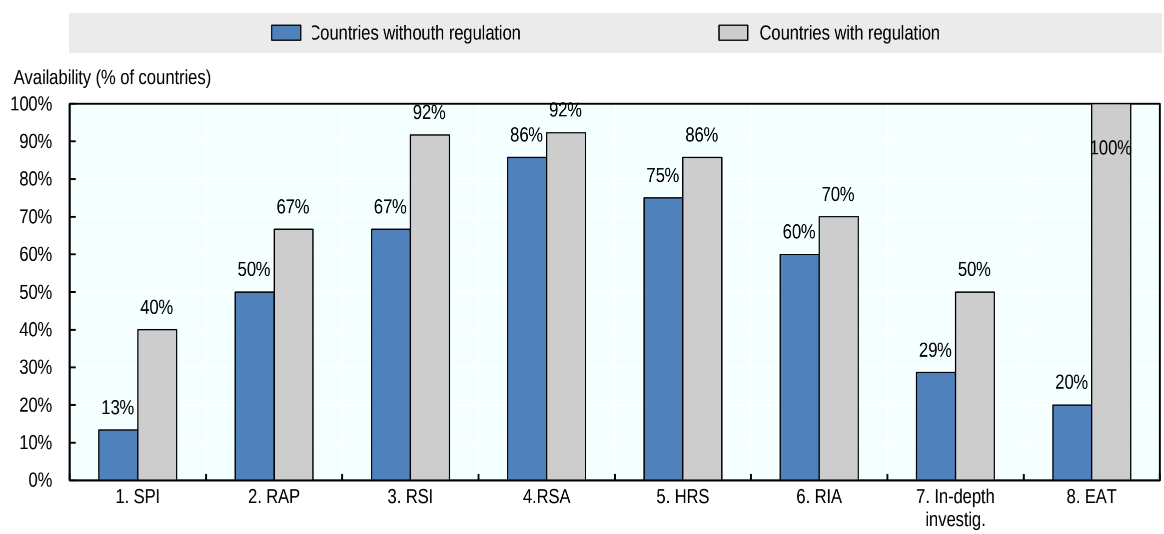
Most of the countries that reported the presence of a national law indicated that technical guidelines are also available (see Figure 3.6). For each RISM procedure the percentage of countries with technical guidelines is always greater among countries with dedicated regulations than among those without. This suggests that where a normative background exists, technical support is also provided for practitioners with published guidelines. Some countries are expecting to publish additional guidelines and, once these are taken into account, the difference is even greater.

Figure 3.5. **Availability of technical RISM guidelines**



Source: Based on data from a survey of IRTAD Members

Figure 3.6. **Availability of technical guidelines: countries with and without dedicated national law**

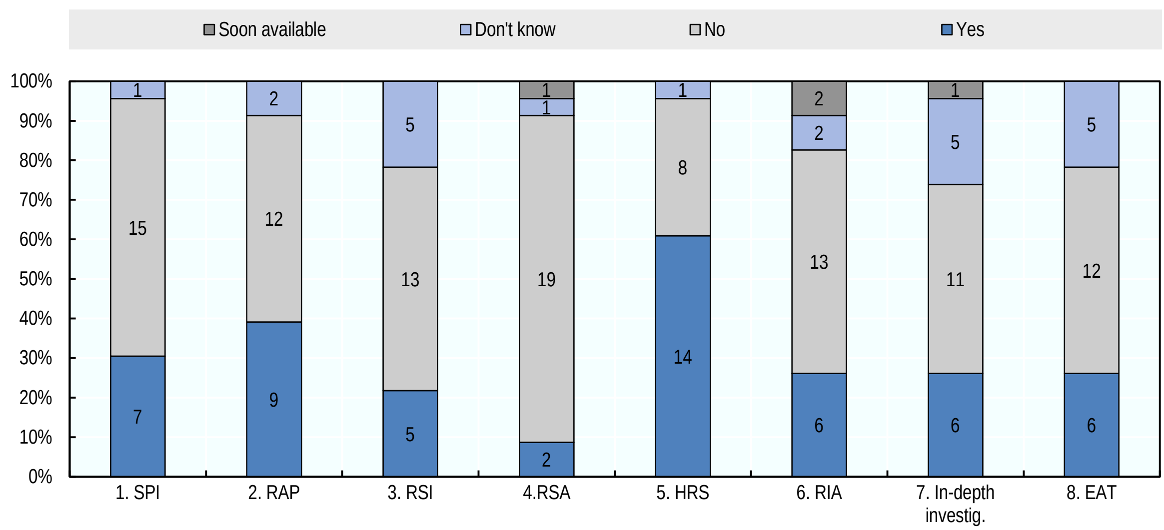


Source: Based on data from a survey of IRTAD Members

Thanks to the evolution of computer science, data management and calculation power has improved extensively in recent years. This supports new work methods. For example, Geographic Information Systems may aid in analysing traffic accidents in relation to the wider context within they happened. In some countries, dedicated software applications have been developed to help practitioners in manipulating data and in undertaking, with less effort, specific operations requested while conducting an RISM procedure.

Software applications are not as popular as technical guidelines (Figure 3.7). Software supporting HRS procedures is available in more than 60% of investigated countries. However software for RSAs and RSIs are less common (9% and 21% respectively). In the case of road SPIs, the number of countries where software applications are available is higher than the number of countries where technical guidelines for the procedure are available. This seems strange, as one would expect that when a consolidated methodology is available in the form of guidelines, the next step would be the development of software supporting the application of the methodology. However, this is not the case for two countries, Ireland and the Netherlands (there is one country, Sweden, where dedicated SPI software is available but it is not known if SPI guidelines are available too).

Figure 3.7. **Availability of software supporting Road Infrastructure Safety Management**



Source: Based on data from a survey of IRTAD Members

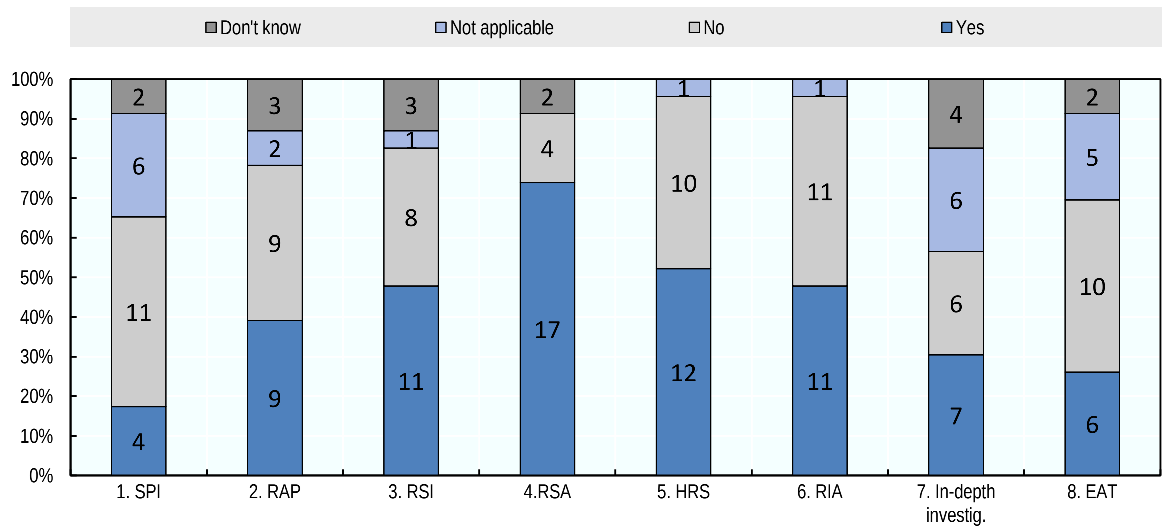
Adequacy of tools and main barriers to the implementation of RISM procedures

For each of the eight procedures, each country was asked whether the tools available in that country (e.g. resources available in terms of software, guidelines, courses, et cetera) are adequate to carry out activities related to each RISM procedure. It was found that the perceived adequacy of tools varies in relation to the investigated RISM procedures (Figure 3.8). For example, 17 of the 23 respondents (over 70%) felt that the tools available for RSAs were adequate. However, the percentage who thought that this was the case for other RISM procedures, such as SPI, In-Depth Investigation and EAT, was below 30%.

The availability of technical guidelines seems to be the critical point of judgement about whether tools are adequate. In countries where technical guidelines are available, most respondents think that the resources available (i.e. the guidelines) are adequate. However, this percentage varies from procedure to procedure. By comparing opinions on tool adequacy with guidelines availability, it can be shown that the percentage of respondents who believe the guidelines available in their countries are not adequate varies from 0% to 45% (Figure 3.9).

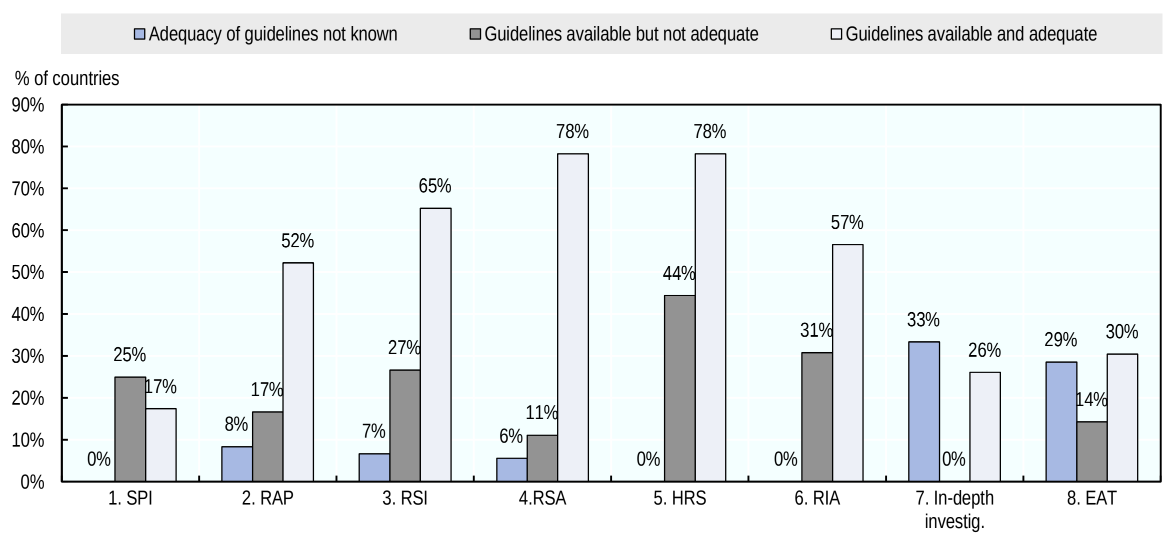
For RISM procedures where a higher percentage of countries have technical guidelines available and a lower percentage of respondents are not satisfied with them, it would mean that tools available for that procedure are consolidated and widespread. An example is RSA, where guidelines are available in most of investigated countries (18 over 23) and only 11% of these countries think that the these tools are not adequate.

Figure 3.8. **Adequacy of existing tools for RISM procedures**



Source: Based on data from a survey of IRTAD Members

Figure 3.9. **Adequacy of guidelines**



Source: Based on data from a survey of IRTAD Members

Each respondent indicated, if appropriate, one or more reasons for not performing an RISM procedure in their country. In this case, it was possible to give open-ended responses, but the reasons given can be classified as the following:

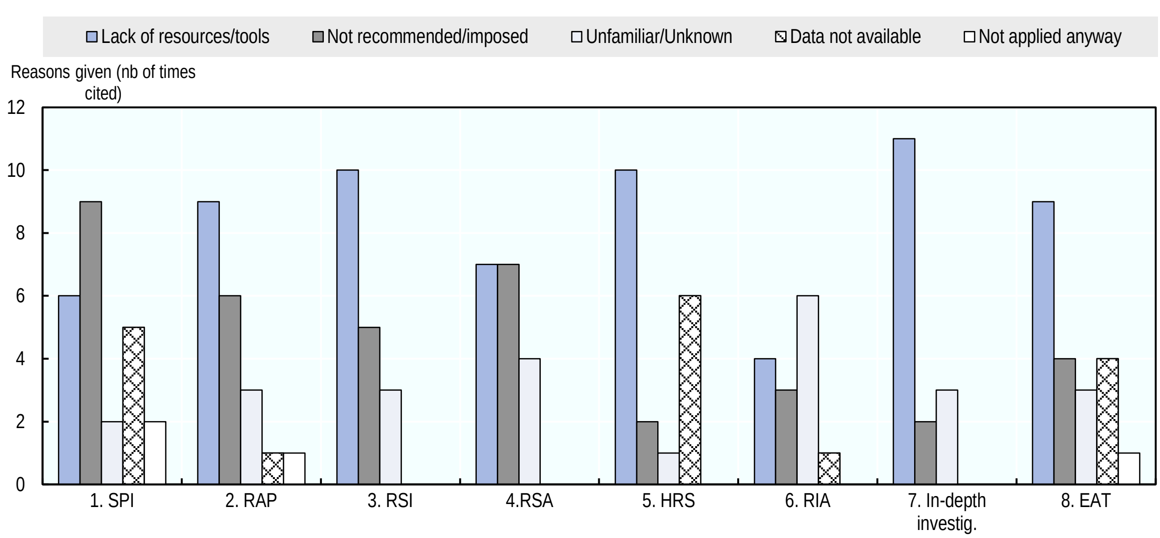
- Lack of resources/tools: costs too large, available tools and/or staff are not sufficient with respect to the effort needed.
- Not recommended/imposed: there is no regulation recommending or biding the undertaking of a procedure.
- Unfamiliar/unknown: lack of know-how about the method and data needed.

- Data not available: data needed to apply the procedure are not gathered or easily accessible.
- Other: other reasons from the above mentioned.
- Not applicable/reason unknown: A specific reason has not been identified.

Lack of resources is frequently cited as a main obstacle to the undertaking of a determined procedure. However, each procedure present specific barriers highlighted by the respondents (Figure 3.10). The most frequent issues for each procedure are synthesised below.

- SPI: The absence of a regulation requesting SPIs present a major issue. Moreover, other relevant barriers seem to be the lack of resources and the unavailability of data requested.
- RAP: Mainly not undertaken due to lack of resources and the fact that they are not compulsory by law.
- RSI: Not undertaken due mainly to lack of resources and, in countries with no regulation for RSIs, because they are not recommended or imposed.
- RSA: Frequently not carried out because there is no obligation by law. Two other reasons are lack of resources/tools and lack of knowledge.
- HRS: Not carried out mainly for a lack of resources and/or tools. Another important issue is the unavailability of needed data.
- RIA: Most common issue a lack of knowledge. Other issues cited are lack of resources/tools and the absence of a regulation imposing them.
- In-Depth Investigation: Main issue is lack of resources. Another cited issue is the lack of knowledge.
- EAT: Not carried out due to a lack of resources/tools. Other relevant barriers are the absence of a regulation, the availability of data and a lack of knowledge.

Figure 3.10. **Main reasons for not performing or data gathering for RISM**



Source: Based on data from a survey of IRTAD Members.

Country comparison

In order to assess if an RISM procedure is fully implemented in a country, an index measuring the implementation level based on survey data has been proposed. The index represents the number of stages among the six life cycle stages covered by at least a fully implemented procedure in a country. To assess the implementation level of an RISM procedure in a country the following assessment criteria have been used:[1]

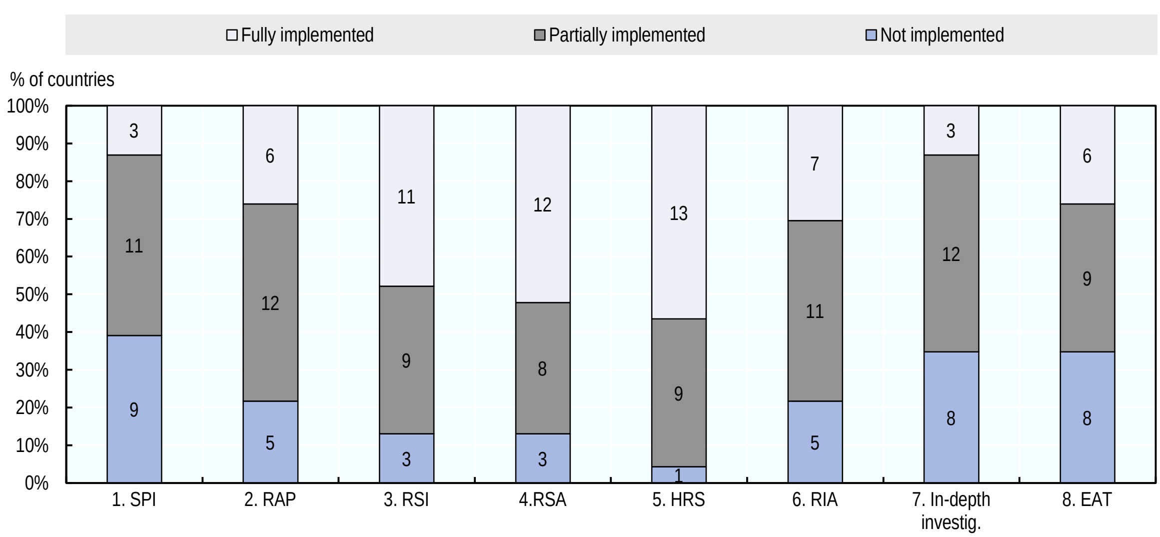
- Procedure regulated by national law (+1).
- Presence of a party responsible for carrying out the procedure (+1).
- Procedure applied to all road network (+2) or to part of the road network (+1).
- Availability of guidelines and/or software (+1).

According to these criteria three categories have been defined to assess the implementation level of a procedure in a country:

- A procedure with a score of 0-1 has been considered as "Not implemented".
- A score of 2-3 has been considered as "Partially implemented".
- A score of 4-5 has been considered as "Fully implemented".

Figure 3.11 shows the number of countries among the 23 examined that have fully implemented, partially implemented or not implemented an RISM procedure. According to this assessment, RSI, RSA and HRS seem to be fully implemented in about half of the investigated countries, while in-depth accident investigation and SPI are the procedures less "fully" implemented.

Figure 3.11. **Number of countries per implementation level of RISM procedure**



Source: Based on data from a survey of IRTAD Members.

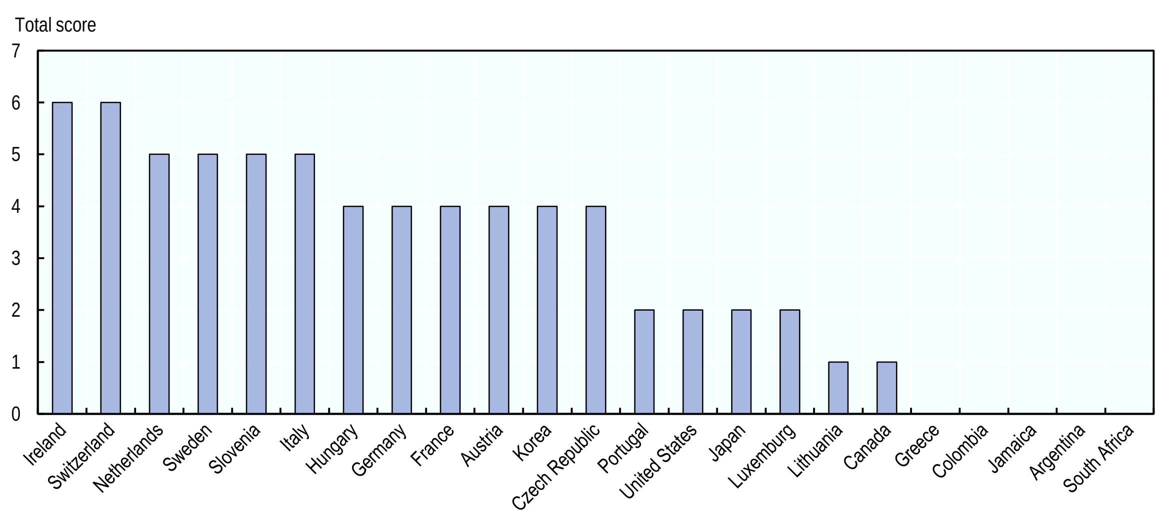
Who is implementing a pro-active approach?

