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Management of Road Infrastructure Safety

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Abstract

Road Infrastructure Safety Management (RISM) refers to a set of procedures that support a road authority in decision making related to the improvement of safety on a road network. Some of these procedures can be applied to existing infrastructure, thus enabling a reactive approach; and other procedures are used in early stages of a project's life-cycle allowing a proactive approach. The objective of this paper is to provide an overview of the most well-known procedures and present a series of recommendations for successful road infrastructure safety management. The work described in the paper was completed by the IRTAD sub-working group on Road Infrastructure Safety Management and presented in detail in the respective Report.

The methodology followed on this purpose included the description of the most consolidated RISM procedures, the analysis of the use of RISM procedures worldwide and the identification of possible weaknesses and barriers to their implementation, the provision of good practice examples and the contribution to the scientific assessment of procedures.

Specifically, the following RISM procedures were considered: Road Safety Impact Assessment (RIA), Efficiency Assessment Tools (EAT), Road Safety Audit (RSA), Network Operation (NO), Road Infrastructure Safety Performance Indicators (SPI), Network Safety Ranking (NSR), Road Assessment Programs (RAP), Road Safety Inspection (RSI), High Risk Sites (HRS) and In-depth Investigation. Each procedure was described along with tools and data needed for its implementation as well as relevant common practices worldwide. A synthesis summarizing the key information for each procedure was also drafted.

Based on a survey on 23 IRTAD member countries from worldwide, the lack of resources or tools is the most commonly stated reason for not applying a RISM procedure. This has been frequently found mainly in European countries. Another common reason is the absence of recommendations / guidelines, especially for SPI, RAP, RSI and RSA. This highlights the importance of

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the presence of some legislation regulating the application of the procedures. Lack of data was found important mainly for SPI, HRS and EAT.

Good practices of road infrastructure safety management have been explored in order to find solutions to the issues highlighted by the survey and provide examples about how these issues have been overcome in some countries. Specifically, issues related to data, legal framework, funding, knowledge, tools and dealing with more RISM procedures were addressed.

Finally, nine key messages and six recommendations for better Road Infrastructure Safety Management were developed based on the conclusions made.

Keywords: Road Infrastructure Safety Management; Road Safety

1. Introduction

When looking at road safety figures in the world, two different faces come out. While high income countries registered a remarkable decrease in road accident fatalities in the last decades, thanks to safer vehicles, roads and users' behaviour, in low and middle income countries the picture is completely different. 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).

These countries are experiencing an increasing usage of motorized vehicles. 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. As a matter of facts, the existing road network needs to be adapted to the changing traffic environment. In order to improve safety, during operation and maintenance stages road authorities have to find and correct safety issues determining road accidents, thus they adopt a mainly reactive approach, because it relies on accident analysis; a typical example is the high-risk site improvement process.

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 (Wegman and Aarts, 2006) and self-explaining (Theeuwes and Godthelp, 1995). 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.

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".

These procedures and others are proven to be effective in preventing road accidents in some (developed) countries, and have the potential to be just as effective in other countries. For example, evaluations of Road Safety Audits (RSAs) have shown positive cost-benefit-ratios, ranging from 1.34:1 ("acceptable") to 99:1 ("excellent") (ROSEBUD, 2006). High Risk Site (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). The use of regularly updated Road Assessment Program (RAP) data to track the overall performance of national road networks between 1999 to 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). Effects from the application of in-depth accident investigation have an impact on both vehicle and infrastructure safety (McLean, 2005).

For these reasons, in the European Union, road infrastructure safety management is legally specified in Directive 2008/96/EC of the European Parliament and of the council (EC, 2008). The Directive introduces the use of Road Safety Audits (RSAs), Road Safety Impact Assessments (RIAs), Network Safety Ranking (NSR), High Risk Sites (HRS) and Road Safety Inspections (RSIs).

However, there may be issues preventing a correct implementation of a good Road Infrastructure Safety Management. For instance, some countries may have a formal safety improvement program for operation stage, but they may not have any official safety improvement activity or procedure that can be applied in the early planning stage. Budget constraints, particularly in developing countries, can easily force road authorities to sacrifice investment on road safety for an expansion of the road network (OECD/ITF, 2013). Consequently, it is not easy to introduce some additional safety procedures that imply further expenditure.