The study has also assessed which of the investigated countries is implementing a pro-active approach. A pro-active approach is fully implemented in a country if one or more RISM procedures are applied in each stage of the road life cycle; the six life cycle stages of a road infrastructure being:

1. Planning and design.
2. Construction and pre-opening.
3. Normal operation.
4. Maintenance and renewal.
5. Error correction and hazard elimination.
6. Major upgrading and renewal.

The index represents the number of road life-cycle stages that are covered by at least one fully implemented procedure in a country. Figure 3.12 shows for each investigated country the total score of this index. Ireland and Switzerland seem to be the only countries applying a road safety pro-active approach, followed by Sweden, Slovenia, the Netherlands and Italy. Countries with a Federal government, like the United States and Canada, received a low score. This is mainly due to the absence of laws regulating RISM procedures at a national level in these countries, since most road safety related laws are defined at state level.

Figure 3.12. **Countries implementing a pro-active approach**



Source: Based on data from a survey of IRTAD Members.

Conclusions

In summary, the survey shows the primary reasons for not applying an RISM procedure are a lack of resources or tools, the absence of recommendations or impositions and the lack of knowledge and/or data. The lack of resources or tools is the most commonly stated reason for not applying an

RISM procedure. This has been found frequently, mainly in European countries. The absence of recommendations or impositions is also frequently noted as an obstacle, especially for SPIs, RAPs, RSIs and RSAs. This highlights the importance of the presence of some legislation regulating the application of the procedures. Finally, a lack of data has been found to be a key obstacle for SPIs, HRSs and EATs, while lack of knowledge inhibits RIAs and RSAs.

An index measuring the implementation level based on survey data has been proposed to assess if an RISM procedure is fully implemented in a country. With regard to the implementation of a pro-active approach, where one or more RISM procedures are applied in each stage of a road infrastructure life cycle, survey results highlight that Ireland and Switzerland seem to be the only countries applying a fully pro-active approach road safety, followed by Sweden, Slovenia, the Netherlands and Italy.

Notes

1. It has been assumed that in a country where there is a law regulating the procedure, it is likely that the norm is applied.

CHAPTER 4. GOOD PRACTICES OF ROAD INFRASTRUCTURE SAFETY MANAGEMENT

This chapter suggests good practices of road infrastructure safety management. It discusses solutions to the issues identified in Chapter 3 and provides examples of how they have been overcome. Solutions are discussed for enhancing data availability, creating a legal framework, ensuring adequate funding and for improving RISM knowledge and tools. Finally, the chapter discusses how RISM procedures can be integrated into general management practices for infrastructure assets.

Creating the conditions for the implementation of an RISM procedure

Data

The availability of reliable road safety related data of high quality is important for the successful implementation of a Road Infrastructure Safety Management (RISM) procedure. In general, road safety related data that may be required are detailed below.

Accident statistics

Accident statistics are data about accidents with fatalities or injuries, including information about: exact location, date and time of an accident, involved vehicles and road users, type of collision, prevailing conditions (weather, lighting, road surface etc.), road infrastructure characteristics, fatalities and injuries etc. These data are primarily collected by the Police and are organised and analysed in national databases. Accident data are required in all of the examined RISM procedures, except for the ones that address regular maintenance (Network Operation, or NO) or refer to the planning/design stage of a project, such as Road Safety Impact Assessments (RIA) and Road Safety Audits (RSA).

In-depth accident investigation data

Data gathering for In-Depth Investigation is generally carried out directly on the accident scene by a team of accident investigators. Data includes the results of the physical examination of the involved vehicles, the characteristics of the road environment and of any skid marks etc. made during the accident, as well as the interviews of persons involved in the accident (drivers, passengers and pedestrians) and witnesses and emergency service personnel that arrived on the accident scene. In-depth accident investigation data, with certain limitations, can also be gathered by secondary data sources, such as the detailed police reports for each accident. Available in-depth accident investigation data can be taken into account when performing Road Safety Inspections (RSI) or High Risk Sites (HRS) treatment, and also in the calculation of certain Road Safety Performance Indicators (SPI).

Accident causation studies

Accident causation studies are generally based on various types of accident data analysis, using either accident statistics or in-depth accident investigation data along with any other additional data. These studies are valuable for the identification of accident and injury causation factors, especially those using in-depth accident causation databases, and can offer valuable assistance in certain RISM procedures. Accident causation studies are used for the In-Depth Investigation of accidents and can also be taken into account in RIA, RSI and HRS procedures.

Safety assessment

The assessment of the level of safety provided by the examined road infrastructure is performed by an independent, qualified team of experts that examine the design of a project or the actual project itself. They then report on its crash potential and safety performance. The safety assessment is an integral part of RSA and RSI procedures and holds a vital role in RAP (especially Star Rating) and NSR procedures.

Traffic data

Traffic data concern quantified traffic characteristics (volume, speed, etc.) in specific locations of road segments, intersections and interchange ramps, as well as their variability and disaggregation by the road, vehicle and road user characteristics. These data are usually collected by road or traffic authorities on a permanent basis, but can also be collected with in-situ recording methods, when no such data are available and they are required for a specific procedure or study. Traffic data are required in many RISM procedures, such as: RIA (as an input to Accident Prediction Models), NO, calculation of SPIs, Network Safety Ranking (NSR), Road Assessment Programme (RAP) (calculation of indicators for Risk Mapping) and HRS. Additionally, traffic data can, optionally, be taken into account when conducting RSA and RSI in order to better understand the extent of a possible safety deficiency.

Road/network characteristics

The physical and operational characteristics of a specific location, a road segment or an entire road network are required for implementation of many RISM procedures. Commonly required characteristics are carriageway type and width, existence of central median, shoulders etc., horizontal and vertical alignment, intersection and interchange layout, existence of signage, lighting and traffic signalling etc. These data are collected either at a large scale, using geo-referenced video recording procedures and producing a relevant database, or with in-situ observation, when no such data are available and they are required for a specific procedure or study. Large-scale data collection is usually performed in order to implement a RAP, NO or NSR procedure, whereas more localised examinations, such as RSI or HRS investigation usually require on-site inspection of the expert team.

Maintenance data

The data required for the efficient maintenance of a road section or road network include the identification of defects on the road environment, either on a regular basis (e.g. renewal of the various elements of the road, such as road markings, road surface, safety fence, signs, vegetation cutting, cleaning of gullies and ditches), or because of unscheduled events (e.g. safety barrier reconstruction after a road accident). Such data can be collected by feedback from road users, local authorities, emergency services etc. Or, more efficiently, collection can be done by on-road patrols on a regular basis, to spot defects coming up and include the remedial operations in the maintenance agenda. Maintenance data are required in order to efficiently perform NO and NSR procedures, and can also be used in RSI.

Data about road safety measures

Data concerning possible road safety measures includes data on: the effectiveness of measures in terms of Accident/Crash Modification Factors (CMF) or Accident/Crash Reduction Factors (CRF), the actual cost of each measure's implementation, and the time required for the implementation. Such data are generally retrieved from relevant studies and handbooks that report CRFs or CMFs for various categories of road safety measures. The estimation of these factors is based on evaluation studies, typically before-and-after observational studies or meta-analysis of studies carried out in several countries. Data about the effectiveness, cost and other characteristics of road safety measures are required during Road Safety Measures Efficiency Assessment Tool (EAT), RIA and NO procedures, and are also useful in RSA, RSI and HRS procedures, in order to propose suitable interventions to address road safety deficiencies.

Measures implementation progress

Data about the progress of implementation of various road safety measures are required in order to assess the efficiency of the implemented measures, through the use of EATs. These data are usually gathered by the authorities or agencies that are responsible for the implementation (e.g. Road/Network Authorities and the Police).

This above list of data types highlights the fact that a variety of different types of road safety data and knowledge must be gathered, collated and analysed, to promote the efficient implementation of each of the aforementioned RISM procedures. An example of bringing together data from different transport related databases and successful data collation and analysis can be found at the development of Crash Analysis System (CAS), KiwiRAP and SafetyNET, by the New Zealand Transport Agency.. A summary of data and knowledge requirements for each of the RISM procedures included in Chapter 2 of the report is presented in Table 4.1.

Table 4.1 **Data and knowledge requirements for various RISM procedures**

RISM PROCEDURES	DATA								
	Accident Statistics	In depth accident investigation	Accident causation studies	Safety assessment	Traffic	Road/Network characteristics	Maintenance	Measures	Measures implementation progress
Road Safety Impact Assessment (RIA)			o		x	x		x	
Road safety measures efficiency assessment tools (EAT)	x							x	x
Road Safety Audit (RSA)				x	o	x		o	
Network Operation (NO)					x	x	x	x	
Road Safety Performance Indicators (SPIs)	x	o			x	x			
Network Safety Management (NSM)	x			x	x	x	x		
Road Assessment Program (RAP)	x			x	x	x			
Road Safety Inspection (RSI)	o	o	o	x	o	x	o	o	
High Risk Sites (HRS)	x	o	o		o	x		o	
In-depth Investigation	x	x	x						

x : required data
o : optional data

Box 2 - The example of New Zealand

The first integrated computer system to collect, map, query, and report on road accident and road safety related data was established by New Zealand Transport Agency in the 1990s. Even the early version of New Zealand's Crash Analysis System (CAS) contained data from all road accidents reported by police and provided a platform to analyse specific accidents, query accidents and visualise crash locations on a digital map of the road network. The current (2012) version of CAS allows users to:

- select road accidents for analysis
- map road accidents
- view images of the crash report diagrams
- locate and map crash clusters
- report on accidents or crash clusters
- monitor trends at accident sites
- automate the production of collision diagrams
- identify high-risk locations.

CAS has been designed to systematically link accident data with data from New Zealand's road maintenance and management system (RAMM) used by all road controlling authorities in New Zealand by linking the road data (condition, traffic flow etc.) to maps of the roads. Accident data is also linked to these maps, allowing it to be combined with road data.

Accident, traffic and road data availability, mainly through CAS, assisted New Zealand's authorities in applying an extensive Road Assessment Programme, at first in rural road network, named **KiwiRAP**. In 2012 this progressed to urban roads with **Urban KiwiRAP**. The programme is under the umbrella of the International Road Assessment Programme (iRAP), and, as with most Road Assessment Programmes, consists of three protocols:

1. Risk Mapping: using historical traffic and accident data to produce colour-coded maps illustrating the relative level of risk on road network sections. Two metrics are mapped as part of KiwiRAP: Collective Risk, based on the average annual number of fatal and serious accidents occurring per Km of State Highway; and Personal Risk, based on the average annual fatal and serious injury accidents occurring per 100 million vehicle Km travelled.
2. Star Rating: road inspections to look at the engineering features of a road (such as lane and shoulder width or presence of safety barriers). Road links are award 1 to 5 stars depending on the level of safety that is "built-in" to the road.
3. Performance Tracking: involving a comparison of accident rates over time to establish whether fewer or more people are being killed or injured and determine if countermeasures have been effective.

In addition to KiwiRAP, as far as intersections are concerned, the *High-Risk Intersections Guide* provides practitioners with best practice guidance to identify, target and address key road safety issues at high-risk intersections. The guide focuses on identifying intersections with an established or estimated occurrence of fatal and serious injury accidents, as opposed to road accidents that result in less severe outcomes. Similar to KiwiRAP Risk Mapping, the guide defines two main types of risk metric:

- Collective Risk is measured as the total number of fatal and serious accidents or deaths and serious injuries per intersection in a crash period.
- Personal Risk is the risk of Death or Serious injuries to each vehicle entering the intersection.

If specific criteria about Collective Risk and Personal Risk values are met, an intersection is characterised as "high-risk".

Building on the analysis performed by KiwiRAP, the *High-Risk Rural Roads Guide* defines a rural road as being high-risk when specific criteria regarding the Collective (fatal and serious accident density) or Personal (fatal and serious accident rate) Risk Rating and/or KiwiRAP Star Rating are met.

The above programmes and guides provide useful guidance on what constitutes "high-risk" road infrastructure for the purposes of targeting road safety improvements. However, it was soon discovered that through these methods a large proportion of the country's road infrastructure was classified as "high risk" (approximately 57% of State Highway network). Further priorities had to be set, in order to effectively target road safety investigations and investments, on the basis of *Safer Journeys* implementation, New Zealand's Road Safety Strategy 2010-20.

Therefore, New Zealand Transport Agency commissioned the development of **SafetyNET,** an innovative online interactive road safety tool that brings together a number of transport datasets and combines this data with industry knowledge. SafetyNET builds on the structure provided by the *High-Risk Rural Roads Guide* and provides a more detailed means at assessing the State Highway network so that high-risk areas that warrant attention can be readily identified. Six performance indicator thresholds are used to identify high-risk areas that warrant attention:

1. Collective Risk of "High" or "Medium – High" (derived from KiwiRAP).
2. Personal Risk of "High" or "Medium – High" (derived from KiwiRAP).
3. Star Rating of 1 or 2 stars (derived from KiwiRAP).
4. The injury performance indicator threshold for a 5km road segment, where the actual number of reported injury accidents is greater than the predicted number of injury accidents derived from the *High-Risk Rural Roads Guide*.
5. The fatal and serious injury indicator threshold for a 5km road segment, where the actual number of reported fatal and serious injury accidents is greater than the predicted number of fatal and serious injury accidents derived from the High-Risk Rural Roads Guide.
6. The injury performance indicator threshold for a 500m road segment is where the actual number of reported injury accidents (annually averaged over the past five years) is greater than the predicted number of injury accidents derived from the *High-Risk Rural Roads Guide*.

The six indicators are combined to create a summary indicator, known as the Investigation Priority Rating (IPR) indicator. The IPR indicator provides an overview of the overall performance and risk profile of a road segment against the defined threshold metrics.

Legal framework

An adequate legal framework is important to permanently establish procedures for road infrastructure safety management in a country. The *2013 Global status report on road safety* (WHO, 2013a) recommends reviewing existing legislation to conform to good practice based on sound evidence of effectiveness.

As highlighted by the results of the RISM survey, the absence of recommendations/impositions is seen as one of the major reasons for not implementing RISM procedures, especially for SPI, RAP, RSI and RSA. It is difficult to determine what prevents enacting a road safety law, as the process is influenced by various factors. In general, one may think that regulation on infrastructure management is less common. In fact, road infrastructure related legislation is usually focused on road network design through standards of design and construction that deliver roads and facilities that conform to best practice. Road safety data, highlighting the evidence of an increasing trend in injuries and/or the presence of road sections with a high concentration of road accidents help direct the attention of road infrastructure related safety issues. A manual by the World Health Organization addresses these issues and identifies a list of factors that may contribute to initiate a legislative action at a national level:

"While traffic statistics can often spur legislation, they are not the only driving forces; other factors include, political will and high-level commitment (especially for legal reform), public pressure, a personal road related tragedy in a law-maker's family, and changes in social norms and values. Global commitment and recommendations on best practice from international policy-making and technical institutions such as the United Nations can also prompt the reform of road safety laws." (WHO, 2013b)

The manual describes methods and resources that practitioners and decision-makers can use for enacting new laws or regulations, or amending existing ones as part of a comprehensive road safety strategy. For instance, as statistics significantly influence policy and legislation, an efficient and comprehensive road accident data management system is fundamental. Moreover, information about the potential economic benefits of the implementation of a regulation may also help support a legislative action.

Good practices and recommendations can be used as a reference to support the design of national road safety laws and regulations. When considering road infrastructure safety management, a good example is the European Directive 2008/96/EC. This requires the establishment and implementation of procedures relating to road safety impact assessments, road safety audits, the management of road network safety and safety inspections. A case study of the application of this Directive is made on Austria, which decided to apply the provisions of the Directive on the entire motorway network (see Box 3).

Box 3 - Infrastructure Safety Management on Austrian Motorways

EU Directive 2008/96/EC on road infrastructure safety management was transposed into Austrian national law by adding two articles to the Austrian National Roads Code (Bundesstraßengesetz1 1) in 2011. The Code now foresees all tools of the Directive to be applied to the Austrian sections of the Trans-European Road Network (TERN). The Austrian motorway agency ASFINAG2 – an executive agency under the Austrian Ministry of Transport, Innovation and Technology (bmvit) – is responsible for implementing the tools. Although not required by the Directive, ASFINAG applies Infrastructure Safety Management on all sections of its 2175 km network of motorways and expressways (as of 2012), i.e. including those that do not belong to the TERN. The whole network is subject to a road toll (toll stickers for cars and on-board units for mileage-dependent charging for HGV >3.5t).

Figure 4.1. **The ASFINAG network**

Source: ASFINAG

The FSV[3], the Austrian Association for Road-Rail-Transport, has issued the following guidelines in the field of infrastructure safety management:

- RVS 02.02.21 Road Safety Analysis (including Accident High Risk Sites; last update: 2004)
- 02.02.33 Road Safety Audit (last update: 2012)
- 02.02.34 Road Safety Inspection (last update: 2012)
- 02.02.35 Certification of Road Safety Auditors and Road Safety Inspectors (last update: 2012)

The application of all but the first guideline is mandatory for the ASFINAG network and recommended on all other roads. The guidelines are available for a fee at the FSV (in German). The bmvit issued a handbook on RSI in 2009[4] and subsidised the drafting of a KFV-Handbook on Road Safety Audits[5].

Box 4 - New road safety programs and legal responsibilities of road authorities

Road safety programmes are implemented for the sake of improving the safety of road users in general. They are not intended for identifying defects of roads or demanding legal responsibility of road authorities in charge of developing and managing roads. However, for road authorities, it is natural to worry about legal liability issues after the introduction of some road safety programmes such as RSA. An RSA is intended to identify possible risks in the road design and to suggest remedial actions to prevent or to reduce those risks. But suggestions cannot always be implemented, due to budgetary, technical, or institutional constraints. In this situations an individual could exploit those unimplemented suggestions as proof that road authorities did not take their responsibility seriously enough.

In the United States, introduction of RSA has been an issue because of legal liability concerns. However, it is now well implemented in many States, resulting in good safety performance of road infrastructure. Owers and Wilson (2001) investigated legal liability issues and RSA in the United States and concluded that it should be implemented by a transportation entity. In the study, they tried to answer two fundamental questions related to implementation of RSA. The first is whether RSA adds value to road authorities and the second is whether the RSA is legally defensible. They concluded with positive answers to both questions. They also emphasised that, "from a utilitarian perspective, the public policy of improving road safety for all road users must reign supreme over the competing policy favouring the plaintiff's redress of his or her harm that favours the individual over the many". They even recommend a legal statute that protects road authorities from litigation in this area. The Federal Highway Administration provides some information on legal issues around RSA on their website. Their survey on RSA in the United States shows that there is no correlation between the application of RSA and whether or not the State had sovereign immunity. Another finding is that liability is one of the major driving factors in performing a good RSA. It can demonstrate proactive efforts of road authorities to identify and mitigate safety concerns. When findings from RSA cannot be implemented, an exception report is developed to address liability and mitigating the recommended measures

Aforementioned legal liability issues can be raised in any countries trying to introduce new road safety programmes such as RSA, RAP, RSI, and RIA. However, it should be noted that all these proactive efforts for road safety can protect road authorities from possible legal liability issues, as US studies on RSA suggest. Application of road infrastructure safety programs is particularly important since they can fill in the gaps that a typical design standard can bring about. Abiding by design standards is essential to protect road authorities from legal liability but perhaps some further efforts are necessary, as a design standard cannot always guarantee safer road infrastructure. Refer to Box 10 for further information on the relation between safety and design standards.

Funding

Improving safety performance of road infrastructures requires, firstly, a funding system for prioritising current resources or for seeking additional resources; and, secondly, an allocation and implementation process that delivers resources to where the greatest benefits will be generated (OECD/ITF, 2008). RISM is an important investment to improve road safety resource allocation, because it gives the possibility to funnel available resources into those interventions on the road network that are likely to produce the highest benefits for the society. In other words, it helps to make the use of available resources more efficient. Procedures such as RIA, HRS and EAT help better target infrastructure related resources to high-risk parts of the road network or to the most cost-effective solutions.