The objective of this paper is to provide an overview of relevant issues related to well-known RISM procedures and present some recommendations for successful road infrastructure safety management. The work described in the paper was completed by a working group on Road Infrastructure Safety Management of IRTAD[†]. A dedicated report presents the detailed results of the study.

The methodology followed on this purpose included the description of the most consolidated RISM procedures, the analysis of the use of RISM procedures worldwide and the identification of possible weaknesses and barriers to their implementation, the provision of good practice examples.

2. Good Road infrastructure safety management

A total of ten consolidated RISM procedures have been examined, these are: Road Safety Impact Assessment (RIA), Efficiency Assessment Tools (EAT), Road Safety Audit (RSA), Network Operation (NO), Road Infrastructure Safety Performance Indicators (SPI), Network Safety Ranking (NSR), Road Assessment Programs (RAP), Road Safety Inspection (RSI), High Risk Sites (HRS) and In-depth Investigation.

A detailed description of each procedure is out of the scope of the paper. A brief definition is provided below for each procedure.

1. Road Safety Impact Assessment. 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. The purpose is to demonstrate, on a strategic level, the implications on road safety of different planning alternatives of an infrastructure project and they should play an important role when routes are being selected.
2. Efficiency assessment tools. Budget 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 a given investment, for instance in road safety, in order to prioritize investment alternatives.
3. Road Safety Audit. 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, as to identify, in a detailed way, unsafe features of a road infrastructure project.
4. Network Operation. It 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. 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

[†] International Traffic Safety Data and Analysis Group

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. 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 Programs. 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. A preventive tool consisting of a regular, systematic, on-site inspection of existing roads, covering the whole road network carried out by trained safety expert teams, resulting in a formal report on detected road hazards and safety issues, requiring a formal response by the relevant road authority.
9. High Risk Sites. 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:
 - 10.1. the cause or causes of the accident
 - 10.2. injuries, injury mechanisms and injury outcomes
 - 10.3. how the accident and injuries could have been prevented

Considering the entire life cycle of a road infrastructure, six main stages of development can be identified (Elvik, 2010), these are: 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.

RISM 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 (i.e. by fixing the safety issues identified on the infrastructure); on the other hand other procedures are used in early stages (e.g. planning and design) allowing a more proactive approach (Fig.1).