Obviously, without reliable and stable funding, no serious actions can be taken to improve road safety. However, road safety is not the only priority when planning and designing a road network. A study that investigated investment and maintenance expenditure in transport infrastructure of over 50 countries showed that advanced economies and emerging economies have different priorities for the infrastructure development (OECD/ITF, 2013a). Middle-income countries focus mainly on construction and rehabilitation of the road network, while in high-income countries most funds are dedicated to improving the performance and safety of infrastructures. Emerging economies in particular, need to find out how to increase the total volume of resources available for road safety in order to apply RISM procedures. Nevertheless, it must be emphasised that the recent economic crisis has had an impact on funding for transport infrastructure in most of the countries examined by the study. Moreover, available trends suggest an overall declining share of maintenance from total road spending, especially over the last few years. This means advanced economies had also reduced the budget available for investment and maintenance of roads (OECD/ITF, 2013a).

As highlighted in the previous chapter, a lack of resources is indicated as one of the primary barriers for RISM. It is therefore important to understand what funding frameworks exist to ensure adequate funding levels to carry out one or more RISM procedures. Road investments and maintenance are generally publicly financed, usually through a combination of contributions from the general state budget and fuel taxes. The items funded vary considerably between countries. In some countries a small percentage of the road fund is allocated to support road safety (e.g. New Zealand) (GRSP, 2005). Other revenues that may be used for road safety purpose include: automobile import tariffs, vehicle registration and licensing fees, driver licensing fees and motorway charges. Some countries levy a fee on vehicle insurance premiums to help fund road safety activities, but the amount of funding raised is often small and used to fund education and road safety campaigns (OECD/ITF, 2008). Furthermore, some taxes can be earmarked for specific road safety purposes. In some countries, revenue from traffic fines is used to finance road safety activities. An example is Great Britain, where the additional income generated by traffic law enforcement is allocated to support better traffic law enforcement programs. However, in the long term, better traffic law enforcement will reduce the funds available from traffic fines.

Box 5 - The National Safety Camera Programme in Great Britain

In Great Britain, transport and police budgets cover expenditure on traffic policing, accident investigation, road safety research, publicity and media campaigns and administration of road safety policy. The Highways Agency is funded from general taxation for both new general road schemes and safety focused improvement schemes on motorways and trunk roads. Local Highway Authorities also have a statutory duty for safety of the roads for which they are responsible and produce Local Transport Plans containing local road safety strategies. Their activities are funded through their annual capital settlements, which reflect their bids in their Local Transport Plans, but there is at present no ring-fenced budget for road safety. Non-capital expenditure, for instance the activities of road safety officers, is funded out of local government grant income and local Council Tax. In 1998, the national government decided to allow local road safety partnerships to recover their enforcement costs, subject to strict criteria to prevent abuse. In 2000, the new system was introduced for eight pilot areas, with a national programme subsequently established.

Speed and red-light enforcement cameras (referred to collectively as "safety cameras") were first deployed in the early 1990s. It was soon concluded that, while cameras were effective at reducing traffic accidents, the full benefits were not being realised due to budgetary constraints (i.e. insufficient funding to cover installation and running costs). The same study noted that these constraints could be removed by allowing local road safety partnerships to recover their enforcement and other related costs from fines incurred by offenders. Since 2000 there has also been separate funding for safety cameras in Great Britain through a cost recovery programme funded out of the fine income from camera operations. This has been administered through a national board and in each area there are local camera partnerships that include local authorities, Magistrates Courts, the Highways Agency and the Police. There was a positive benefit to cost ratio of around 2.7:1. In the fourth year, the benefits to society from the avoided injuries were in excess of GBP 258 million compared to enforcement costs of around £96 million.

The public supported the use of safety cameras for targeted enforcement. This was evidenced by public attitude surveys, both locally and at a national level, that have shown support consistently from at least 70% of respondents."

(Source: OECD/ITF, 2008. Towards Zero: Ambitious Road Safety Targets And The Safe System Approach).

Funding sources may vary with respect to the agency responsible for an RISM procedure. In general, as road operators are involved, a percentage of road funds, eventually integrated by other contributions, should be dedicated to support road infrastructure safety management activities. Since 1982, the World Bank has had funding guidelines on the road safety component that should be included in road projects. According to these guidelines road safety funding should constitute 5-10% of total project costs. These funds should be allocated to a much more comprehensive system of road infrastructure appraisal and assessment and related road safety measures (Make Road Safe, 2006). The European Union is supporting the implementation of Europe's strategic TEN-T transport network (and Directive 96/2008/EC) through several financial instruments; the TEN-T programme; the European Cohesion Funds; the European Regional Development Fund; and the European Investment Bank's loans and credit guarantees, including its new Project Bond (OECD/ITF, 2013a).

An evaluation framework should be developed to prioritise possible interventions, including RISM, and identify the socio-economic returns of expenditures on road safety. The goal is to channel available resources into those road safety activities that are likely to produce the maximum benefits for society. The body of evidence available to road safety managers means that road safety allocation mechanisms can be underpinned by rigorous cost-benefit analyses (OECD/ITF, 2008).

Optimising an RISM procedure

Knowledge

A European research project (ROSEBUD) identified lack of knowledge as a potential barrier for developing EAT in a country. One of the solutions suggested by the study is a better training of professionals in the area (Elvik and Veisten, 2005). RISM procedures need an adequately trained staff in order to ensure that are effectively performed. Potential barriers to this may reside in a lack of road safety education in universities, a lack of specialised professional training and a lack of standardisation in training.

Road safety encompasses various expertises in fields such as engineering, education, psychology, law enforcement and medicine. It rarely has a dedicated degree course in academic curricula but it frequently appears as a part of a university course (e.g. in transport planning courses). A study on the workforce road safety education and training carried out in the United States (TRB, 2006) reported that there were a limited number of safety courses available in universities and that many courses do not provide the needed knowledge, skills or perspective. Therefore, the same study explores "core competencies" for a safety professional, intended as the "minimum set of core knowledge, skills, and abilities to begin functioning effectively in the highway safety field". These are:

- Understand the management of highway safety as a complex multidisciplinary system.
- Understand and be able to explain the history of highway safety and the institutional settings in which safety management decisions are made.
- Understand the origins and characteristics of traffic safety data and information systems to support decisions using a data-driven approach in managing highway safety.
- Demonstrate the knowledge and skills to assess factors contributing to highway accidents, injuries, and fatalities, identify potential countermeasures linked to the contributing factors, apply countermeasures to user groups or sites with promise of accident and injury reduction, and implement and evaluate the effectiveness of the countermeasures.
- Be able to develop, implement, and manage a highway safety management programme.

Road Infrastructure Safety Management professionals usually have a strong civil or transport engineering background. In the UK, for instance, the most appropriate candidates for Audit Team Leader and Audit Team Member roles are individuals whose current employment involves Accident Investigation or Road Safety Engineering on a regular basis[6]. However, this is not always the case, for example, physicians, psychologists and policemen may be part of an accident In-Depth Investigation team.

Capacity building initiatives should start with the formal education in road safety disciplines offered at universities and colleges and extend to further on-the-job training. However, post-graduate courses for professionals in a country may be totally absent, rare or may not meet the knowledge and skills requirements to perform a specific RISM procedure. For countries that do not have institutions that offer appropriate safety courses, managers should consider sending their staff to one of the many road-safety courses offered, for example in Australia, New Zealand, Canada, the Netherlands, UK or the United States.

For instance, road safety training courses have been activated in the Netherlands, Belgium and India: the "Delft Road Safety Courses"[7], the "Traffic Safety in Asian and Latin American Countries: Principles and Approaches"[8] and the "International Course on Transportation Planning and Safety"[9]. These courses typically run for one to two weeks and are specifically targeted to post graduates and road safety professionals from low- and middle-income countries. The main content of these courses relates to policy development and implementation of road safety plans, financing, evaluation methods and technical safety measures in the area of engineering, enforcement and education. However several other courses are available worldwide which treat more specifically, for example, the fundamentals of road infrastructure safety management, network screening, road safety audits and inspections, etc. For instance, further post-graduate road safety courses available in the United States are reported in the *Highway Safety Manual Training Guide* (McGovern and van Schalkwyk, 2011).

Box 6 - *Highway Safety Manual Training Guide*

The AASHTO *Highway Safety Manual* (HSM) provides transportation practitioners with knowledge, techniques, and methodologies to quantify accident frequency and severity and integrate that information into roadway planning, design, operations, and maintenance decisions. The *Highway Safety Manual Training Guide* focuses on identifying HSM training currently available in United States to state and local agencies that are considering implementation of the HSM. The guide identifies key focus groups that can be used as a basis for identifying particular training needs and sequence of training:

- The Management focus group represents professionals and management that are not intricately involved in the planning, design, and operations and maintenance activities (e.g., transportation administration and decision makers).
- The Planning Focus Group includes those involved in the development of long and short range plans, corridor studies, environmental assessments, and alternatives assessment.
- The Design Focus Group includes those involved in project scoping, preliminary design, and final design, including alternative comparisons.
- The Operations and Maintenance Focus Group includes those who conduct operational analysis and develop traffic control plans.
- The Safety Analysis Focus Group includes those who are responsible for collecting and analysing roadway safety data, system safety performance reviews, accident investigations, safety assessments and audits, and/or countermeasure selection.

For each focus group the guide suggests appropriate course modules from the ones available and sequence of training.

In 2010, the IRTAD Group initiated twinning programmes with a view to assist low- and middle-income countries (LMIC) in developing and improving their accident data collection and analysis system. These programmes consist of a special co-operation between an existing IRTAD Member and a sister organisation in a LMIC in order to audit existing system and provide recommendations on further developments. "The ultimate goal is that these countries become after the programme full and permanent member of IRTAD providing national safety data on a regular basis for inclusion in the IRTAD database" (ITF/OECD, 2012). These programmes are funded by voluntary contributions. Three twinning projects have been launched so far: Argentina and Spain, Cambodia and the Netherlands, Jamaica and the UK.

The Road Traffic Injuries Research Network is an example of a university based research collaboration. The association facilitates networking and creation of partnerships by connecting researchers in developing countries to the international traffic safety research community. The network has sponsored training, meetings, pilot research projects, a Listserv, and an electronic newsletter (Road Traffic Injuries Research Network).

If sufficient training funding is not available, a country should consider developing its own training curricula based on the many reference materials that are available. A good starting point is a freely downloadable TRB report (TRB, 2012) that provides a broad overview of the *Highway Safety Manual* format and procedures. The enclosed CD-ROM includes presentation slides with speaker notes, participant hand-outs, interactive sample problems, smart spreadsheets, and similar supporting documents.

In general, on-the-job experience is fundamental in order to gain valuable knowledge. However, even if road safety professionals are available in a country to perform some RISM procedures, there could still be a lack of standardisation in the applied tools and procedures. This was an issue reported when implementing road safety audits and inspections in Mexico. RSIs are not yet nationally legislated and compulsory but Mexican authorities have been carrying them out throughout the entire country for a few years. Mexico has implemented an annual programme by which potentially risky roads are identified and then audited. Most (traditional) auditing work has been done on the main corridors which link the most important locations in the country such as state capitals, cities, ports and borders[10]. CAPUFE (Federal Roads and Bridges Commission), as part of a Road Safety working group, developed a software suite by which CAPUFE's toll roads are audited by a qualified team of auditors trained by CAPUFE. The Secretariat of Communications and Transportation (SCT) and the Health Secretariat provide training courses on RSA that are available for both public and private staff involved in operation, maintenance and management of roads. These local and national road-related entities, located in different states, are expected to have their staff trained for later organising auditing teams and carrying out the RSAs.

However, training, accreditation and further education of auditors is still not standardised across the entire country. Mexico is aiming at providing standardised and certified courses. This implies substantial changes to regulations, guidelines and manuals and is a bureaucratic process that has not concluded yet. The process should lead to certified professionals able to apply standardised procedures within the country.

The European Directive on road infrastructure safety management with respect to RSA, states that Member States shall ensure that a qualified auditor is appointed to carry out this work. The EURO AUDITS project recommends including in training requirements: the need for pre-auditing experience, formal training, certification of competence, and periodic re-training (Falco et al., 2007). In the UK and Ireland, an RSA team member is required to have previously attended at least ten days of formal training in accident investigation or road safety engineering to form a solid theoretical foundation on which to base practical experience. An example of how training and capacity building issues have been treated in Austria is given in Box 7.

Box 7 - Education and training of auditors and instructors in Austria

In Austria, road safety auditors and inspectors undergo a joint five day course organised by the FSV. As of mid-2013, around 200 experts have attended the course, which features a comprehensive set of issues including:

- Road planning and maintenance.
- Facilities and measures for pedestrians, cyclists, and powered 2-wheelers.
- Planning of urban roads and intersections.
- Road furniture and optical guidance.
- Lighting technology.
- Traffic control and traffic lights.
- Aspects of large vehicles.
- Accident analysis and treatment of high-risk sites.
- Psychological aspects.
- Human perception.

RSA or RSI contracts are only being granted by ASFINAG to certified auditors and inspectors. The certification, issued by the bmvit, requires completion of the above course, a university degree in a relevant field (or adequate alternative education) and several years of work experience in the planning and road safety fields. As of mid-2013, a total of 17 certificates had been issued. The list of experts is available on the bmvit website (in German)[11].

Tools

Making dedicated manuals and guidelines accessible can and promote the implementation of a road safety oriented approach through facilitating the use of RISM procedures by road administrations. The survey results presented in Chapter 3 highlight several tools to assist practitioners in managing safety of road infrastructures. However, it is not certain that these tools will be used, even if available, as they may not meet the safety needs of road administrations. Furthermore, the details of assessment and evaluation tools may not always be available or well documented, making it a challenge to access these as a ready resource (Schemes et al., 2011). Moreover, it should be noted that road safety varies from country to country and the likely limitation of resources, especially for local road agencies and road administrations in developing countries, should be taken into account.

Therefore, it is important to ensure that tools and procedures are practical and relatively easy to apply. In this sense, guidelines could represent a useful resource for practitioners. Examples of clear and comprehensive guidelines are the ones used in UK and Ireland for conducting RSA and RSI (see Box 8).

Box 8 - UK Guidelines of Road Safety Audits

The first guidance on RSA was firstly introduced in UK in the 1990s. At present, RSAs in the UK are conducted in accordance with HD19/03 of the Design Manual for Roads and Bridges: Volume 5. The manual includes:

- Definition of relevant terms used.
- Scope of the audit and definition of the relevant schemes and stages in the design and construction process at which audits shall be undertaken.
- Audit Team Training, Skills and Experience.
- Auditing process and the requirement for monitoring highway improvement schemes after opening.
- Checklists and examples of audit reports

An RSA is defined as a process for checking the safety of highway improvement schemes. There are some key factors that are highlighted in the guidelines:

- RSA is a **formal process** carried out systematically.
- RSA is **restricted to road safety** matter. The scope of RSA is not a technical check that the design conforms to standards and it does not consider structural safety.
- RSAs are conducted from the **road users' point of view.**
- RSAs are carried out by a team **independent** from road designer and builder.

On UK trunk roads and motorways, RSA are mandatory for all new road and improvement schemes (HD19/03), while on local UK roads they are recommended as good practice (1988 Road Traffic Act implies a requirement for new roads). There are four stages within the design and implementation of a highway scheme when a RSA might be undertaken:

- Stage 1: Completion of Draft Design
- Stage 2: Completion of Detailed Design
- Stage 3: Completion of construction (Pre-Opening Stage)
- Stage 4: Monitoring (1-3 years following construction)

The audit team has to be independent of the design team and requires at least two people: an Audit Team Leader and an Audit Team Member (Observers may also join the team to gain experience in RSA). Auditors should have relevant experience and training. For instance, the Audit Team Leader is required to have a minimum of four years accident investigation or road safety engineering experience, to have completed a minimum of five Road Safety Audits, and should have attended at least ten days of formal accident investigation or road safety engineering training.

In carrying out RSAs, the auditors should consider road safety issues for all road users and will ask two key questions of the scheme: 1) Who could be hurt and why?; and 2) What can be done to reduce the risk? At all stages the Audit Team prepare a written report, including the specific road safety problems identified, supported with the background reasoning; and recommendations for action to mitigate or remove the problems. It is important to stress that the audit report details aspects of the scheme design of concern to the Audit Team and their recommendations for addressing these. The designer may choose which recommendations to accept and incorporate in the design and which ones not to accept. The designer should provide their response to the RSA recommendations in an Exceptions Report.

In order to consider the needs of non-motorised users and support efforts to increase safety and accessibility by non-motorised modes, standards for Non-motorised User Audits have been introduced in 2005 (HD 42/05).

The cost of undertaking a RSA ranges from around £800 for a minor access to a development to £2,000 for a major signal junction (Sustrans, 2011).

Surrey County Council (1994) in the UK undertook a study of 19 audited and 19 non-audited traffic schemes. For sites with audited schemes, the average number of casualties dropped by 1.25 per year (from 2.08 to 0.83) while casualty accidents at the un-audited sites dropped by only 0.26 per year (from 2.60 to 2.34).

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In order to support decision makers in the quest to select appropriate road safety measures, some of the most important international initiatives for providing standardised and accurate methods or tools for the estimation of safety effects of road safety measures are presented in Table 4.2. Further tools can also be found in Annex 7.

Apart from international initiatives listed in Table 4.2, national approaches and initiatives for providing standardised and accurate methods or tools for the estimation of safety effects of road safety measures also exist in several countries worldwide. Specifically, such national approaches and initiatives are available in Australia, Austria, Canada, Finland, Germany, Greece, Ireland, Japan, the Netherlands, Norway, Spain, Sweden, the United Kingdom and the United States of America. References to tools and guidelines used in these countries are given in the Annex.

Table 4.2. **Selected international initiatives for effects estimation of road safety measures**

Initiative	Description
The Handbook of Road Safety Measures (Elvik et al., 2009)	The handbook aims to provide a systematic overview of current knowledge regarding the effects of road safety measures, by presenting state-of-the-art summaries of current knowledge regarding the effects of 128 road safety measures. The types of measures that are included are road design and road equipment, road maintenance, traffic control, vehicle design and protective devices, vehicle and garage inspection, driver training and regulation of professional drivers, public education and information, police enforcement and sanctions, post-crash care and general purpose policy instruments.
The Highway Safety Manual (AASHTO, 2010)	The *Highway Safety Manual* (HSM) aims to introduce a science-based technical approach and to provide tools for conducting quantitative safety analyses. This allows safety to be quantitatively evaluated alongside other transportation performance measures such as traffic operations, environmental impacts, and construction costs. In particular, the HSM provides a method to quantify changes in accident frequency as a function of cross-sectional features. With this method, the expected change in accident frequency of different design alternatives can be compared with the operational benefits or environmental impacts of these same alternatives.
The Rosebud Handbook (ROSEBUD Consortium, 2006)	Within the activities of the Rosebud thematic network, a handbook titled *Examples of assessed road safety measures - a short handbook* was issued in July 2006 as the main outcome of the Rosebud project. The handbook includes information about various assessed road safety measures. The assessment methods used are cost effectiveness analysis (CEA) or cost-benefit analysis (CBA). In CEA, the costs of a measure are confronted with its effects; the effects of the measures are not expressed in monetary terms. On the contrary, in CBA the result of the evaluation is obtained by comparing costs with benefits. Economic evaluation of road safety measures using cost-benefit analysis is based on the costs incurred as a result of road accidents. Avoiding such costs represents the economic benefit of road safety measures. The benefit-cost ratio represents the economic advantage of the safety measures.
The FHWA Clearinghouse CMFs (n.d.)	The Crash Modification Factor (CFM) Clearinghouse is home to a web-based searchable database of CMFs along with supporting documentation to help transportation engineers identify the most appropriate countermeasure for their safety needs. In addition to search functions, one can also submit CMFs to be included in the clearinghouse. CMFs are rated using a five star system for quality; five stars are needed for a CMF to be included in the HSM. Stars are applied based on a review of five criteria: study design; sample size; standard error; potential bias; and data source.