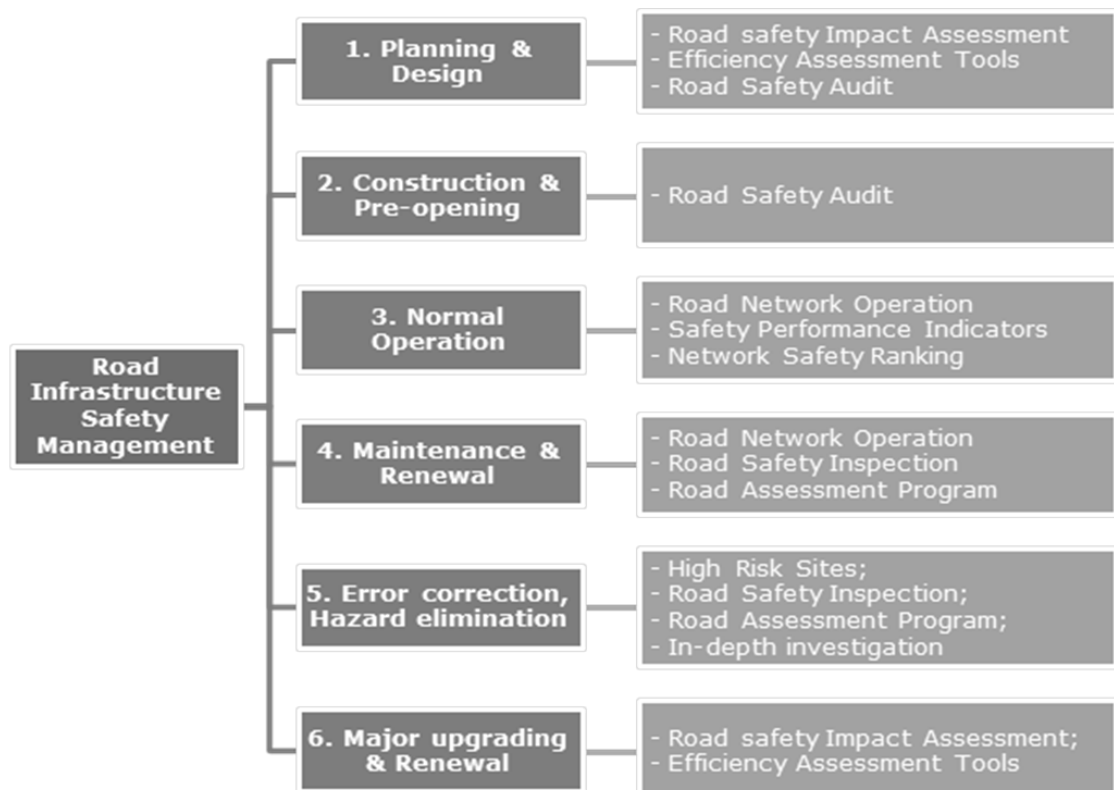


Fig.1. Road safety procedures in each stage of road development

Some RISM procedures are applied to an entire road network or to a part of it. For instance, 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, like Road Safety Inspections, are usually applied at section or intersection level. The use can be extended also to an entire road network but proceeding on a section per section basis.

One further aspect to consider is related to the specific needs of a country, linked mainly to the peculiarities of the roads and their uses of each country. This aspect is important especially for developing countries, where an uncontrolled growth of population and vehicle 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).

A good Road Infrastructure Safety Management approach is one considering these three aspects: all the various stages of development of roadways, the context of application of RISM procedures and the calibration of the procedures to the specific needs of the country.

3. Use of Road infrastructure safety management procedures

Do countries adopt a good approach to Road Infrastructure Safety Management?

First of all, since there was no clear information available for most of these procedures about which of them are applied worldwide and how, a survey has been carried out to investigate which of these procedures are used in a sample of countries. This allowed understanding which stages of a road infrastructure life-cycle are covered by at least one RISM procedure.

In case of countries not using an RISM procedure, a second aim of the survey was to understand why certain countries do not use an RISM procedure. RISM procedures may require specialised knowledge and extensive data, may present some limitations of use (e.g. due to legislation in force in a country), they may be subject to prejudices or need specific requirements to be used, etc.

The survey took place in 2013 with the main aim of understanding the diffusion and the main difficulties to the use of RISM procedures. A total of 23 countries belonging to IRTAD network responded to the questionnaire, 15 from Europe and 8 from other continents (5 from America, 2 from Asia and 1 from Africa).

The survey explored only 8 procedures among the 10 considered by the Working-Group. Road Network operation and Network Safety Ranking have been included in the study in a second phase, after the completion of the survey.

For each RISM procedure the following topics have been explored:

- Presence of a national law regulating an RISM procedure.
- Road network coverage (extent of road network interested by the procedure).
- Party responsible for the application.
- 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.
- Main barriers to the implementation of an RISM procedure.

4. Survey Results

Main conclusions from the analysis of the five topics within the survey are summarized below.

4.1. National law regulation.

According to the survey results, RSI appears in law in 64% of the countries, RSA in 59%, HRS in 68% and RIA in 55%. Within the responding countries, the percentage of countries with a law regulating an RISM procedure in Europe is higher than those from 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.

4.2. Road Network coverage.

RISM procedures are hardly applied to the whole road network (up to 17% of cases depending on the procedure). For the majority of the cases they are applied to only a part of the road network, and most of the times that involves National level roads or motorways. 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. For example, some countries, like Lithuania, perform Road Safety Inspections regularly on national level roads. In USA, RSAs are not mandatory but currently there are 15 States that have formal RSA programmes across State, local and Federal Lands roads. In South Africa and Argentina, RSAs are performed on a voluntary basis on a limited part of the road network.