Further RISM procedures and processes

A main objective in road infrastructure safety management is to implement a pro-active approach that takes into account all life cycle stages of a road. This can be accomplished by developing and applying an RISM system able to take action with appropriate procedures in all the six life cycle stages, and by integrating safety related procedures in asset management and life cycle management practice. This section describes the required organisational structure as well as the associated human and financial resources required to implement more procedures and to integrate road safety in asset management practice.

Dealing with more RISM procedures

The commitment to a proactive approach for RISM requires several key factors: a supportive legislative framework; adequate and stable funding; extensive knowledge; and suitable tools and methods. An adequate organisational structure is a further key factor to support the implementation of effective RISM. As recommended in OECD/ITF (2008), adequate management capacity requires the "identification of a lead agency and definition of the roles, responsibilities and accountabilities of key road safety organisations and individuals and the delivery of related management functions critical to success". The Austrian experience of dealing with the four procedures suggested by the EC Directive 96/2008 is detailed in Box 9.

However it is not the case that an extensive use of all RISM tools automatically ensures a superior road safety performance (Elvik, 2010). There is no need to implement all RISM procedures. However, there is also no one procedure that is better than the others. Countries should find the procedures that fit their situation and needs.

Box 9 - Safety management tools in practice

This box outlines the use of RISM tools in relation to EU-Directive 96/2008/EC by the Austrian motorway and expressway operator ASFINAG. ASFINAG has concluded a framework contract for integrative accident analysis on its network with the KFV (*Kuratorium für Verkehrssicherheit*) for providing statistical reports and section-wise indices and ratings (such as on accident cost rates) on an annual basis.

Road safety Impact Assessment (RIA)

According to the Austrian National Roads Code RIA is a strategic and comparative analysis of the impact of a new – or substantially modified – national road on road safety of the network. RIA is to be applied before new construction of a section exceeding 2 kms in length, or before the closing down of a road section. The ASFINAG submits the relevant RIA results to the bmvit for approval before or together with the first stage (permit application) planning materials. In addition to the requirements of the Directive, the socio-economic costs of accidents are included within the investigation framework and the "zero option" (i.e. "build nothing") is also assessed.

Road Safety Audits (RSA)

ASFINAG tenders road safety audits for all construction projects for new sections in four phases. Prior to implementing the Directive there were only three stages; the requirement for an additional audit shortly before traffic approval was a new stage introduced in 2011. Audits are also carried out during the current extensive roadwork and renovation projects of the ASFINAG network. ASFINAG has proactively contributed to the FSV's training and further education track for auditors.

Adding the fourth audit phase (before opening to traffic) can pose timing problems in practice. If done too late, the construction staff and machinery may already have left the work zone (and re-instalment is unfeasible with time and financial restrictions). If done too early, the picture of the finished road might be difficult to envisage for the auditor.

Road Safety Inspections (RSI)

The ASFINAG tenders RSIs for at least 150 km of the network for thorough analysis, whereby the Austrian RSI Handbook and the RSI checklist included therein are to be applied. On this basis, every section of the whole network should undergo inspection by an independent expert around every ten years. The road sections in need of thorough inspection are subject to a distinct prioritisation process (on the basis of accident rates) and deficiencies are to be consistently fixed. In addition, the entire network undergoes regular (usually annual) RSIs by ASFINAG road surveyors, based on simplified criteria. Employees of the ASFINAG Road Services are trained on the basis of the inspection results in order to be able to better detect emerging problems during their daily maintenance visits.

To further improve the quality of its network ASFINAG invited "ASFINAG Pilots" – a number of dedicated frequent drivers, private or business related – to provide ASFINAG with their observations of the road, e.g. potholes, road cracks, lane grooves, storm and thunderstorm damage, hidden or unrecognisable traffic signs, and deficient signage of roadwork zones.

Treatment of High-Risk Sites

ASFINAG receives from KFV annual rankings of high-risk sites in accordance with the procedures and definitions laid out in the Austrian Guideline RVS 02.02.21. The definition of a High-Risk Site (a road section of up to 250 m length or junction) is as follows:

- At least three similar injury accidents (according to collision type) in three years, at a traffic volume (expressed as the average annual daily traffic, or AADT) of up to 10 700, or at least four injury accidents at an AADT of up to 16 700, five at 22,600, and six at 28,600
- At least five similar accidents (including damage-only) in one year.

ASFINAG decides on adequate treatment in the course of a process that also involves representatives such as of the district authorities, the police and KFV. Implemented measures are reported to the bmvit (by the relevant regional authority, one of nine in Austria) and evaluations are to be carried out within two years after implementation of the treatment.

Network Safety Ranking

ASFINAG developed a methodology for safety ranking (based on accident cost rates) of its network, which is largely based on the German ESN methodology. The KFV provides to ASFINAG an annual safety ranking for the approximately 270 sections of the network (usually covering accident data for the three preceding years). The ranking, together with detailed information on accident characteristics, informs the decision on which immediate measures are to be taken on the most costly (in terms of costs to society) of those sections, i.e. those sections with the highest potential for accident reductions.

Future developments

In its Road Safety Programme, ASFINAG commits itself to compile the findings from audits and inspections, and to feed them back to planners and ASFINAG personnel.

Study on typical design deficiencies as revealed from RSA

The first RSAs in Austria that were carried out by independent experts date back to 2003. Between 2003 and 2012, more than 80 audits were carried out for various construction, reconstruction and work zone projects in different stages. The audit reports were jointly analysed in an unpublished study in 2013 (carried out by KFV, assigned by ASFINAG). The focus of this study was especially on the lists of design deficiencies (by auditors) and the subsequent comments (by planners). Some of the groups of deficiencies identified were:

- Cross sections (such as too wide or narrow, inconsistent, missing hard shoulders, improper design of roadsides).
- Crossfall/superelevation (such as insufficient drainage, too sudden changes).
- Horizontal alignment (such as lacking consistency/uniformity, too low radii).
- Vertical alignment (such as excess longitudinal gradient).
- Road restraints.
- Road furniture.
- Sight distances.

Between 39% and 47% (depending on the audit stage) of stated deficiencies were taken into account in further phases of the design process. Among the reasons for dismissal of auditor's recommendations were:

- Design deemed adequate with respect to road safety, or design considered safer than auditor's recommendation, or auditor misinterpreted features of the design, or dissenting interpretation of the RVS Guidelines.
- Design in accordance with RVS Guidelines.
- Deficiency not part of the project.
- Implementation not possible due to lack of space, or other external factors.
- Ecologic reasons.
- Economic reasons.

Various conclusions and recommendations for future contents and design of guidelines, for auditors, as well as for planners and the contracting bodies were drawn from the study,. They will be passed on to the relevant entities in due course.

Revision of the Austrian RSI Handbook

The RSI Handbook was issued in 2009 and instructs users to list deficiencies and recommendations in a table, including the urgency with respect to road safety (low, medium, high) and time frame for implementation (short-, medium-, long term). The various RSIs carried out during recent years show that the inspectors' appraisals of these two dimensions vary widely, even if similar deficiencies and remedial measures are in question. Therefore, bmvit revised recently the Handbook (2014), so as to give better guidance to inspectors in this area.

Safety-related management practice

Transportation management strategies are used for managing and addressing needs in transportation projects. In addition, they contribute to improving the performance of transportation systems, and modify travel behaviour without costly infrastructure improvements. The basic goals of transportation management strategies are to (Yusoff et al, 2005):

- Maintain and improve the capital infrastructure of the existing transportation system.
- Preserve the national transportation system to maximise the efficiency of carrying people and goods.
- Provide a safe and secure transportation system that allows for the movement of people and goods.
- Provide a transportation system that supports existing and future patterns of land development as recommended by locally adopted land use plans and adopted plans and policies already in place.
- Provide a transportation system that is sensitive to the quality of the environment and enhances the natural resources.

Asset management and life cycle management are management practices that have been implemented in the transportation sector too and which may contribute to the overall improvement of the road networks and subsequently of the level of safety on them. The asset management approach draws from best practices in economics, engineering, and business with the respective decision-making framework covering an extended time horizon (Kuhn et al, 2011). The objective of asset management is to achieve cost-effective resource allocation and programming decisions that will result in greater system value and overall satisfaction for users through improvements in programme effectiveness and system performance (FHWA, 2007). The term "asset management system" embraces all the processes, tools, data and policies necessary to achieve the goal of effectively managing assets. Asset management as applied to the roads sector represents "a systematic process of maintaining, upgrading and operating assets, combining engineering principles with sound business practice and economic rationale, and providing tools to facilitate a more organised and flexible approach to making the decisions necessary to achieve the public's expectations" (OECD, 2001).

Transportation agencies have been mainly focused on constructing and expanding transportation infrastructure. In recent years, operation and maintenance costs have increased significantly (FHWA, 2007). In addition, both governments and the public demand increased the efficiency of, and accountability for, the management of the road network by road administrators. Formal accountability and reporting requirements regarding asset management have been established in many countries around the world (OECD, 2001). In order to adapt to these new conditions, many cooperation schemes between authorities and industry have been initiated, to advance the concepts and practices of asset management. The systematic integration of performance and return-on-investment considerations into programme evaluation and selection improves efficiency and productivity as well as the value of services and products to transportation users (FHWA, 2007). Through asset management, transportation agencies are able to focus on strategic goals and consider assets comprehensively (Kuhn et al, 2011).

As defined by FHWA (2007), transportation asset management is a strategic and systematic process of operating, maintaining, upgrading, and expanding physical assets effectively throughout their lifecycle. Transportation asset management links user expectations for system condition, performance, and availability with system management and investment strategies. Regardless of the definition, the focus is on performance of assets (FHWA, 2007). As far as asset management of a road infrastructure is concerned, the components with the greatest interest are (AUSTROADS, 2002): components with the highest life cycle costs; components with a key role to performance; and components vulnerable to deterioration or needing on-going management interest. Such components of a road network include road formations (cuttings and embankments), bridges, pavements, drainage, traffic control equipment (e.g. signals), roadside ITS installations etc.

International experience shows the need to integrate road safety within asset management systems. An exclusive safety management system has many benefits at both network and project level. At the network level, safety data such as accident statistics, high-risk sites, deficiencies and needs, priorities, and schedules can be readily identified. At project level, data would include site-specific accidents/high-risk sites, lane and shoulder widths, skid characteristics, roughness and road equipment. Through the safety management system, safety can be quantified and the management of policies for the reduction of road accidents can be supported (Tighe et al, 2001).

The life cycle approach in transportation planning and development involves planning a system based on environmental, economic, technical and social considerations during its whole life. This approach enhances resource efficiency, energy conservation, pollution reduction and sustainable development. Long term planning is a complicated and demanding element of transportation system design. The use of life cycle tools for the assessment and improvement of the system facilitates long-term decisions and optimises the management strategy (Yusoff et al, 2005).

The basic idea of the life cycle approach is to examine the current conditions on the system, identify all potential improvements in specific areas of interest of the planning system, and explore the environmental, technical, and cost implications of the resulting changes. The objective of the life cycle approach is to provide a holistic solution for improvement, taking into consideration the environmental and socio-economic performance. Additionally, improvements are fully integrated into the system making sure that no aspects of the transportation are isolated in the planning process (Yusoff et al, 2005).

The life cycle approach is increasingly considered a useful approach to focused environmental analysis and improvement of specific aspects of the overall transportation service system. Implementation of the life cycle approach allows for a change in the way that strategic and operational decisions are made, so that they become more effective for identifying improvement opportunities. This new approach on decision making may also improve competitiveness in the long term and will provide most benefits when integrated into the planning, design and implementation of the national transportation system (Yusoff et al, 2005).

Tools and data

Asset management systems require various types of data, not all of which are available to transport authorities. On the other hand, asset management systems supply information to various levels and parts of an administration (e.g. senior management and decision makers) where it may be combined with data from other systems. This indicates that the quality of both input and output data is crucial and, therefore, appropriate control procedures must be established. Typically, an asset management system used by a road administration will be in need of the following data (OECD, 2001):

- Definition of the network.
- Definition of the assets on the network (e.g. bridge, pavement).
- Location of the assets on the network.
- Condition of the assets.
- Levels of use (e.g. traffic flows).
- Policies and standards (e.g. maintenance standards and treatment designs as well as monitoring information such as performance measures).
- Budget information (e.g. broken down by asset type, programme level).

A large number of analytical tools that support asset management, including tools for investment analysis, management systems, needs and project evaluation, risk management, and results monitoring are nowadays available for the analysis of such data (Kuhn et al, 2011). In the United States, state transport authorities (Departments of Transportation, - DOT) currently have many databases used for asset management and inventory control, which are often maintained by various sections or divisions of the authorities. Asset management requires taking this knowledge and combining or integrating it into one system or programme. Such a system, centring on geographic information system (GIS) technology to manage four major systems of asset management (bridges, pavement, maintenance, and budget/financial management) has been created in the Colorado DOT. A team that will provide input and guidance regarding integrated information technology planning was also formed (Kuhn et al, 2011).

In Texas, a comprehensive Guidebook and a Screening Tool were developed to help the local transport authority quickly identify the best approach for managing assets. These tools provide guidance on developing a well-designed asset management system as a critical component of the authority's approach to customer mobility. This includes preserving the existing infrastructure, planning for future improvements of that infrastructure, and being responsive and accountable to the public regarding the financial investments. Such a system will be an integral part of the authority's ability to meet its goals of reducing congestion, enhancing safety, expanding economic opportunity, improving air quality, and increasing the value of transportation assets (Kuhn et al, 2011).

Common practices

An effective asset management framework is a balance of 1) goals, policies, and budgets, 2) technical information, and 3) integration, all connected via technology in the form of powerful computer systems capable of managing the amount and complexity of infrastructure information held by a major transport authority (Kuhn et al, 2011).

Generally, there are three main goals on which transportation professionals focus: maintaining infrastructure, logical capital improvement, and containing costs. Transportation asset management focuses on transportation infrastructure and system performance. Specifically, it provides decision makers with the information necessary to implement a logical capital improvement plan at acceptable costs.

The main questions that should be addressed by a successful transportation asset management plan are (Kuhn et al, 2011):

- What is the current state of assets?
- What is the required level of service?
- Which assets are critical to sustained performance?
- What are the best investment strategies for operations and maintenance and for capital improvement?
- What is the best long-term funding strategy?

Once these questions are answered, asset management systems can be applied to the transportation infrastructure. Data gathered may be used to set up an initial group of goals, which can then be incorporated into the short and long-range transportation improvement plans. Data gathered through asset management may also be utilised in decision making for operations, preservation, and maintenance of assets, performance measurement and evaluation (Kuhn et al, 2011).

According to FHWA (2007) the core principles of asset management are:

- Policy-driven: Resource allocation decisions are based on a well-defined set of policy goals and objectives.
- Performance-based: Policy objectives are translated into system performance measures that are used for both day-to-day and strategic management.
- Analysis of Options and Trade-offs: Decisions on how to allocate funds within and across different types of investments (e.g., preventive maintenance versus rehabilitation, pavements versus bridges) are based on an analysis of how different allocations will impact achievement of relevant policy objectives.
- Decisions Based on Quality Information: The merits of different options with respect to an agency's policy goals are evaluated using credible and current data.

- Monitoring Provides Clear Accountability and Feedback: Performance results are monitored and reported for both impacts and effectiveness.

Although these core asset management principles rule transportation asset management too, there is no single method for implementing transportation asset management. Each transportation authority has its particular needs, resources and structure. Typically, the first step toward implementation involves the realisation of a need for change. Still, a reason for change must also be found in order to further proceed with the implementation. The first step is always the most difficult as it involves figuring out what needs to be done. Since there is no specific sequence of actions that needs to be taken; authorities identify the most appropriate approaches and practices for their specific needs and priorities (FHWA, 2007).

Employing asset management techniques

In the United States, in recent years, numerous states have implemented either comprehensive or limited asset management plans. Limited plans most often concern pavement or bridge management plans. More complex or comprehensive forms of asset management expand the practice to other aspects of transportation and allow states to use good quality management practices. States that have some form of asset management plans include Washington, Louisiana, Colorado, Utah, Idaho, Indiana, Georgia, Oregon, Virginia, Florida, New York, Michigan, Maryland, Pennsylvania, North Carolina, New Mexico and Rhode Island (Kuhn et al, 2011).

In 2005, international research on employing asset management techniques in Australia, Canada, England, and New Zealand found long-term commitment to asset management. The primary incentive for employing asset management was limited resources in the face of growing demand. Asset management programs have also helped transportation agencies focus on network performance and have helped identify the “best value for dollar” of limited investment resources (Kuhn et al, 2011).

Australia and New Zealand began reporting the financial value of their road infrastructure assets in the late 1980s, and since 1997 all major road agencies in the two countries have recognised road assets in annual financial statements. The two countries have collaborated to advance their respective programmes in asset management. They both utilise long-term (10 year), performance-based contracts for maintenance of roads. In Australia, one contract on 450 km of urban roads improved road conditions by an estimated 15% while saving an estimated 35% in costs. Transit New Zealand, the national highway agency in New Zealand, currently uses a national asset management plan to guide planning on transportation assets and resource allocations decisions. The agency uses performance measures and indicators at all levels of planning and decision-making (Kuhn et al, 2011). In Australia, many transport authorities have developed asset management manuals, detailed processes and analytical tools that support the day-to-day management and planning of road-related assets (AUSTROADS, 2002).

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CHAPTER 5. CONCLUSION AND RECOMMENDATIONS FOR BETTER ROAD INFRASTRUCTURE SAFETY MANAGEMENT

This chapter sets out key messages and policy recommendations arising from this study.

Road authorities are key players for improving road safety

Road authorities are responsible for the safety of road infrastructure and, as such, they are key players for improving engineering aspects of road safety, in conjunction with vehicle manufacturers. They share responsibility for the overall road safety with road users, education and enforcement authorities. Road authorities need to recognise that there are still further road accidents that can be prevented, or at least result in fewer victims, by providing safer road infrastructure.

Road conditions contribute on 53% of all road deaths and 38% of all injuries in the United States. Road conditions can be the single most lethal contributing factor, ahead of speeding, alcohol or non-use of seat belts (Miller and Zaloshnja, 2009). A study in Sweden (Stigson, Krafft, and Tingvall, 2008) developed a model to systematically identify which of the three components - the road, the vehicle or the road user - are linked to fatal outcomes. The results from 230 fatal accidents show that of the three components, road infrastructure was most often linked to a fatal outcome.

There are substantial opportunities, programmes and tools to deliver safety improvements to road infrastructure. There is no “one size fits all” standard for road safety programmes. The best road safety programmes to use varies according to the preferences and circumstances of each country. However, it is important to benchmark good practices in other countries to find further opportunities to reduce and prevent fatalities and severe injuries from road accidents.

Hill and Starrs (2011) estimated 600 lives can be saved per year, in addition to significant savings in trauma and accident costs, by implementing the new minimum safety standards (3 star rates or above according to Road Assessment Programme; refer to Chapter 2 for details) in the trunk road network of Great Britain. Some countries, like the Netherlands, Sweden, and Malaysia, announced proposals to upgrade the safety of roads to the minimum 3-star standard by either 2020 or 2025. Between 1980 and 2000, in Sweden, the Netherlands, and the United Kingdom, infrastructure treatments combined with speed management measures reduced the number of deaths of vulnerable road users by around a third (FIA Foundation, 2010).

Recommendations

Benchmark good practices in other countries to find further opportunities to reduce and prevent fatalities and severe injuries from road accidents.

Implement new minimum safety standards (3-star rates or above in the Road Assessment Programme) for road infrastructure.

Road Infrastructure Safety Management procedures are effective and efficient

As reported in Chapter 2, there are several RISM procedures that are designed to prevent road accidents as much as possible. These include Road Safety Audits (RSAs), Road Safety Impact Assessments (RIAs), and Road Safety Inspections (RSIs). Those procedures are not common as High-Risk Site (HRS) improvement programmes. However, they are proven to be effective in preventing some road accidents in some countries, and have the potential to be just as effective in other countries. It should be also noted that these preventive programs do not necessarily have high costs. Although it is not always easy to assess the safety benefits of RISM procedures, and no clear relationship was found between the general use of these procedures and road safety performance (Elvik, 2010), there is strong evidence that RISM procedures may support improvements road safety and be highly cost-effective.