4.3. Responsible party.

Responsibility for an RISM procedure may change from country to country, and it can depend to the political framework of a country and to the part of the road network involved. For example, countries organised as a federation, like the USA, 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, 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 of 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 exemptions. In case of RISM procedures carried out during the road planning or design stage (i.e. 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 could be of a road contractor (e.g. Hungary, France) or of certified road safety auditors working for the responsible state agency (e.g. Greece).

4.4. Tools supporting 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 which reported the presence of a national law indicated that technical guidelines are also available. For each RISM procedure the percentage of countries with technical guidelines is always greater among countries with dedicated regulations than those without (79% compared to 43%). 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 a RISM procedure. Nevertheless, software applications are not as popular as technical guidelines, only HRS software is available in more than half of the countries but RSI and RSA software is fairly less common.

4.5. Adequacy of available tools.

For each of the 8 procedures, it was asked if the tools available in a country are adequate or not to carry out activities related to each RISM procedure. For two procedures, HRS and RIA, as much as half of the respondents stated that guidelines were inadequate.

4.6. Implementation of RISM procedure

In order to assess if a RISM procedure is fully implemented in a country, an index measuring the implementation level based on survey data has been proposed. To assess the implementation level of a RISM procedure in a country the following criteria have been used:

- 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”.

The diagram in Figure 2 shows the number of countries among the 23 examined that have fully, partially or not implemented a 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 “fully” implemented in only few countries.

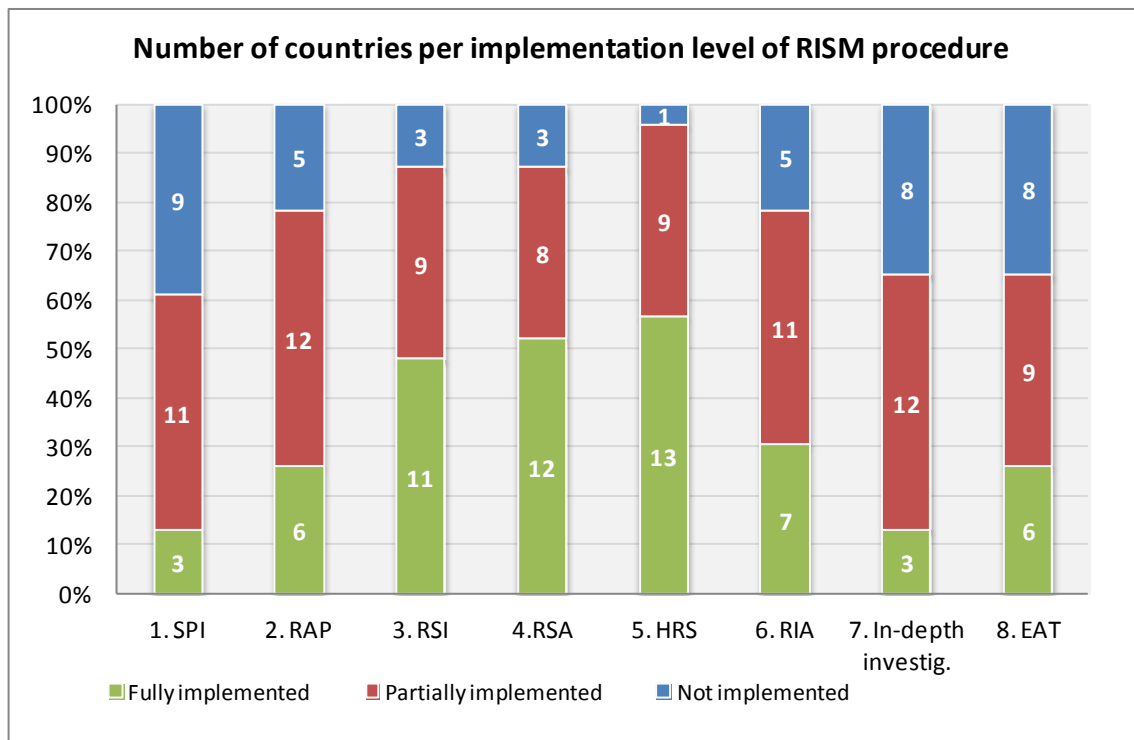


Fig. 2. Number of countries per implementation level of RISM procedure

4.7. Main barriers to the implementation

Each respondent could mention, if appropriate, one or more reasons for not performing an RISM procedure in his/her own country from a list of pre-selected answers. In addition, it was possible to indicate open-ended responses to this question. An attempt has been made to classify the reasons in the following items:

- *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 bidding 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 applied anyway/Reason unknown*. A specific reason has not been identified.