High-level policy and planning decisions affect the safety of the network at every level of the road network. RIAs and Efficiency Assessment Tools (EATs) aim at providing better information to policy-makers in order to take better decisions for road safety. The research shows that choices about which traffic-safety measure to use depend on the level of knowledge regarding the effects of the measure (Elvik et al, 2009). The decisions made affect the number of road accidents expected to occur on the network by determining one of a number of factors, for instance, an increase/decrease of risk exposure, a change in the travel mode used or the redistribution of traffic flows over the network.

Evaluations of RSAs have shown positive cost-benefit-ratios, ranging from 1.34:1 ("acceptable") to 99:1 ("excellent") (ROSEBUD, 2006). A study undertaken by Surrey County Council in the UK compared the effects on injury accidents from 19 audited and 19 non-audited traffic schemes. For sites with audited schemes, the average number of casualties dropped by 1.25 per year from 2.08 to 0.83. Non-audited sites dropped by only 0.26 per year from 2.60 to 2.34 (Surrey County Council 1994 in Elvik et al. 2009).

Network Operation (NO) enables road operators to take appropriate actions to prevent risky situations and to minimise the negative effects of incidents and road accidents. The traffic congestion that results from these incidents can lead to additional accidents and delay responses to emergency situations.

The use of regularly updated Road Assessment Program (RAP) data to track the overall performance of national road networks between 1999 and 2004 has shown reductions of about half in the length of roads in the highest risk band in Spain, Britain and Sweden (Lynam et al, 2007). Furthermore, in an evaluation carried out in Australia, the benefit–cost ratio for RSIs has been estimated between 2.4 and 84 (Macaulay and McInerney 2002).

HRS approach to road safety results in an 18% reduction in casualties, and in most cases is cost-effective (Elvik, 1997). The benefit–cost ratio for HRSs has been estimated between 1.1 and 5.7 (Elvik et al., 2009). OECD/ITF (2008) states targeted road safety projects that identify and treat HRSs with specific treatments such as audible edge-ling, shoulder sealing, clearing of roadside vegetation and the construction of passing lanes, can generate accident cost savings of up to 60 times of investment. Network Safety Ranking (NSR) is expected to offer to similar results.

Effects from the application of in-depth accident investigation have an impact on both vehicle and infrastructure safety. A good example of the value of such studies was the finding in the early 1950s that led to vehicle door latches being modified to reduce the risk of doors opening in a road accident, thus greatly reducing the risk of occupants being ejected (McLean, 2005).

Recommendation

Continue evaluation and research to quantify the safety impacts of medium and high level planning decisions on different types of networks, road types, and traffic volumes.

Road design standards cannot guarantee road safety in all conditions

Some road engineers insist road infrastructure is already secured with the necessary level of safety by satisfying design standards. The introduction of additional safety procedures is perceived either as redundant or a reinforcement for safety. However, some studies have shown that design standards are not an automatic guarantee of road safety (Refer to Box 10).

Box 10 - Road safety and design standards

Why do we need design standards?

When roads are developed, road designers usually refer to design standards. It helps to maintain a certain level of consistency within roads of identical class and function on continuing routes, as well as to guarantee interoperability between roads of different classes and authorities. Ruyters et al (1994) states three main grounds of road design standards based on McLean (1980).

Firstly, it is necessary to ensure uniformity among different designs, particularly across administrative boundaries. This feature makes road user behaviour more predictable. Secondly, it enables the broad application of existing expertise in geometric design, which tends to be centred in the major road authorities. Lastly, it ensures road funds are spent efficiently to ensure safe operations at the current time and avoiding inadequate provision for the future in case of traffic growth.

Design standards can be written to maintain the balance between safety, economic cost efficiency, environments and other competing social values. The Design Manual for Road and Bridge (Volume 6, Section 1, 2002) in the United Kingdom specifically states: “The standards represent the various criteria and maximum/minimum levels of provision whose incorporation in the road design would achieve a desirable level of performance in average conditions in terms of traffic safety, operation, economic and environmental effects.”

Can safety can be guaranteed if roads satisfy design standards?

Safety seems to be well considered in design standards together with other values, but safety can be an issue in certain cases. Usually, design standards specify the minimum values (radii of horizontal curve, super elevation, lane width etc.) to follow, but these minimums are not necessarily sufficient from a safety perspective.

For example, the minimum value for radii of a turning lane is not good enough in a junction that is frequently used by heavy vehicles. This can happen if designers are encouraged to save construction cost and are not aware of future traffic conditions of the roads. Combinations of different design elements, which all satisfy design standards individually, can also cause unexpected safety concerns. When roads have both horizontal and vertical curves, maintaining the minimum values can cause inconsistent driving conditions. This means that safety cannot be not necessarily be guaranteed by maintaining design standards irrespective of the specific circumstances.

Hauer (1999) rigorously notes that the relationship between design standards and road safety is unclear and the level of safety designed into roads is unpremeditated. He provides some specific examples where design standards cannot explain the level of safety achieved. The first reason for this is that most design standards are based on surrogate concepts of failures (e.g. shortfall in sight distance, lack of clearance between oncoming vehicles, or insufficient centripetal force), not on the frequency or severity of accidents, which can directly show level of safety. The second reason is that the current design standards try to represent road users through certain fixed parameters and fail to recognise the fact that they adapt behaviour according to road conditions. Consequently, some human-related parameters are treated as constants in all cases. He also suggests differentiating substantive safety (the expected accident frequency and severity) from nominal safety (compliance with standards, warrants, guidelines etc.) to change the current practice of road design. He emphasise the values of design standards to keep up with nominal safety, but stresses that substantive safety should be incorporated into the design process to ensure compliance with safety principles.

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Recommendation

In order to adopt a safety oriented cost-effective approach to the management of road infrastructure, road authorities should implement suitable road infrastructure safety management procedures for each stage of road development including planning, design, pre-opening, and full-operation. In particular, it is important to consider safety aspects as thoroughly as possible before the full operation of road infrastructure. It costs less to prevent road accidents than to treat road victims or deal with the consequences of accidents.

Success factors for the implementation of an RISM procedure

Success factors for the implementation of an RISM procedure are: an adequate level of investment, a regulation for the procedure, and availability of required road safety data. Sustainable funding sources are critical to the establishment of a road infrastructure safety management procedure. As reviewed in Chapter 4, there are many different funding combinations.

Awareness of RISM effectiveness is rarely sufficient to achieve successful implementation. It is recommended that these safety programmes are made legally binding. Otherwise, they can be easily skipped to reduce times and costs. For example, the European Commission mandates that roads in the Trans-European Road Network should undergo safety programmes under EU-Directive 2008/96/EC. When RISM procedures are not mandatory, they might be skipped to save time and reduce costs.

Road operators aiming at a higher level of safety need to take into account as many factors influencing safety as possible or, at least, those factors they are able to affect or control (ETSC, 2001). Early involvement of road authorities when developing road accident databases can be beneficial to all and contributes to making the most of a database's capability to help prevent and reduce the severity of road accidents. Road authorities are responsible for the safety of road infrastructure. They need good road accident data to identify the best ways of making road infrastructure safer. From this perspective, they have some demands of national road accident databases and they can contribute to better utilisation of national road accident data. Involvement of health authorities is also useful to bridge the gap between casualties reported by the police and by health authorities. Where possible, health authorities should contribute data on seriously injured casualties.

Road authorities in some countries feel they are not provided with sufficient or good enough road accident data. However, the primary aims of accident data collection and management are to analyse causes and locations of accidents and to help find appropriate countermeasures and policies. Wide sharing of road accident databases helps to attain these primary aims. Discussions between managers of road accident databases and user groups are essential to avoid unnecessary disputes over data sharing issues.

Recommendations

Road Infrastructure Safety Management procedures should be made legally binding.

Both road and health authorities should be involved when developing road accident databases.

Adequate institutional management capacity is critical for effective interventions

A critical prerequisite of developing and implementing effective interventions is an adequate institutional management capacity. Here institutional management capacity refers to the ability of a government to develop and manage its institutional management functions, i.e. result focus, coordination, legislation, funding and resource allocation, promotion, monitoring and evaluation, research and development and knowledge transfer (Bliss and Breen, 2008).

As suggested by Elvik (2010), the use of a formal procedure entails the risk of becoming a purely ritual act. An RSA could be performed because it is mandatory, but if it is treated as purely a formality there is the risk that it will not lead to the intended road safety results. Adequate institutional management capacity to support the development and implementation of effective interventions is a critical component. Road safety management tools need to be embedded in a well-functioning political system in order to produce the safety improvements they are designed for.

Important factors expressing a strong institutional management capacity include: political commitment to improving safety, adoption of ambitious long term targets for improving safety, good co-ordination between various governmental levels and agencies, well-funded road safety measures, and so on. Countries may refer to Bliss and Breen (2008) for guidelines for assessing and strengthening road safety management capacity.

Recommendation

Road authorities and central and local governments should assure the basic conditions for the implementation of an RISM procedure by providing adequate levels of investment, binding regulations and the essential road safety data. Adequate institutional management capacity is another critical factor for successfully implementation of procedures.

Tools to support road infrastructure safety management are already available

A large number of tools that support the implementation of RISM procedures, including guidelines, manual and software tools are available, as can be found in Chapter 4. State of the art of approaches (e.g. RIPCORD-ISEREST, 2007a), representing the best available method, are not always feasible, especially in low- and middle-income countries, where data required may be not adequate. In these cases a second best solution may be adopted or steps can be taken to bring current practice closer to the state of the art (Elvik, 2010).

Moreover, as highlighted by the survey (Chapter 3), aside from the international initiatives, national approaches providing useful and accurate guidelines or tools also exist in several countries worldwide. Specifically, such national guidelines and software are available in Australia, Austria, Canada, Finland, Germany, Greece, Ireland, Japan, the Netherlands, Norway, Spain, Sweden, the United Kingdom, the United States, etc. More information about tools used in these countries is available in Annex 7.

Recommendations

Use the existing tools and guidelines.

Adopt second-best-solutions where state-of-the art solutions are not feasible.

Each country has specific needs and barriers around implementing RISM

Some general barriers and specific issues that may prevent the implementation of an RISM procedure are identified in Chapter 3. Certain road safety management procedures are not welcomed in some countries mainly because of possible legal liability issues. For example, RSA which is well implemented in many countries including United Kingdom, was formerly not welcomed in the United States, but now it is being rapidly implemented there as Federal Highway Administration promotes this new programme nationwide. They even studied legal liability issues of RSA (Refer to Box 4 for details). The details of inspections should be adapted to the specific conditions of each country. Therefore, there does not seem to be a need to develop very detailed guidelines at the international level. An exchange of experiences between countries is strongly encouraged.

It is evident that countries with different safety levels have different needs. Low- and middle-income countries in particular must concentrate on procedures that will require low capital expenditure and maximum benefits. Rather than rely on costly systems, the effective use of methods that utilise existing facilities may prove to be much more cost effective. Moreover, some procedures, like HRS improvement programmes, may have a higher impact in countries where existing roads are in poor condition or not adequate for their current use (e.g. low- and middle-income countries). On the other hand, countries with better safety records should consider the implementation of Network Safety Ranking.

There is no need to implement all existing RISM procedures. No procedure is better than others, and it is not the case that a more extensive use of these tools automatically ensures a superior road safety performance. Countries should find the ones that best fit their needs.

Recommendations

Road authorities should identify those RISM procedures that best fit their needs and must understand the potential barriers for implementation in order to tailor tools and methods according to the specific context.

As road safety measures can be effectively and efficiently transferred to various regions and countries with the help of Crash Modification Functions, good road infrastructure safety management procedures can also be effective in other regions and countries. Relevant international organisations should try to promote good programmes worldwide. Improvement of high-risk sites has been successfully spread around the world, and most countries responding to the survey (refer to Chapter 3) implement programmes to reduce high-risk sites on the roads. Recently, RSAs and RAPs are being exported from Europe to the rest of the world. RSAs have been adopted in 20 of the 23 countries surveyed, and RAPs are now partially or fully applied in 18 countries. Other good practices for better safety management of road infrastructure can be promoted worldwide. Some specific and detailed explanation for good practices can be found in Chapter 4.

Introduction of some targeted road safety measures that have proved to be effective can also be worthwhile sharing worldwide. In urban areas, for instance, reduction of speed limits and installation of traffic calming measures can help reduce fatalities from accidents. Roundabouts can be a good solution for safety improvement junctions. All of these example measures can easily be transferred from the origin country to elsewhere. Further information on sharing road safety measures can be found in OECD/ITF (2012).

International communities in road safety need to share good practices of road infrastructure safety procedures as well as safety intervention measures.

Road safety performance monitoring helps achieve safety targets

Road safety performance monitoring helps to achieve the safety targets of road authorities. By monitoring, one can examine how much progress has been made toward the safety target, and which parts of road sections need special care to achieve the target in time.

There can be several options for Safety Performance Indicators (SPIs) for monitoring. Annex 3 suggests some potential SPIs suitable for country comparison purposes. Primary indicators can include the number of accidents per kilometre and accident rates over vehicles travelled. Some additional indicators can be potential accident savings, accident risk by road types, equivalent accident number (equivalent property damage only), and expected average accident frequency with empirical Bayes adjustment. Selection of additional indicators can be made according to the circumstances of individual road authorities. However, there are some principles to monitor safety performance of road infrastructure as follows:

- Road networks need to be divided into sections and junctions for monitoring.

- For comparison, each section and junction can be grouped according to traffic volumes, number of lanes, road width, median types, speed limits, junction types, etc.

- Fundamental road safety performance indicators can be the number of road accidents or fatalities per unit distance or unit number of vehicles or vehicle travelled. Some additional variables can be included to understand details of road safety performance. These could be, for example, fatalities of pedestrians, cyclists, motorcyclists and the number of severe injuries, accident costs etc.

- Monitoring can be effective if the exact location of accidents or x, y coordinates are available. In this case, Geographic Information Systems, which link geographic information to statistics can be conveniently utilised to analyse characteristics of road safety in a certain location associated other variables such as land use, population, and even geometric design parameters if details are available. Some advantages of using GIS for road accident data management are given in Box 11.

Box 11 - Advantage of using Geographic Information System for road accident database

Geographic Information Systems (GIS) are now widely applied in many areas including transport planning, design, management and operation. Development of road accident databases in GIS helps to link road accident data with other spatial and attributional data. For instance, by knowing the exact location of a road accident, one can easily relate the accident to the design features of roads in detail, if this information is held in a suitable spatial format. From this perspective, the collection of the exact accident location is crucial for maximising the potential use of accident databases.

GIS based accident databases helps to monitor safety performance of road infrastructure conveniently. By linking traffic databases to the accident databases through a GIS, casualty and fatality rates by distance travelled can be easily calculated. GIS also helps to make the most of various road safety programmes by storing some important details of individual road safety programmes. For example, one can easily investigate the details of Road Safety Audits to identify possible safety countermeasures in a certain high-risk sites.

GIS can be useful in promoting the sharing of road accident data widely for improving road safety. At the same time, the data access rights can be used to easily control user access using GIS platforms.

Recommendation

Road authorities should regularly monitor the safety performance of road infrastructure with acceptable indicators. Full access rights to the data should be given to road authorities unless it encroaches personal privacy.

Self-explaining roads help guide drivers to adopt appropriate behaviours

Road infrastructure should be improved with the development of self-explaining roads to guide drivers to adopt appropriate behaviours. Self-explaining roads are roads designed and built to elicit correct assessments from road users on appropriate driving behaviour matched to the road environment (Theeuwes and Godthelp, 1995). There is some evidence of increased safety after the implementation of the self-explaining roads. For example, in Holland self-explaining roads have produced encouraging results with a 30% reduction in accident casualties in pilot areas. In general, a more pro-active approach to road infrastructure design and management is desired, where road safety is taken into account in all the stages of a road life cycle (Box 12).

Box 12 – Safety oriented approaches

Sweden's Vision Zero approach was adopted in 1997 and has the long-term goal of eliminating all deaths and serious injuries from the road transport system. Under this approach, it is unacceptable to trade off human life and health for other benefits of the transport system (e.g. mobility).

The Netherlands' Sustainable Safety approach was launched in the Netherlands in the early 1990's. It aims to prevent road accidents or at least minimise their severity while allowing for human capacities and limitations. The approach recognises that human beings are susceptible to injury and prone to errors. Sustainable Safety aims to prevent these errors as far as possible or to reduce their consequences by allowing for human limitations in designing the traffic system.

Australia's Safe System approach advocates for a safe road system, better adapted to the physical tolerance of its users. It reflects international best practice as defined in the ITF/OECD's landmark report *Towards Zero: Ambitious Road Safety Targets and the Safe System Approach*.

Safety Conscious Planning (SCP) is a comprehensive, system wide and proactive process that integrates safety into transportation decision making for all transportation modes including walking, cycling, and transit. SCP aims to create safety-planning procedures that are explicit and quantifiable. SCP is not limited to the consideration of specific sites or "black spots", but includes corridors and the entire transportation network at the local, regional, and country levels. SCP is also not limited to current safety problems, but aims to reduce the number of accidents by establishing inherently safe transportation networks through identifying opportunities to prevent future hazards and problem behaviours. On an inherently safe transportation network, it is difficult for the driver to have a road accident. Road safety improvements are achieved through small changes, targeted at the whole network (Depue, 2001).

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Recommendation

Road authorities should improve the safety performance of infrastructure with the development of self-explaining roads and in general all planning authorities should consider safety in the transportation planning process by adopting a comprehensive, system wide and pro-active road-safety planning approach.

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Annexes

ANNEX A. COMPARISON OF RISM PROCEDURES

Road Infrastructure Safety Management (RISM) procedures support engineers and decision-makers to decrease the risk level of the road network. Chapter 2 has shown that some RISM procedures share similar goals. For example:

- Road Safety Impact Assessments (RIAs) and Road Safety Measures Efficiency Assessment Tools (EATs) aim at comparing different scenarios from road safety point of view.
- Identifying infrastructure or traffic related factors increasing injury/accident risk is common to RSAs, Road Assessment Programmes (RAPs), Road Safety Inspections (RSIs), High-Risk Sites (HRSs) and In-Depth Investigations.
- Ranking elements of a road network based on their safety level is shared by RAPs, Network Safety Ranking (NSR) and HRSs.

However, differences exist among these procedures. In particular, the data and tools required to achieve a target vary, and they are used in different road life cycle stages. In general, the choice of which procedure to use is strictly linked to the data available; yet one can also be interested in understanding if they lead to similar results and in being aware of which differences one may run into.

This aspect has been analysed in the literature, particularly with regard to the group of procedures dedicated to the evaluation of safety performance of road infrastructure, with the aim of obtaining a ranking of the road elements of the network (road sections and road intersections). In general, these procedures differ in the type of data used to assess the safety of road elements. NSRs use indicators based on historical accident data, while RAPs are based exclusively on surveys of the infrastructure design (e.g. width of the lanes, roadsides characteristic, etc.).

The main advantage of adopting an approach based only on the characteristics of the infrastructure is it avoids the need for accident data. This data is often lacking, particularly, but not only, in low- and middle-income countries. On the other hand, research adopts the frequency of accidents as the main indicator for estimating the performance of security infrastructure and to evaluate the effectiveness of the interventions (HSM, 2010). It is therefore reasonable to wonder whether NSRs and RAPs lead to similar results.

The aim of this section is to examine existing studies carried out on this issue, in order to identify if, and in which cases, NSR and RAP methods lead to similar results.

Evidence from research

The relationship between indicators based on accidents and indicators based on the road infrastructure characteristics has been investigated in a number of studies. Most of these studies refer to EuroRAP methodology, as it is currently the most widely used internationally (McInerney et al, 2008; Harwood et al, 2010; Vlakveld and Louwerse, 2011; Lawson, 2011). The methods used to verify the presence of a relationship vary from the simple visual comparison of maps produced by applying the two procedures, to more sophisticated statistical methods (Lawson, 2011).