As reported in Fig. 3. *Lack of resources or tools* is the most commonly stated reason for not applying a RISM procedure. This has been found frequent mainly in European countries. Another frequent reason is the *absence of recommendations/impositions*, especially for: SPIs, RAPs, RSIs and RSA. This highlights the importance of the presence of some legislation regulating the application of the procedures.

A lack of data has been found important mainly for SPIs, HRSs and EATs. Lack of know-how is a frequent issue found for RIAs and RSAs.

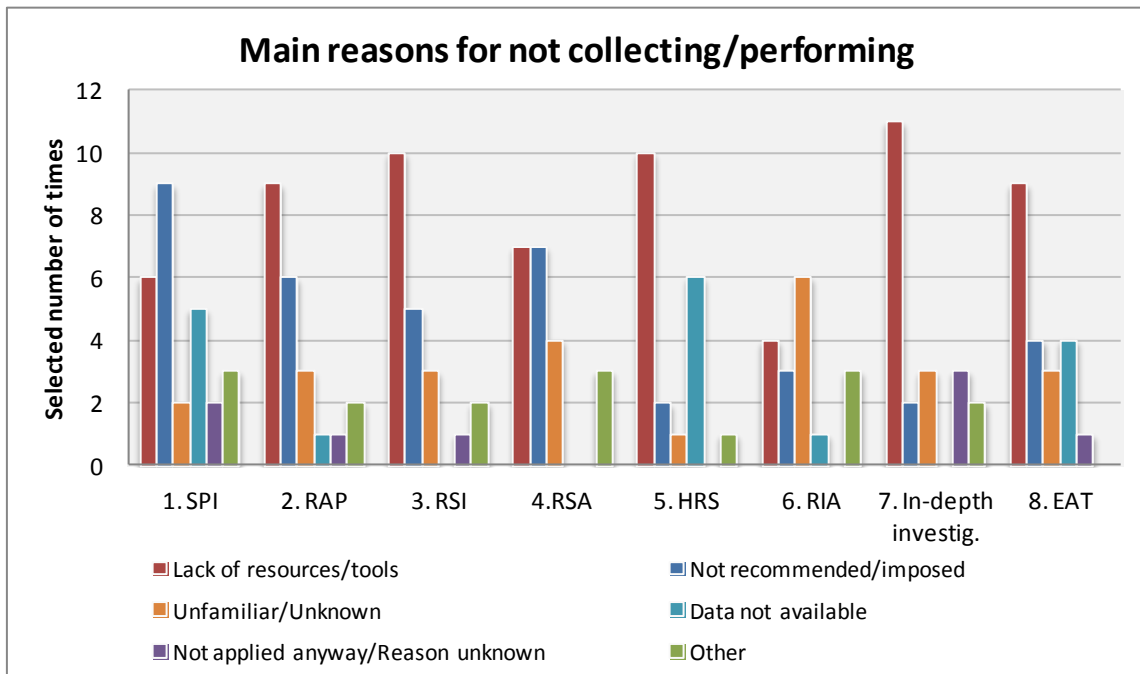


Fig. 3. Number of countries per implementation level of RISM procedure

Other relevant reasons mentioned, beyond the pre-defined items, are reported below.