An Australian study (McInerney et al, 2008), examined the relationship between the number of stars, or Road Protection Score (RPS), and accident costs per vehicle-kilometre travelled. In this study, data related to network road sections were grouped by the number of stars, by calculating an average cost per vehicle-km. It showed that as the number of stars decreases, the cost per vehicle-kilometre increases. The study did not account for the type of road infrastructure examined (e.g. divided or undivided road). A regression analysis was also attempted in order to examine the relationship between RPS and cost per vehicle-kilometre. However, the wide variability observed in the results and the fact that, for a large number of individual sections, no crash history was observed discouraged the continuation of this approach.

An exhaustive study has been carried out by Harwood et al (2010) who have verified that the accident rate (fatal and serious-injury accidents per 100 million vehicle miles travelled) decreases in a statistically significant way along with the increasing Star Rating values (safer roads). No clear relationships could be demonstrated for freeways because the design characteristics of freeways are very uniform. Harwood et al (2010) also investigated the relationship according to the type of accidents, finding a statistically significant relationship for:

- run-off road accidents on two-lane undivided highways and six-lane divided freeways
- accidents at junctions on two-lanes undivided highways and four-lane undivided non-freeways
- head-on accidents on two-lane undivided highways.

Vlakveld and Louwerse (2011) examined the relationship between the number of stars and the casualty rate for each road section of provincial roads in the province of Utrecht in the Netherlands. They found that along with an increase in the number of stars (safer roads), the average rate of serious accidents per million vehicle-km decreases. This was the case for the overall assessment of the road section as well as for the individual assessments of the roadside, the separation of driving directions (single carriageway road sections) and the intersection. However, they showed a high variance in the rate of accidents linked to road sections where there had been no serious accidents. Further results from comparisons of RPS and crash rates confirming the presence of a relationship are reported in Lawson (2011).

Other indicators similar to the iRAP RPS have been also examined. For instance, in Cafiso et al. (2010) a Safety Index is proposed and validated by demonstrating the significance of the relationship between the indicator and the expected number of accidents. However, these approaches have not been used as extensively as the iRAP method and need to be tested under more conditions in order to be fully validated.

Existing limitations

Even if the research results show significant relationships between infrastructure characteristics and accidents, one should still take into account the existing limitations of the iRAP methodology and the limitations of the research studies carried out. With reference to the methodology, Lawson (2011) lists a number of conditions for which such a relationship might be lacking. First, the RPS evaluates the infrastructure and does not reflect those accidents where the driver's behaviour was not in compliance with the applicable regulations (e.g. speed higher than limits and failure to use seat belts). Secondly, the RPS also evaluates the ability of the infrastructure to mitigate the severity of injuries suffered by the transported people in vehicles marked as safe by EuroNCAP (score of at least 4 stars).

Further aspects that should be considered are (Lawson, 2011):

- The number of fatal and serious crashes is small and there is substantial variation in crash totals from one potential comparison period to another.
- The injured persons are unduly frail.
- The car occupant accident pattern is dominated by types other than those that are modelled – e.g. run-off, junction or frontal car-to-car impacts.
- There are a substantial number of accidents resulting in injuries to road users other than car occupants (and if these crashes to other road users are not excluded from the analyses).
- The presence of substantial under-reporting of fatal and serious crashes or there is miscoding of their location.

A poor relationship may be due also to confounding factors and limitations present in a study such as:

- Small sample sizes, for example of 1 and 2-star roads (to be able to make a useful comparison of different roads and scores it is necessary to have a sufficiently large sample of roads within each of the categories to be analysed and a sufficiently large number of fatal and serious crashes that have occurred within each category).
- Changes to the network that might have occurred throughout the considered accident period.
- Low quality data, e.g. the traffic flows on which the crash rates are based are substantially inaccurate.

Conclusions

Most of studies examined show evidence of a significant relationship between the two types of indicators, i.e. accident rate and iRAP RPS (or Star Rating). No clear relationship was found for those roads where design characteristics are very uniform (e.g. freeways). In these cases, the RPS methodology is useful only to identify possible infrastructure-related risk factors included in the iRAP methodology on the examined road.

Although several studies have been conducted on the subject, no analysis compares the final rankings developed to the two types of indicators. At present, it is not known if, and under which conditions, the two assessment approaches lead to the identification of the same best performing and/or worst performing road sections. For this purpose further research is needed to understand if the two assessment approaches lead to similar results.

In general, if accident data are available, accident-based methods are preferred for ranking purposes, unless the analysis is oriented to assess infrastructure risk factors. In this case, as RPS does not capture all aspects of risk, it can potentially be a better indicator of the influence of road design on the risk of serious injury than total accident numbers because it highlights some of the risks arising directly from road design rather than from road-user behaviour (Lawson, 2011).

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ANNEX B. SURVEY RESULTS

Road Safety Impact Assessment worldwide

Up until recently, traffic impact studies seldom dealt explicitly with the effects of interventions on road safety. With Directive 2008/96/EC it is compulsory for European Member States to carry out an RIA in the planning phase whenever substantial modifications to road infrastructure are applied to the Trans-European road Network. However, there is still a lack of standardisation at European level about RIA studies.

The results of the survey performed within IRTAD Members in 2013 show that in 12 countries out of 23 (about 52% of surveyed countries) there is a national law regulating RIA (Table B.1). However, in 15 countries, RIAs seem to be currently performed on either a portion of or on the entire road network (Germany and Switzerland). The responsibility for RIA development ranges over a variety of agencies including: National Road Authorities, Ministry of Transport and research bodies. In 13 countries there are technical guidelines to perform RIAs. France and Italy will soon have technical guidelines as well. Software tools supporting data gathering and elaboration are available in six of the investigated countries: Canada, Germany, Netherlands, Portugal, Sweden and the United States.

The absence of familiarity with the data is the main reason for not performing RIAs in the six countries that do not use them. Other reasons mentioned are the lack of resources and/or tools (4 countries) and the fact that the State doesn't recommend HRSs (3 countries). In 11 countries worldwide the current tools are not considered adequate.

Table B.1. **Main survey results related to RIA**

Country	1 - Tool regulated by National law	2 - Network coverage	3 – Agency in charge	4 - Technical guidelines	5 - Software Tools
Argentina	No	Part of the road network	National and/or local Road Administrations	No	No
Austria	Yes	Part of the road network	Other	No	No
Canada	No	Part of the road network	National and/or local Road Administrations	Yes	Yes
Colombia	No	Not performed	Not performed	No	No
Czech Republic	Yes	Part of the road network	National and/or local Road Administrations	No	No

Country	1 - Tool regulated by National law	2 - Network coverage	3 – Agency in charge	4 - Technical guidelines	5 - Software Tools
France	Yes	Not performed	Other	Soon available	No
Germany	Yes	All roads	Ministry / National Administration	Yes	Yes
Greece	Yes	Not performed	Other	No	No
Hungary	Yes	Part of the road network	Other	Yes	No
Ireland	Yes	Part of the road network	Other	Yes	Don't know
Italy	Yes	Part of the road network	Ministry / National Administration	Soon available	Soon available
Jamaica	No	Part of the road network	Ministry / National Administration	No	No
Japan	No	Not performed	Not performed	Yes	No
Korea	No	Not performed	Not performed	Don't know	Don't know
Lithuania	No	Part of the road network	National and/or local Road Administrations	Yes	No
Luxemburg	Yes	Part of the road network	National and/or local Road Administrations	Yes	No
Netherlands	Yes	Part of the road network	National and/or local Road Administrations	Yes	Yes
Portugal	No	Not performed	Not performed	Yes	Yes
Republic of South Africa	No	Not performed	Ministry / National Administration	No	No
Slovenia	Yes	Part of the road network	National and/or local Road Administrations	Yes	No
Sweden	No	Not performed	National and/or local Road Administrations	Yes	Yes
Switzerland	Yes	All Roads	National and/or local Road Administrations	Yes	Soon available
United States	No	Part of the road network	Ministry / National Administration	Yes	Yes

Efficiency Assessment Tools worldwide

The efficiency assessment of road safety measures is considered to be a very useful tool in decision-making. In particular, cost-benefit and cost-effectiveness analyses are carried out in several countries, in a more or less systematic way, at national, regional or local level (Yannis et al, 2012). Cost benefit analysis is applied primarily when larger infrastructure investment is considered, but that does not necessarily imply that the safety effects of such projects are only assessed monetarily (Elvik and Veisten, 2005).

The results of the survey performed within IRTAD Members in 2013 show that national laws regulating Efficiency Assessment Tools (EAT) are present in only five countries out of the 23 surveyed (about 20% of surveyed countries) (Table B.2). However, EAT is used on a portion of the roads, or on the entire road network (specifically in Germany, Slovenia, Sweden and Switzerland), in 17 countries. The agents responsible for the collection and calculation of EAT vary between countries, including: National and Local Road Authorities, Ministries of Transport and research bodies.

In most countries there are no technical guidelines to perform EAT. The exceptions to this are: Canada, Colombia, Ireland, Italy, Netherlands, Switzerland and the United States. Software tools to support data gathering and analysing for EAT are available in six countries: Canada, Colombia, Ireland, Portugal, Sweden and the US.

The lack of resources and/or tools is identified as the main reason for not performing EAT in most countries (nine countries). Other reasons given are that the lack of data (four countries), the fact that the State doesn't recommend EAT (four countries) and the absence of familiarity with the data (three countries). In ten countries, worldwide, the current tools available in those countries are not considered adequate.

Table B.2. **Main survey results related to EAT**

Country	**1 - Tool regulated by National law**	**2 - Network coverage**	**3 – Agency in charge**	**4 - Technical guidelines**	**5 - Software Tools**
Argentina	No	Part of the road network	Not performed	No	No
Austria	No	Part of the road network	Other	No	No
Canada	No	Part of the road network	National and/or local Road Administrations	Yes	Yes
Colombia	No	Part of the road network	Ministry / National Administration	Yes	Yes
Czech Republic	No	Part of the road network	Not performed	No	No
France	Don't know	Not performed	Not performed	Don't know	Don't know

Country	1 - Tool regulated by National law	2 - Network coverage	3 – Agency in charge	4 - Technical guidelines	5 - Software Tools
Germany	No	All roads	Not performed	No	No
Greece	No	Part of the road network	National and/or local Road Administrations	No	No
Hungary	No	Not performed	Not performed	No	No
Ireland	Yes	Part of the road network	Other	Yes	Yes
Italy	Yes	Part of the road network	Ministry / National Administration	Yes	No
Jamaica	No	Part of the road network	Ministry / National Administration	No	No
Japan	No	Not performed	Not performed	No	Don't know
Korea	No	Not performed	Not performed	Don't know	Don't know
Lithuania	No	Part of the road network	National and/or local Road Administrations	No	No
Luxemburg	No	Don't know	National and/or local Road Administrations	No	Don't know
Netherlands	Yes	Part of the road network	National and/or local Road Administrations	Yes	No
Portugal	No	Part of the road network	Other	No	Yes
Republic of South Africa	No	Not performed	Ministry / National Administration	No	No
Slovenia	Yes	All Roads	National and/or local Road Administrations	Don't know	Don't know
Sweden	No	All Roads	National and/or local Road Administrations	Don't know	Yes
Switzerland	Yes	All Roads	National and/or local Road Administrations	Yes	No
United States	No	Part of the road network	Ministry / National Administration	Yes	Yes

Road Safety Assessment worldwide

The first standards for Road Safety Assessment (RSA) were set up in the UK (1991), New Zealand (1993), Australia (1994) and Denmark (1997). Today RSA is mandatory for road infrastructure projects on the Trans-European Road Network (TERN) across all 27 countries of the EU. The TERN predominantly consists of high-level roads, mostly made up of motorways. The relevant Directive[1] was to be transposed by the Member States into national laws by 2011, together with issuing national technical guidelines on RSA.

At present, most EU countries have technical guidelines available and the use of RSA is legislated by a national law. In general, RSAs are always performed on national roads, and on a voluntary basis on the rest of the network. In addition, some EU countries have extended the requirements of carrying out RSAs to projects on (parts of) the secondary road network. It is the explicit objective of the European Commission that RSAs (and the other road safety management tools prescribed in the above Directive) are applied on all types of roads, even when design and operation of these roads are entirely subject to subsidiarity (i.e. to a country's own jurisdiction).

In countries outside the EU, such as Jamaica, the United States, Colombia and Argentina, RSA is not nationally legislated and its implementation is rather diverse. The main issue in these countries is that, if performed, RSAs are not systematically carried out across the entire country. In the United States, for instance, there are technical guidelines, training and certification programmes available and RSAs are performed on several types of roads but its widespread implementation is still in progress.

In Argentina, provinces and municipalities are autonomous regarding road traffic legislation. Even though, at present, most provinces and municipalities have adhered to national laws, road safety is achieved differently in each jurisdiction. RSAs have been carried out in some jurisdictions and on varied road types but without standardised procedures. There are plans to introduce mandatory implementation of RSAs in Argentina and some training programmes have been carried out in recent years, but the capacity to perform RSAs extensively is still lacking.

As a general rule, in countries where RSAs are not compulsory for certain (or any) types of road the lack of resources and their nature as non- compulsory are usually the main issues for not implementing RSAs. The results of the survey performed within IRTAD Members in 2013 show that 13 countries (about 56% of surveyed countries) have a national law regulating RSAs (Table B.3). In 21 countries RSAs are currently evaluated on a portion of the road network, while in 2 they are implemented on the entire road network (Lithuania and Switzerland). The agents responsible for the development of RSA vary between countries, including: National and Local Road Authorities, Ministries of Transport, Police, Public Insurers and research bodies.

Most of the countries surveyed have technical guidelines to develop RSAs. The few exceptions are Argentina and Greece, while in Colombia the technical guidelines will be soon available. Software tools to support RSA are available in only two of the investigated countries: Germany and the United States.

The fact that RSAs are not required by law was identified as one of the main reasons for not performing them (seven countries). Another important reason is lack of resources and/or tools (seven countries) and unfamiliar/unknown data (four countries). In four countries, the current tools are not considered adequate.

Table B.3. **Main survey results related to RSA**

Country	1 - Tool regulated by National law	2 - Network coverage	3 – Agency in charge	4 - Technical guidelines	5 - Software Tools
Argentina	No	Part of the road network	Not performed	No	No
Austria	Yes	Part of the road network	Other	Yes	No
Canada	No	Part of the road network	National and/or local Road Administrations	Yes	Soon available
Colombia	No	Part of the road network	Other	Soon available	No
Czech Republic	Yes	Part of the road network	National and/or local Road Administrations	Yes	No
France	Yes	Part of the road network	Other	Yes	No
Germany	No	Part of the road network	Ministry / National Administration	Yes	Yes
Greece	Yes	Part of the road network	Other	No	No
Hungary	Yes	Part of the road network	Other	Yes	No
Ireland	Yes	Part of the road network	Other	Yes	No
Italy	Yes	Part of the road network	Ministry / National Administration	Yes	No
Jamaica	No	Part of the road network	Ministry / National Administration	Don't know	No
Japan	No	Not performed	Not performed	Don't know	Don't know
Korea	Yes	Part of the road network	National and/or local Road Administrations	Yes	No
Lithuania	Yes	All Roads	National and/or local Road Administrations	Yes	No
Luxemburg	No	Part of the road network	National and/or local Road Administrations	Yes	No

Country	1 - Tool regulated by National law	2 - Network coverage	3 – Agency in charge	4 - Technical guidelines	5 - Software Tools
Netherlands	Yes	Part of the road network	National and/or local Road Administrations	Yes	No
Portugal	No	Not performed	Not performed	Yes	No
Republic of South Africa	No	Part of the road network	National and/or local Road Administrations	Yes	No
Slovenia	Yes	Part of the road network	National and/or local Road Administrations	Yes	No
Sweden	Yes	Part of the road network	National and/or local Road Administrations	Yes	No
Switzerland	Yes	All Roads	National and/or local Road Administrations	Yes	No
United States	No	Part of the road network	National and/or local Road Administrations	Yes	Yes

Road Safety Performance Indicators worldwide

Usually road design Road Safety Performance Indicators (SPIs) are used within road safety plans to monitor defined performance targets. Indicators and targets concerning road design are, to date, only formulated in special cases where a policy plan explicitly addresses a certain measure, for example, controlling traffic at junctions or installing guard rails. Some countries, like the Netherlands, Sweden, and Malaysia referred to the road design SPI derived from RPS and announced to upgrade the safety of roads to the minimum 3-star standard mostly by either 2020 or 2025.

On the contrary, road network SPIs seem still to be confined to research and need to be further tested. It will not be easy to arrive at internationally comparable road Safety Performance Indicators, because of differences in road types, safety policies and standards. As found by ETSC (2001), road infrastructure SPIs are still rarely included in road safety management. This is confirmed by the results of the survey performed within IRTAD Members in 2013. Only five countries (about 20% of surveyed countries) have a national law regulating road SPIs. The five with national laws are: Austria, Czech Republic, Hungary, Ireland and Switzerland (Table B.4).

Despite only being a requirement in five countries, road SPIs are calculated on at least a portion of the network in 15 countries, with three of them applying it to the entire road network (Lithuania, Slovenia and Sweden). The organisations responsible for the collection and calculation of SPIs vary between country, including: National and Local Road Authorities, Ministries of Transport, Police, Public Insurers and research bodies.

Most countries do not have technical guidelines to collect road SPIs. The few exceptions that do have them are Czech Republic, Jamaica, Portugal and Switzerland. Software tools supporting data gathering and calculation of SPIs are available in one-third of the countries surveyed: Ireland, the Netherlands, Portugal, Czech Republic, Jamaica, Sweden and Switzerland. The fact that road infrastructure SPIs are not required by law was identified as the main reason for not collecting them in most countries (nine countries). Other mentioned reasons are lack of resources and/or tools (six countries) and a lack of availability of data (five countries). In 11 countries, worldwide, the current tools are not considered adequate.

Table B.4. **Main survey results related to SPI**

Country	1 - Tool regulated by National law	2 - Network coverage	3 – Agency in charge	4 - Technical guidelines	5 - Software Tools
Argentina	No	Part of the road network	National and/or local Road Administrations	No	No
Austria	Yes	Part of the road network	Other	No	No
Canada	No	Part of the road network	Ministry / National Administration	Don't know	No
Colombia	No	Not performed	Not performed	No	No
Czech Republic	Yes	Not performed	Ministry / National Administration	Yes	Yes
France	Don't know	Not performed	Not performed	Don't know	Don't know
Germany	No	Not performed	Not performed	No	No
Greece	No	Not performed	Not performed	No	No
Hungary	Yes	Part of the road network	Other	No	No
Ireland	Yes	Part of the road network	National and/or local Road Administrations	No	Yes
Italy	No	Part of the road network	Ministry / National Administration	No	No
Jamaica	No	Part of the road network	Ministry / National Administration	Yes	Yes
Japan	No	Not performed	Not performed	No	No
Korea	No	Not performed	Not performed	No	No
Lithuania	No	All Roads	Other	No	No
Luxemburg	No	Not performed	Not performed	No	No

Country	1 - Tool regulated by National law	2 - Network coverage	3 – Agency in charge	4 - Technical guidelines	5 - Software Tools
Netherlands	No	Part of the road network	National and/or local Road Administrations	No	Yes
Portugal	No	Part of the road network	Other	Yes	Yes
Republic of South Africa	No	Not performed	Ministry / National Administration	No	No
Slovenia	No	All Roads	National and/or local Road Administrations	No	No
Sweden	No	All Roads	National and/or local Road Administrations	Don't know	Yes
Switzerland	Yes	Part of the road network	National and/or local Road Administrations	Yes	Yes
United States	No	Part of the road network	Not performed	No	No

Road Assessment Programmes worldwide

A project to develop Road Assessment Programmes (RAPs) began in Europe in the early 2000s with the aim to improve infrastructure to reduce unnecessary and preventable casualties on Europe's roads. EuroRAP was then recognised and applied in other parts of the world, including Australia, New Zealand, and the United States. Application of RAPs has now expanded worldwide, and iRAP (international Road Assessment Programme) is actively working in developing countries in Asia, Latin America, and Africa. RAPs (such as iRAP, USRAP and AusRAP) are now active in over 70 countries worldwide covering Europe, Asia Pacific, North America, Latin America and the Caribbean, and Africa.

Figure B.1. **Map of countries that have applied a RAP**

The results of the survey performed within IRTAD Members in 2013 show that only six countries (about 26% of surveyed countries) have national laws regulating RAPs. These countries are: Hungary, Ireland, Luxemburg, Netherlands, Sweden and Switzerland (Table B.5). Despite most countries not having any laws on RAP, they are used on at least part of the road network in 19 countries and on the entire road network in three of these (Hungary, Slovenia and Switzerland). The responsibility for RAPs development involves a variety of agencies including: National Road Authorities, Ministry of Transport and Public Insurers.

Most countries have technical guidelines to develop RAPs. Software tools to support RAPs are available in nine of the countries surveyed: Argentina, Colombia, Czech Republic, Germany, Ireland, Jamaica, Slovenia, Switzerland and the United States.

The lack of resources and/or tools is the main reason for not developing RAPs in most countries (nine countries). Other mentioned reasons are the fact that the State doesn't recommend the development of RAPs (six countries) and the fact that RAPs are unfamiliar/unknown (three countries). In nine countries, worldwide, the current tools are not considered adequate.

Table B.5. **Main survey results related to RAP**

Country	**1 - Tool regulated by National law**	**2 - Network coverage**	**3 – Agency in charge responsible**	**4 - Technical guidelines**	**5 - Software Tools**
Argentina	No	Part of the road network	Ministry / National Administration	No	Yes
Austria	No	Part of the road network	Other	Yes	No

Country	1 - Tool regulated by National law	2 - Network coverage	3 – Agency in charge responsible	4 - Technical guidelines	5 - Software Tools
Canada	No	Part of the road network	Not performed	Yes	No
Colombia	No	Part of the road network	Ministry / National Administration	Yes	Yes
Czech Republic	No	Part of the road network	Other	Yes	Yes
France	Don't know	Not performed	Not performed	Don't know	Don't know
Germany	No	Part of the road network	Ministry / National Administration	Yes	Yes
Greece	No	Part of the road network	Not performed	No	No
Hungary	Yes	All Roads	Ministry / National Administration	No	No
Ireland	Yes	Part of the road network	National and/or local Road Administrations	Yes	Yes
Italy	No	Part of the road network	Other	No	Don't know
Jamaica	No	Part of the road network	Ministry / National Administration	No	Yes
Japan	No	Not performed	Not performed	No	No
Korea	No	Part of the road network	Other	No	No
Lithuania	No	Not performed	Not performed	No	No
Luxemburg	Yes	Part of the road network	National and/or local Road Administrations	No	No
Netherlands	Yes	Part of the road network	National and/or local Road Administrations	Yes	No
Portugal	No	Not performed	Not performed	No	No
Republic of South Africa	No	Part of the road network	National and/or local Road Administrations	Yes	No
Slovenia	No	All Roads	National and/or local	Yes	Yes

Country	1 - Tool regulated by National law	2 - Network coverage	3 – Agency in charge responsible	4 - Technical guidelines	5 - Software Tools
			Road Administrations		
Sweden	Yes	Part of the road network	National and/or local Road Administrations	Yes	No
Switzerland	Yes	All Roads	National and/or local Road Administrations	Yes	Yes
United States	No	Part of the road network	Other	Yes	Yes

Road Safety Inspection worldwide

In the 27 countries of the EU, RSI is mandatory for road infrastructure projects on the Trans-European Road Network (TERN), which predominantly consists of motorways. The relevant Directive (Directive 2008/96/EC) was to be transposed by the Member States into national laws by 2011, together with the issuing of national technical guidelines on RSI. Some EU countries are now also starting to carry out RSIs on (parts of the) secondary road network. Switzerland, which is not member of the EU, performs periodical RSIs on all roads.

For countries outside the Europe the picture is rather diverse: although RSIs are generally not prescribed by national legislation or technical guidelines anywhere, several countries and individual states, regions or municipalities/cities therein, have recently started to carry out RSIs on a regular basis (e.g. in the United States, Colombia, and Jamaica).

There is still, however, a long way to go before RSI can be regarded a standard safety management tool across the globe. The main barriers currently lie in limited financial resources of road authorities and in a lack of knowledge of both the mechanisms of RSI and of the substantial accident and cost savings that are associated with its implementation.

The results of the survey performed within IRTAD Members in 2013 show that about 60% of surveyed countries (14 countries, 13 of them in Europe) have national law regulating RSI (Table B.6). RSI is used on at least a portion of the road network in 19 countries, and, of these, the entire road network in Germany and Switzerland. The organisation responsible for the development of RSI varies between countries, including: National and Local Road Authorities, Ministries of Transport, Police and research bodies.

Most countries have technical guidelines to develop RSI. The few exceptions are Argentina, Greece and Republic of South Africa. Technical guidelines will be soon available in Colombia, Hungary and Netherlands. Software tools supporting RSI development are available in five of the countries surveyed: France, Ireland, Jamaica, Portugal and Switzerland.

The lack of resources and/or tools is the main reason for not developing RSI in most countries (ten countries). Other mentioned reasons are the fact that the State doesn't recommend to apply RSI (five countries) and a lack of familiarity with RSI (three countries). In eight countries, the current tools used are not considered adequate.

Table B.6. **Main survey results related to RSI**

Country	**1 - Tool regulated by National law**	**2 - Network coverage**	**3 – Agency in charge**	**4 - Technical guidelines**	**5 - Software Tools**
Argentina	No	Not performed	Not performed	No	No
Austria	Yes	Part of the road network	Other	Yes	No
Canada	No	Part of the road network	National and/or local Road Administrations	Yes	No
Colombia	No	Part of the road network	Other	Soon available	No
Czech Republic	Yes	Part of the road network	National and/or local Road Administrations	Yes	Don't know
France	Yes	Part of the road network	National and/or local Road Administrations	Yes	Yes
Germany	Yes	All Roads	National and/or local Road Administrations	Yes	No
Greece	Yes	Part of the road network	Other	No	No
Hungary	Yes	Part of the road network	National and/or local Road Administrations	Soon available	No
Ireland	Yes	Part of the road network	National and/or local Road Administrations	Yes	Yes
Italy	Yes	Part of the road network	Ministry / National Administration	Yes	No
Jamaica	No	Part of the road network	Ministry / National Administration	Yes	Yes
Japan	No	Not performed	Not performed	Don't know	Don't know
Korea	Yes	Part of the road network	National and/or local Road Administrations	Yes	Don't know
Lithuania	No	Part of the road network	National and/or local Road Administrations	Yes	No
Luxemburg	Yes	Part of the road network	National and/or local Road Administrations	Yes	Don't know

Country	1 - Tool regulated by National law	2 - Network coverage	3 – Agency in charge	4 - Technical guidelines	5 - Software Tools
Netherlands	Yes	Part of the road network	National and/or local Road Administrations	Soon available	No
Portugal	No	Not performed	Not performed	Yes	Yes
Republic of South Africa	No	Part of the road network	Ministry of Transport	No	No
Slovenia	Yes	Part of the road network	National and/or local Road Administrations	Yes	No
Sweden	Yes	Part of the road network	National and/or local Road Administrations	Yes	No
Switzerland	Yes	All Roads	National and/or local Road Administrations	Yes	Yes
United States	No	Part of the road network	National and/or local Road Administrations	Don't know	Don't know

High-Risk Sites worldwide

Within the European Union the ranking of high accident concentration sections, carried out on the basis of reviews, at least every three years, of the operation of the road network is obligatory for the trans-European road network under Directive 2008/96/EC. Each member country had to adopt the specific Directive by December 2011.

The results of the survey performed within IRTAD Members in 2013 show that in 15 countries (about 65% of surveyed countries) have national laws regulating HRSs (Table B.7). Most European countries deal with HRS, but focus mainly on motorways and national roads, under the auspices of the respective road authority. Outside the European Union, there is a great diversity of practices regarding HRS. For example, in countries such as the United States and Switzerland, HRSs are regulated by national laws that cover all State-maintained roads (United States) or the whole network (Switzerland). In these countries technical guidelines and software tools are available. On the other hand, in other countries such as Colombia and Jamaica, HRSs are not regulated by national laws and they are dealt with on urban and on main roads respectively. However, technical guidelines as well as software tools are available. In these countries, the lack of laws making it compulsory and the lack of knowledge of its importance, were identified as the main reasons for the lack of activity regarding HRS.

HRSs are identified on at least portion of the road network in all the countries surveyed. Some countries, such as Germany, Korea and Switzerland, go further and identify them on the entire road network. The responsibility for HRS development ranges over a variety of agencies including: National and Local Road Authorities, Ministry of Transport, Police, Public Insurers and research bodies.

In most countries there are technical guidelines to collect data about HRSs. Few exceptions are Swiss, Japan, Republic of South Africa and Sweden. Software tools to support data gathering of HSRs are available in 14 of the countries investigated.

The lack of resources and/or tools is the main reason for not identifying HRSs in most countries (ten countries). Other mentioned reasons are the unavailability of the data (six countries), the fact that the State doesn't recommend HRSs (two countries) and the absence of familiarity with the data (one country). In ten countries, worldwide, the current tools are not considered adequate.

Table B.7. **Main survey results related to HRS**

Country	1 - Tool regulated by National law	2 - Network coverage	3 – Agencies in charge	4 - Technical guidelines	5 - Software Tools
Argentina	No	Part of the road network	Not performed	Yes	No
Austria	Yes	Part of the road network	National and/or local Road Administrations	Yes	Yes
Canada	No	Part of the road network	Ministry / National Administration	Yes	Yes
Colombia	No	Part of the road network	Other	Yes	Yes
Czech Republic	Yes	Part of the road network	National and/or local Road Administrations	Yes	Don't know
France	Yes	Part of the road network	Other	Yes	Yes
Germany	Yes	All Roads	Other	Yes	Yes
Greece	Yes	Part of the road network	Other	No	No
Hungary	Yes	Part of the road network	National and/or local Road Administrations	Yes	Yes
Ireland	Yes	Part of the road network	National and/or local Road Administrations	Yes	Yes
Italy	Yes	Part of the road network	Ministry / National Administration	Yes	Yes
Jamaica	No	Part of the road network	Ministry / National Administration	Yes	Yes
Japan	Yes	Part of the road network	Ministry / National Administration	No	Yes

Country	1 - Tool regulated by National law	2 - Network coverage	3 – Agencies in charge	4 - Technical guidelines	5 - Software Tools
Korea	Yes	All Roads	National and/or local Road Administrations	Yes	No
Lithuania	No	Part of the road network	National and/or local Road Administrations	Yes	No
Luxemburg	No	Part of the road network	National and/or local Road Administrations	Yes	No
Netherlands	Yes	Part of the road network	National and/or local Road Administrations	Yes	Yes
Portugal	Yes	Part of the road network	Other	Yes	Yes
Republic of South Africa	No	Part of the road network	Ministry / National Administration	No	No
Slovenia	Yes	Part of the road network	National and/or local Road Administrations	Don't know	No
Sweden	No	Part of the road network	Not performed	No	No
Switzerland	Yes	All Roads	National and/or local Road Administrations	Yes	Yes
United States	Yes	Part of the road network	National and/or local Road Administrations	Yes	Yes

In-Depth Investigation worldwide

Some European countries (e.g. Finland, Sweden, Germany and the United Kingdom) have already set up dedicated agencies or research centres that operate In-Depth Investigation of accidents on a permanent basis over a defined area. There is still no international standardisation of variables and data collection methods. A first attempt in this direction has been made in Europe with European projects STAIRS - Standardisation of Accident and Injury Registration Systems[2], and PENDANT - Pan-European Co-ordinated Accident and Injury Database[3]. These projects were mainly focused on issues related to passive safety. At the European level a step further has been taken with DaCoTA project. The DaCoTA project aimed to contribute to standardisation by developing a common methodology and a common database and by establishing a Pan-European In-Depth Accident Investigation Network.

The results of the survey performed within IRTAD Members in 2013 show only six countries (about 26% of surveyed countries) have national laws regulating In-Depth Investigation (Table). However, In-Depth Investigations are used on at least a portion of the road network in 19 countries, with Switzerland carrying them out on the entire road network. The responsibility for the connected data collection and calculation ranges over a variety of agencies including: National Road Authorities, Ministry of Transport, Police, Public Insurers and research bodies.

Most countries do not have technical guidelines to develop In-Depth Investigation. The few exceptions that do are Canada, Czech Republic, Germany, Korea, Sweden and the United States. Software tools to support data gathering and implementation of In-Depth Investigations are available in six of the countries investigated: Canada, Czech Republic, Germany, Jamaica, Sweden and Switzerland.

The lack of resources and/or tools is the main reason for not performing In-Depth Investigation in most countries (11 countries). Other mentioned reasons are the absence of familiarity with the data (3 countries) and the fact that the State doesn't recommend HRSs (2 countries). In six countries, worldwide, the current tools are not considered adequate.

Table B.8. **Main survey results related to In-Depth Investigation**

Country	**1 - Tool regulated by National law**	**2 - Network coverage**	**3 – Agencies in charge**	**4 - Technical guidelines**	**5 - Software Tools**
Argentina	No	Part of the road network	Not performed	No	No
Austria	No	Part of the road network	Not performed	No	No
Canada	Yes	Part of the road network	Ministry / National Administration	Yes	Yes
Colombia	No	Part of the road network	Other	No	No
Czech Republic	No	Part of the road network	Other	Yes	Yes
France	Don't know	Not performed	Not performed	Don't know	Don't know
Germany	No	Part of the road network	Other	Yes	Yes
Greece	No	Part of the road network	Not performed	No	No
Hungary	No	Not performed	Other	No	Don't know
Ireland	No	Part of the road network	Other	Don't know	Don't know
Italy	No	Part of the road network	Not performed	No	No
Jamaica	No	Part of the road network	Ministry / National Administration	No	Yes
Japan	No	Not performed	Not performed	No	Don't know
Korea	Yes	Part of the road network	Other	Yes	No
Lithuania	No	Part of the road	National and/or local	No	No

Country	1 - Tool regulated by National law	2 - Network coverage	3 – Agencies in charge	4 - Technical guidelines	5 - Software Tools
		network	Road Administrations		
Luxemburg	No	Don't know	Other	Don't know	Don't know
Netherlands	Yes	Part of the road network	National and/or local Road Administrations	Soon available	No
Portugal	No	Part of the road network	Other	No	No
Republic of South Africa	Yes	Part of the road network	Ministry / National Administration	No	No
Slovenia	Yes	Part of the road network	Ministry / National Administration	No	No
Sweden	No	Part of the road network	National and/or local Road Administrations	Yes	Yes
Switzerland	Yes	All Roads	National and/or local Road Administrations	Soon available	Yes
United States	No	Part of the road network	National and/or local Road Administrations	Yes	Soon available

Notes

1. DIRECTIVE 2008/96/EC on road infrastructure safety management.

2. Vallet G., Laumon B., Martin J.L., Lejeune P., Thomas P., Ross R., Kossmann I., Otte D., Sexton B. (1999). STAIRS - Standardisation of Accident and Injury Registration Systems, Final Report, 1999.

3. Morris A, J Lenard, L Rackliff (2004). "PENDANT Data Analysis" Deliverable D11 PENDANT (Pan-European Co-ordinated Accident and Injury Database), Workshop Report.

ANNEX C. INFRASTRUCTURE SAFETY PERFORMANCE INDICATORS IN IRTAD DATABASE

Starting in the 1970s, in-depth studies on road accidents have highlighted the importance of the role played by the road infrastructure in the accident process. Research has also shown how it is possible to improve the infrastructure safety performance by acting on its characteristics (Elvik et al., 2009).

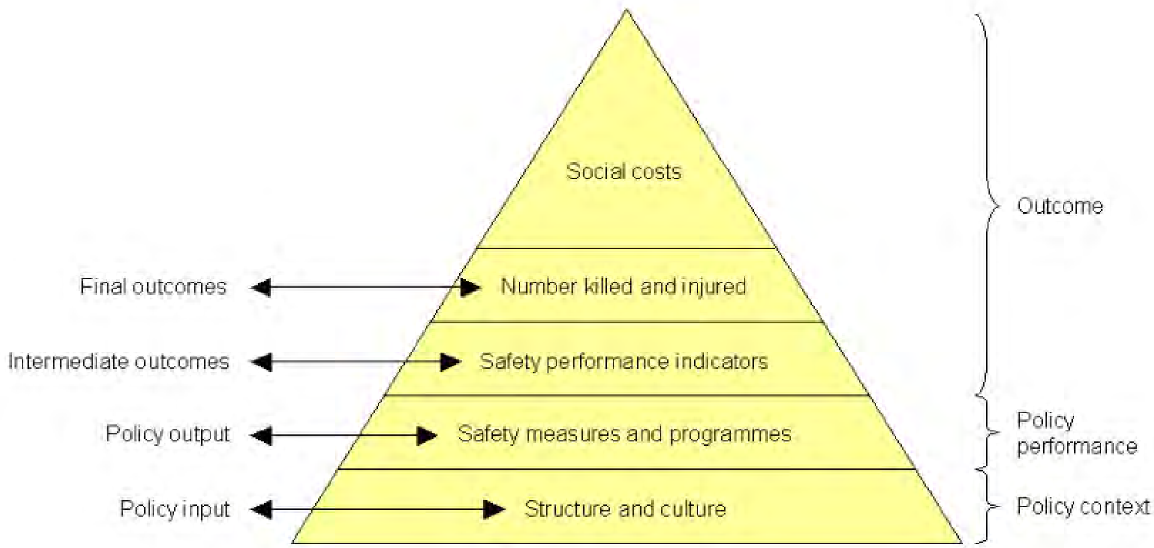
Over the last few years, countries such as Sweden, the Netherlands and Australia have adopted a new approach (or philosophy) towards road safety called "Safe System" (OECD/ITF, 2008), which starts from two assumptions: vulnerability of the human body and admission of the road user's fallibility. Here, the road system and, consequently, the infrastructure should be designed and operated so as to overlook the user's errors or oversights. Therefore, the organisation that plans and manages the road network is responsible for providing the road user with a safe infrastructure (Wegman and Aarts, 2006). However, in many cases, road authorities limit their intervention to meet the requirements specified in regulations and manuals, trying to maintain the balance between economic cost efficiency and safety levels.

In this scenario, the evaluation on the safety performance of roads with objective criteria may encourage the road authorities to enhance the safety levels of the managed road network. Moreover, another promising approach for road safety is comparing performances. Comparing and benchmarking road safety performance may begin to look a possibility to learn from each other. However, in order to be meaningful for learning purposes, comparing and benchmarking cannot be limited to the traditional fatality rates. The IRTAD database can encompass monitoring results of safety performance of road infrastructure for those countries that agree to provide relevant data. The comparison framework should rely on a sound approach and be based on clear and objective indicators. In this sense, the benchmark results provide policy makers and road authorities with information about others that can be used as a basis for developing measures and programmes to increase their own performance (Wegman et al. 2008).

A suitable approach that has established itself in the last decade is the so-called pyramid approach (Wegman et al. 2008). This approach uses a target hierarchy as presented in Figure C.1, covering: social costs; number of killed and injured; Safety Performance Indicators; safety measures and programmes; and structure and culture

The relationships between indicators at different layers must be seen as causal for the top four layers. This means that a road safety measure will first need to have an effect at the level of the intermediate variables (SPIs) in order for it to be plausible that the measure had an effect on the number of fatalities and injuries.

Figure C.1. **Pyramid road safety model**



Source: Koornstra et al., 2002.