- SPI: a) Absence of budget allocated for surveying Road Infrastructure Safety Performance Indicators.
- RAP: a) Public availability of technical details; b) Moreover, road authorities may worry about legal disputes over accidents in deficient road sections.
- RSI: a) RSIs are not adequately performed due to budgetary constraints, b) or not performed at all due to a limited availability of qualified inspectors.
- RSA: a) A limited availability of qualified inspectors; b) Liability concerns of the agency that owns the road and concerns about ability to implement the recommendations. c) Road designers do not wish to be audited on their work.
- HRS: A limited availability of qualified staff.
- RIA: a) Regulation requiring RIA exists but an implemental decree has still not been issued; b) Resistance to an increased administrative burden of design procedure based on negative experiences with Environmental Impact Assessment and Strategic Environmental Assessment.
- In-depth investigation: Lack of cooperation between agencies
- EAT: No other relevant issues specified.

5. Conclusion and Recommendations

The improvement of road infrastructure safety management is a key component for the improvement of road safety. Good practices of road infrastructure safety management provide examples on how to overcome the related issues that stood out in the survey: data, legal framework, funding, knowledge and tools. Examples and conclusions regarding each of these issues and recommendations for RISM are drawn below.

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. Therefore, in order to promote the efficient implementation of an RISM procedure, a variety of different types of road safety data and knowledge must be gathered, collated and analysed, to allow for application 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.

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 recommends reviewing existing legislation to conform to good practice based on sound evidence of effectiveness. A good example is European Directive 2008/96/EC. The Directive requires the establishment and implementation of procedures relating to road safety impact assessments, road safety audits, the management of road network safety and safety inspections.

Funding. Road Infrastructure Safety Management is an important investment in improving road safety resource allocation, because it allows the possibility of funneling 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 maximise the efficient use of available resources. Procedures such as Road safety Impact Assessment, High Risk Sites, and Efficiency Assessment Tools help with better targeting of infrastructure related resources to high risk parts of the road network or to the most cost-effective solutions. 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 given by UK, where the additional income generated by traffic law enforcement is allocated to support better traffic law enforcement programs.

Knowledge. Road Infrastructure Safety Management procedures need adequately trained staff in order to ensure that are carried out effectively. Potential barriers to this may reside in a lack of road safety education in universities, a lack of specialised professional training or a lack of standardisation in training. 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. For instance, road safety training courses have been activated in Netherland, Belgium and USA.

Tools. Accessible dedicated manuals and guidelines can strongly facilitate the use of RISM procedures by road administrations. It is important to ensure that these 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 Road Safety Audits and Inspections. Important international initiatives for providing standardised and accurate methods or tools for the estimation of safety effects of road safety measures are: The Handbook of Road Safety Measures (Elvik et al., 2009) and the Highway Safety Manual (AASHTO, 2010).

On the basis of the analysis carried out, a number of key messages and recommendations are outlined in Table 1.

Table 1. Key messages and Recommendations on Road Infrastructure Safety Management

Key message	Recommendation
Road authorities are key players for improving road safety .	Benchmark road infrastructure against good practices in other countries
Road Infrastructure Safety Management (RISM) procedures are effective and efficient tools to help road authorities reduce the number of accidents and casualties ,	Implement new minimum safety standards for road infrastructure Continue evaluation and research to quantify safety impacts of

Design standards alone cannot guarantee road safety in all conditions.	planning decisions
Successful implementation of RISM procedures requires an adequate level of investment, supporting regulation, availability of relevant road safety data and adequate institutional management capacity .	Implement suitable Road Infrastructure Safety Management procedures for each stage of road development including planning design, pre-opening and full operation
Making RISM procedures compulsory is preferable, as awareness of RISM alone is rarely sufficient for success .	Make Road Infrastructure Safety Management procedures legally binding
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.	Involve both road and health authorities when developing road accident data bases
Tools to support RISM are already available	Assure adequate institutional management capacity and investment levels
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.	Use existing tools and guidelines; adopt second-best solutions where state-of-the-art solutions are not feasible
The exchange of experiences with RISM among countries can be highly useful for finding the best solutions.	Identify the Road Safety Infrastructure Management procedures that fit specific needs and understand barriers to implementation
One of the main tools to help drivers to adopt appropriate behaviour are self-explaining roads	Share good practices of Road infrastructure Safety Management procedures and intervention measures
	Monitor the safety performance of road infrastructure
	Develop self-explaining roads

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