For significant and realistic comparisons, road infrastructure safety should be assessed at different levels of the pyramid and be based on reliable data. In order to assess a country's road infrastructure safety performance, without taking into account policy and implementation performances, in SUNflower it is suggested to focus on the top three layers of the pyramid (Koornstra et al., 2002):

- The third level of the pyramid corresponds to indicators aimed at monitoring intermediate outcomes or Safety Performance indicators. SPIs for road infrastructures aim to assess the safety hazards related to road infrastructure at two levels: the *road network level* (roads should be located at the right place from a functional point of view) and *road design level (*individual roads should be designed in a safe way*)*. More details can be found in Chapter 2.6 of the study.
- The second level corresponds to final outcomes, i.e. the number of fatalities and injuries on the roads. Indicators that are potentially suited for international comparisons are the number of road accidents per length of road and the number of accidents per unit of exposure, meaning per vehicle-kilometres or population in urban area.
- Finally, based on the number of people killed and injured and the consequences of road accidents it is possible to express the socio-economic burden imposed on societies by road accidents. This type of information allows making comparisons with other sectors in society. It also enables rational prioritization of policy actions based on cost-benefit analyses.

In order to choose and adopt such performance indicators, a number of issues need to be solved for a meaningful comparison among countries. In general terms some of these issues are reported below.

- Firstly, it is necessary to set up candidate safety indicators useful for comparison and benchmarking among countries. It may be wise to adopt indicators based on available data, avoiding indicators based on data not present in the IRTAD database or in national road safety databases. However, referring to the IRTAD database, this decision could be taken only referring to final outcomes, because data required for indicators referred to the other two pyramid levels are not available at present. Road infrastructure SPIs are quite demanding in term of data collection and calculation needed, as highlighted in Chapter 2.6. These intermediate indicators need a detailed guideline to be calculated.

- Secondly, the type of roads for comparison, need to be decided. At an initial stage, comparison between performances of motorways can be considered a good starting point. Then it can be extended to national trunk roads and then even into selected urban roads according to data availability.
- In case of data demanding indicators, e.g. road design SPIs, due especially to the entity of resources required for data collection and elaboration, a selection process aimed at identifying a sample of road sites representative of each selected road network (i.e. motorway, rural network…) could be introduced.
- Indicators need to be compared between roads with similar road and traffic characteristics. In this respect, performance indicators need to be averaged for some range of traffic volumes and geometric features including the number of lanes, range of section length etc.
- For comparison purpose, the division of roads into sections and junctions is a sensitive issue. Some clear guidelines need to be given and agreed between participating countries. For example, in the case of motorways, one can divide a motorway into sections identified by the presence of on-off ramps. Some guidelines can be found in the Highway Safety Manual (AASHTO, 2010). Possibly, the number of road sections or length that needs improvement can be suggested according to some agreed thresholds. Some positive aspects of road safety can be addressed by showing the number of road sections or length that shows high performance comparatively.

International comparison of road infrastructure safety performance is important as it may provoke the attention of some countries that need comparatively better infrastructure safety management. As explained, referring to the pyramid approach represents a solid comparison framework. Potential road infrastructure related safety indicators help to compare countries according to three level of the pyramid: Social costs, Final outcomes (road accidents) and Intermediate outcomes (SPIs). There are many indicators that could be proposed for each level; some of them can be adopted relatively easily, because the required data are available in the IRTAD database. Other indicators, like road infrastructure SPIs, are more complex to be calculated and may require specific tools and methods, besides a relevant amount of resources.

Comparing and benchmarking the safety performance of countries is achievable only once reliable data is available. It is clear that a number of steps need to be taken before being able to compare countries according to the safety level of their road network. Focusing on these issues is outside of the scope of this report; nevertheless it is recommended that a specific study is carried out before a final decision is made about the choice of indicators.

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Wegman, F. and Aarts, L. (2006), *Advancing Sustainable Safety*, Leischendam, Dutch Institute for Road Safety Research.

ANNEX D. GUIDELINES AND MANUALS USED IN INVESTIGATED COUNTRIES

In the following tables, references are provided to guidelines and manuals used internationally and in surveyed countries.

Table D.1. **References to RIA guidelines and manuals used in investigated countries**

Country	References
Canada	Available at: http://www.safetyanalyst.org
Germany	BVWP (Bundesverkehrswegeplanung - Federal Transport Infrastructure Plan). Available at: www.bmvbs.de
Ireland	Available at: http://nrastandards.nra.ie/road-design-construction-standards/dmrb/volume5/nra-hd-18-road-safety-impact-assessment
Japan	Not available on the web.
Lithuania	Available at: http://www3.lrs.lt/pls/inter3/dokpaieska.showdoc_l?p_id=395037
Luxemburg	Internal documents, respecting German or French standards. Not available on the web
Portugal	Available at: www.inir.pt or www.lnec.pt
Slovenia	Available at: http://www.mzip.gov.si/fileadmin/mzip.gov.si/pageuploads/DC_splosno/predpisi/RSIA-SMERNICA.pdf
Switzerland	Available at: www.astra.admin.ch/www.vss.ch
United States	The AASHTO Highway Safety Manual (HSM) (http://www.highwaysafetymanual.org) includes some relevant guidelines. The Federal Highway Administration HSM Integration Guide (http://safety.fhwa.dot.gov/hsm/hsm_integration) provides some guidance.

Table D.2. **References to EAT guidelines and manuals used in investigated countries**

Country	References
Canada	Available at: http://www.safetyanalyst.org or at: http://www.mtq.gouv.qc.ca/portal/page/portal/entreprises/zone_fournisseurs/c_affaires/analyse_avantages_couts_projets_publics
Colombia	IRAP protocol is used.
Germany	Available at: e.g. www.fgsv-verlag.de (Nr. 316/1 M Uko, Nr. 316/2 MAS T2, Nr. 132 EWS)
Ireland	Available at: http://www.nra.ie/Publications/ProjectAppraisal/
Italy	Available at: http://www.mit.gov.it/mit/site.php?p=cm&o=vd&id=2429
Sweden	Available at: www.trafikverket.se
Switzerland	Available at:www.astra.admin.ch/www.vss.ch

Country	References
United States	HSIP Manual, available at: http://safety.fhwa.dot.gov/hsip/ resources/fhwasa09029/

Table D.3. **References to RSA guidelines and manuals used in investigated countries**

Country	References
Austria	Austrian RVS guideline "02.02.33 Road Safety Audit". Not available on the web
Canada	Available at: http://www.mtq.gouv.qc.ca/portal/page/portal/Librairie/bpm/guide_real_audits-sec-rout.pdf orhttp://www.tac-atc.ca/english/bookstore/
Czech Republic	Available at: http://www.audit-bezpecnosti.cz/
France	http://portail.documentation.developpement-durable.gouv.fr/dtrf/notice.html?id=Dtrf-0006508&qid=sdx_q3&p=1&no=1&nb=110
Germany	Not available on the web, only hard copies. www.fgsv-verlag.de (Nr. 298 and 298/1)
Ireland	Available at: http://nrastandards.nra.ie/road-design-construction-standards/dmrb/volume5/nra-hd-19-road-safety-audits-incorporating-ha-42-where-applicable
Italy	Available at: http://www.mit.gov.it/mit/site.php?p=cm&o=vd&id=2429
Jamaica	Under development (under the Inter-American Development Bank's Road Improvement Programme).
Lithuania	Available at: http://www3.lrs.lt/pls/inter3/dokpaieska.showdoc_l?p_id=395038
Luxemburg	Internal documents, respecting German or French standards. Not available on the web.
Portugal	Available at: www.inir.pt or in www.lnec.pt
Republic of South Africa	Available at: www.rtmc.co.za under publications
Slovenia	Available at: http://www.mzip.gov.si/fileadmin/mzip.gov.si/pageuploads/DC_splosno/predpisi/RSA-smernica.pdf
Sweden	Available at: www.transportstyrelsen.se (only in Swedish)
Switzerland	Available at: www.vss.ch
United States	Available at: http://safety.fhwa.dot.gov/rsa/

Table D.4. **References to SPI guidelines and manuals used in investigated countries**

Country	References
Canada	Many jurisdictions use the Transportation Association of Canada documents as guidelines. TAC is available at: www.tac-atc.ca
Portugal	SafetyNet report on road network SPI. Available at: http://ec.europa.eu/transport/wcm/road_safety/erso/safetynet/fixed/WP3/sn_wp3_d3p8_spi_manual.pdf
Switzerland	Available at: www.mistra.ch

Table D.5. **References to RAP guidelines and manuals used in investigated countries**

Country	References
Colombia	Provided by IRAP (www.irap.org)
Ireland	Available at: http://nrastandards.nra.ie/road-design-construction-standards/func-startdown/916
Sweden	Available at: www.transportstyrelsen.se (only in Swedish)
Switzerland	Available at: www.astra.admin.ch
United States	Available at: http://www.usrap.us/
Canada	Available in French at: http://www3.publicationsduquebec.gouv.qc.ca/produits/ouvrage_routier/guides/guide14.fr.html or at: http://www.tc.gc.ca/media/documents/roadsafety/CanRAP_Data_Collection_Analysis_Jan_2009.pdf
Czech Republic	Available at: www.eurorap.org
South Africa	Available at: www.rtmc.co.za under publications

Table D.6. **References to RSI guidelines and manuals used in investigated countries**

Country	References
Austria	Manual for Conducting RSI https://www.bmvit.gv.at/service/publikationen/verkehr/strasse/verkehrssicherheit/vsf/downloads/38_rsi_handbuchEN.pdf
Canada	Available at: http://www.e-laws.gov.on.ca/html/regs/english/elaws_regs_020239_e.htm also see www.tac-atc.ca
Czech Republic	Available at: http://www.audit-bezpecnosti.cz/
France	Available at: http://portail.documentation.developpement-durable.gouv.fr/dtrf/notice.html?id=Dtrf-0005450&qid=sdx_q0&p=1&no=1&nb=2
Germany	Merkblatt and KommentarMdV - Available at: www.fgsv-verlag.de (Nr. 389)
Ireland	Available at: http://nrastandards.nra.ie/road-design-construction-standards/dmrb/volume5/nra-hd-17-road-safety-inspection
Italy	Available at: http://www.mit.gov.it/mit/site.php?p=cm&o=vd&id=2429
Lithuania	Available at: http://www3.lrs.lt/pls/inter3/dokpaieska.showdoc_l?p_id=395039
Luxemburg	Internal documents, respecting German or French standards. Not available on the web.
Portugal	Available at: www.inir.pt or in www.lnec.pt
Slovenia	Available at: http://www.mzip.gov.si/fileadmin/ mzip.gov.si/pageuploads/DC_splosno/predpisi/RSI-SMERNICA1.pdf
Sweden	Available at: www.transportstyrelsen.se (only in Swedish)
Switzerland	Available at: www.astra.admin.ch/www.vss.ch

Table D.7. **References to HRS guidelines and manuals used in investigated countries**

Country	References
Argentina	Guidelines not available on the web and procedure is not standardized.
Austria	Austrian RVS guideline "02.02.33 Road Safety Audit". Not available on the web
Canada	Available at: http://www.mtq.gouv.qc.ca/portal/page/portal/grand_public/vehicules_promenade/securite_routiere/sites_potentiel_amelioration or at: http://www.tac-atc.ca/english/bookstore/ or at: http://www.safetyanalyst.org/
Czech Republic	Available at: http://www.audit-bezpecnosti.cz/
France	Available at: http://portail.documentation.developpement-durable.gouv.fr/dtrf/notice.html?id=Dtrf-0004250&qid=sdx_q2&p=1&no=6&nb=81
Germany	It is called "MerkbalttfürUnfallkommissionen -MUKO". Available at: www.fgsv-verlag.de (Nr. 383 and 316/1)
Ireland	Available at: http://nrastandards.nra.ie/road-design-construction-standards/dmrb/volume5/nra-hd-15-network-safety-ranking
Italy	Available at: http://www.mit.gov.it/mit/site.php?p=cm&o=vd&id=2429
Lithuania	Available at: http://www3.lrs.lt/pls/inter3/dokpaieska.showdoc_l?p_id=395036
Luxemburg	Internal documents, respecting German or French standards. Not available on the web.
Portugal	Currently two methods are used. One method is based on accident frequencies and severity - not accounting for exposure. These are not really high risk sites, but just sites with a high number of severe accidents. The other method is based on expected accident frequencies and accounts for both exposure and road class (further information in AASHTO's Road Safety Manual).
Slovenia	Available at: http://www.mzip.gov.si/fileadmin/ mzip.gov.si/pageuploads/DC_splosno/predpisi/NSM-SMERNICA.pdf
Switzerland	Available at: www.astra.admin.ch/www.vss.ch
United States	Highway Safety Improvement Program Manual. http://safety.fhwa.dot.gov/hsip/resources/fhwasa09029/

Table D.8. **References to In-Depth Investigation guidelines and manuals used in investigated countries**

Country	References
Canada	Many major police services. Transport Canada has collision investigation teams.
Czech Republic	Available at: http://hadn.cdvinfo.cz/
Ireland	FCI training provided and accredited by City and Guilds.
Portugal	The police have procedures for collecting evidence at the road accident scene.
Sweden	Available at: www.trafikverket.se
Switzerland	Available at: www.astra.admin.ch
United States	Available at: http://www.nhtsa.gov/NASS

Table D.9. **International guidelines and tools**

Report	**Description**
The CEDR Report	The source of Conference of European Directors of Roads (CEDR) measures is the Final report of "Best Practice on Cost Effective Road Safety Infrastructure Investments", 2008. According to the report, the five most promising investments were identified (as a result of preliminary assessment and related ranking of investments) and selected for further in-depth analysis using the existing literature in conjunction with the results of Questionnaire 2 of the CEDR task group O7 (Road safety). These investments concern the following measures: Roadside treatment; Speeding; Junctions layout; Junction traffic control; Traffic calming. *Conference of European Directors of Roads (CEDR) (2006). Most Effective Short-, Medium- and Long-Term Measures to Improve Safety on European Roads. Final Report prepared by the Conference of European Directors of Roads.*
The Cochrane reviews	Cochrane Reviews are systematic reviews of primary research in human health care and health policy. They investigate the effects of interventions for prevention, treatment and rehabilitation. They also assess the accuracy of a diagnostic test for a given condition in a specific patient group and setting. The Cochrane Injuries Group has been preparing Cochrane Reviews on the effectiveness of interventions for road safety, including slowing traffic speed, wearing helmets, and driver education. The findings of these Cochrane Reviews provide guidance on the effectiveness of interventions for road safety in the hope that governments, urban planners, and individuals will be encouraged to improve road safety as a matter of urgency. *The Cochrane Injuries Group Reviews. (2011). Prevention of road traffic injuries. Available on-line at: http://injuries.cochrane.org/injuries-group-reviews*
Countermeasures that work: A Highway Safety Countermeasure Guide For State Highway Safety Offices	This Guide is intended to be a key reference to assist State Highway Safety Offices (SHSOs) in the United States selecting effective, evidence-based traffic safety countermeasures for major road safety problem areas. The Guide describes strategies and countermeasures that are relevant to SHSOs, summarizes their use, effectiveness, costs, and implementation conditions and includes references to the most important publications (research summaries and individual studies) in the field. The Guide includes countermeasures related to the following road safety problems and research areas: Alcohol-impaired driving; Seat-belt use and child restraints; Aggressive driving and speeding; Distracted and drowsy driving; Motorcycle Safety; Young drivers; Older drivers; Pedestrians; Bicycles. *National Highway Traffic Safety Administration (NHTSA). (2013). Countermeasures that work: A Highway Safety Countermeasure Guide For State Highway Safety Offices (7th Edition*).
Austroads Road Safety Engineering Toolkit	The Road Safety Engineering Toolkit is a reference tool for road engineering practitioners in state and local governments in Australia and New Zealand. It outlines best-practice, low cost, high return road environment measures to achieve a reduction in road trauma. The Toolkit seeks to reduce the severity and frequency of accidents involving road environment factors. The Toolkit draws together existing road safety engineering knowledge for easy access by practitioners. The presented knowledge has been updated with recent experience from local and state government agencies, and with the results of comprehensive road safety research reviews. The Toolkit is considered a 'living' document including updates and revisions, so that more recent safety 'wins' are captured and disseminated. *ARRB Group. (n.d.). Austroads Road Safety Engineering Toolkit. Available from: www.engtoolkit.com.au*
International Road Assessment Programme (iRAP) Road Safety Toolkit	The Road Safety Toolkit provides information on the causes and prevention of road accidents that cause death and injury. Building on decades of road safety research, the Toolkit helps engineers, planners and policy makers develop safety plans for car occupants, motorcyclists, pedestrians, bicyclists, heavy vehicle occupants and public transport users. It is aimed primarily at users in developing countries. It has been translated into French, Spanish and

Report	Description
	Mandarin. *International Road Assessment Programme (iRAP). (n.d.). Road Safety Toolkit http://toolkit.irap.org/*
The PROMISING project	The PROMISING project is aimed at developing measures that reduce the risk of injury to vulnerable and young road users as much as possible in a non-restrictive way. PROMISING project measures come from the WP5 "Cost-benefit analysis of measures for vulnerable road users", July 2001. Cost-benefit analysis was carried out for a number of measures. *PROMISING. (2001). Promotion of Measures for Vulnerable Road Users, Deliverable D5 Cost-benefit analysis of measures for vulnerable road users, July 2001.*
The SUPREME project	The goal of the SUPREME research project was to collect, analyse, summarise and publish best practices in road safety in the Member States of the European Union as well as in Switzerland and Norway. The target audiences of the project are decision and policy makers at all levels, from European to local, as well as the scientific community and practitioners in the field. The aim was to provide users with specific information on outstanding safety measures with a view to implementation in other countries or at the European level. SUPREME measures come from the final report and are mainly from Part C of "Handbook for measures at the Country level", and Part D of "Handbook for measures at the European level", both from June 2007. The evaluated safety measures described are ranked as best, good or promising practices in the following areas: Licensing; Policy; Enforcement; Campaigns; Infrastructure interventions; Safety equipment; Data analysis; Post impact care. *SUPREME (2007a) Part C, Handbook for measures at the Country level, June 2007.* *SUPREME (2007b) Part D, Handbook for measures at the European level, June 2007.*
The Road Safety Engineering Risk Assessment Project	Funded by Austroads, this programme of research began in 2002 on a relatively limited scale, but formed a substantial part of the Austroads road safety research programme from 2004 to 2007. The results were intended to provide road authorities with more effective methods and tools to reduce road accidents and injuries. This has included assessment of the effectiveness of commonly used road safety measures, as well as reviews of other associated issues required as part of an economic evaluation for road safety. A total of 11 reports were published based on this research (available from www.austroads.com.au), as well as 15 newsletters (the 'risk reporter' newsletter series is available from www.arrb.com.au).
I-cars network, thematic group on impact assessment measures	This project provides an overview of impact assessment studies (all types of studies, from expert judgment to crash studies) for intelligent vehicle systems. The objective of the project is to exchange experience regarding the use of different methods of impact assessment and socio-economic evaluation with the goal of leading to more reliable methods with higher predictive validity. *iCars Network, thematic group on impact assessment measures. (n.d.). iCARS Thematic Network Project. Available from: http://www.icarsnetwork.eu/en/thematic_groups/tg3_-_impact_assessment_methods/*
Urban safety management: guidelines for developing countries	This document contains guidelines developed for local and regional highway authority officers in developing countries who have a responsibility for road safety issues in urban areas to implement Urban Safety Management (USM) techniques, as developed in Europe. *Quimby, A., Hills, B, Baguley, C., Fletcher, J. (2003). Urban safety management: guidelines for developing countries. Available from: http://www.transport-links.org/transport_links/filearea/documentstore/104_USMv2%20Full.PDF*

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International Transport Forum

Road Infrastructure Safety Management

This report describes the most consolidated Road Infrastructure Safety Management (RISM) procedures, analyses their use worldwide, identifies possible weaknesses and barriers to their implementation. It provides examples of good practices and aims to generally contribute to the scientific assessment of RISM procedures. Important parts of this report are based on a survey of road safety authorities in 23 countries on their use of RISM procedures.

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