Safety at the Heart of Road Design

Final Report of the ERA-NET programme

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This project was initiated by ERA-NET ROAD.

Executive summary

Within the framework of ERA-NET Road this joint research programme, Safety at the Heart of Road Design, was initiated.

The aim of the programme was to improve traffic safety by increasing the awareness and acceptance of road authorities to implement joint road safety solutions following the concepts of self-explaining roads and forgiving roadsides, taking human factors and human tolerance into consideration. The programme was based on three objectives: A) Development of evaluation tools, B) Assessment of forgiving road safety measures and C) Comparison and Implementation of approaches of self-explaining roads.

The objectives were developed with the concepts of forgiving roadsides and self-explaining roads in mind, focusing on rural roads combined with the most substantive issues of the European road safety goals and the Vision Zero. The analysis of road design for self-explaining roads or forgiving roadsides should look for cost-effective solutions in order to reduce fatal accidents as quickly as possible.

Five research projects were funded by the programme and started in 2009:

- **IRDES**: Improving Roadside Design to Forgive Human Errors
- **EuRSI**: European Road Safety Inspection
- **RISMET**: Road Infrastructure Safety Management Evaluation Tools
- **SPACE**: Speed Adaption Control by Self Explaining Roads
- **ERASER**: Evaluations to Realise a common Approach to Self-Explaining European Roads

The first project was focussed on the concept of forgiving road sides. The main outcomes of **IRDES** were the following two guides:

1. A practical guide for the assessment of treatment effectiveness
2. A Forgiving Roadside Design Guide.
   The road side features for which recommendations have been developed are:
    a. Barrier terminals
    b. Forgiving support structures for road equipment
    c. Shoulder rumble strips
    d. Shoulder width

The second and third projects were focussed on road infrastructure safety management. The outcomes of **EuRSI** were primarily recommendations for Road Safety Inspection (RSI) through automated data capture methodology, measurement and classification.

Three prototype software applications were developed and data from three separate road surveys were tested. Initial results are promising and indicate a potential new approach in conjunction with RSIs. Further development is however needed to give reliable estimates of safety risks for RSI.

1. An automated road edge extractor using LiDAR data
2. A Road Feature Classifier was developed to exploit the spatially encoded video captured during the surveys. Along with the GPS data this toll enables both road

geometry and road side features to be extracted and output.

3. A Risk Analysis Tool that takes the outputs from LiDAR Processing and Road Feature Classifier and offers a possibility to build a risk matrix, based on static road geometry and road side features. An index score can be computed for any sample point along the road network under inspection. A safe profile velocity (Vsp) dataset can also be created and this together with collision data can be compared with the Risk Index Score. This application enables the user to identify areas of risk and understand the factors. These risk maps can be used to carry out a preliminary assessment of risk as part of the RSI process.

The main outcomes of **RISMET** are two guides (recommendations) for the development and application of evaluation tools for road safety infrastructure management in the EU.

The first guide is based on data that are currently being collected within EU countries. It recommends a minimum set of data that can provide a basis for basic road safety assessments. The guide is intended to stimulate road authorities to collect a minimum set of data needed for conducting road safety evaluations and serves to provide a set of standard definitions for these data.

The second guide provides a state-of-the-art reference document in which the following tools are described and discussed:

1. Road safety audits
2. Safety inspections (as per the EU Directive)
3. Network screening (referred to as network safety management in EU Directive)
4. Accident modelling
5. Road protection scoring
6. Identification and analysis of hazardous road locations
7. Impact assessment of investments and road safety measures (referred to as road safety impact assessment in EU Directive)
8. Monitoring of road user behaviour
9. Conflict studies
10. In-depth analyses of accidents

The guides are intended for road authorities and road safety engineering practitioners.

The two latter projects focused on the concept of self-explaining roads (SER). The project **SPACE** evaluated and developed recommendations for two different methods for evaluating SER treatments

1. Expert workshops using
    a. Questionnaires
    b. Video and photo material
2. Driving simulator

From the results of the driving simulator study specific recommendations for SER treatments at curves were also given, i.e. choice of treatment (level) depending on severity of curve.

Within **ERASER** a prototype tool to help European road authorities make decisions to improve the safety and “self-explainingness” of their roads has been developed. The tool requires that road characteristics are entered and, based on this the tool calculates what would be a “safe speed” (i.e. survivable) and assesses whether the actual speed limit is credible.

At the conclusion of the ERA-NET programme a one day conference was organised to present the findings and recommendations of the five projects. The conference was held on January 13th at Arlanda Airport, Sweden. At the conference two parallel workshops were carried out with focus on discussing the implementation of the findings and recommendations of the projects.

From the discussions at the workshops it was identified that more coordination among the projects and the ERA-NET organisers could have been incorporated in the initial project negotiations. The project managers indicated that more interaction between the projects would have been valuable. It was said that it would have been done but it did not happen. Meetings in the beginning and at the end are recommended in order to obtain synergies between projects.

The project managers and PEB agreed that a greater end user benefit would be achieved if the Project Managers and PEB had interactions while deliverables were in progress. Most deliverables were finalized (in terms of work effort) before the PEB comments were submitted. PEB comments that could improve the results were too late to implement. In order to transfer the results into recommendations for implementations further work needs to be carried out. This could be gained by forming a project with the specific task to create just that.

A number of guides and recommendations have been developed by the projects. It is important that the members of the PEB make these guides/guidelines known and available to the European road authorities. However, these are rather comprehensive reports that are maybe not to be expected to be read by practitioners. To facilitate the dissemination of the recommendations and guides presentation material, such as power point presentations, could be prepared. This should be material suitable to be used for the education of practitioners.

Factsheets from each project could be prepared showing the most important outcomes (as was done in ERASER) in order to facilitate the dissemination of the project results.

In addition the tools developed could be further tested in demonstration projects. In order to ensure that recommendations for implementation is provided as an outcome from the demonstration project this could be a more highlighted part of the aim of the project. Furthermore, dissemination before the end of the project on this particular aspect is recommended as a requirement for running the project.

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1 Introduction

“ERA-NET ROAD – Coordination and Implementation of Road Research in Europe” was a Coordination Action funded by the 6th Framework Programme of the EC. The partners in ERA-NET ROAD (ENR) were United Kingdom, Finland, Netherlands, Sweden, Germany, Norway, Switzerland, Austria, Poland, Slovenia and Denmark (www.road-era.net). Within the framework of ENR this joint research programme, Safety at the Heart of Road Design, was initiated. The funding National Road Administrations (NRA) in this joint research programme are Austria, Belgium, Finland, Hungary, Germany, Ireland, Netherlands, Norway, Slovenia, Sweden and United Kingdom. The total budget for funding research projects was 1 485 000 EUR. 18 proposals with 66 partners from 19 different countries were submitted for the call. 8 of those countries are not members of the funding Programme Executive Board (PEB) of ERA-NET ROAD.

Improving road safety has been the key objective for road authorities for many years. In recent years many of them have adopted the principles of Vision Zero; the concept of self-explaining roads and forgiving roadsides. As new research findings are published, differing theories evolve and road safety visions change. Common implementation strategies are however missing.

The aim of the programme is to improve traffic safety by increasing the awareness and acceptance of road authorities to implement joint road safety solutions following the concepts of self-explaining roads and forgiving roadsides, taking human factors and human tolerance into consideration. The programme was based on three objectives: A) Development of evaluation tools, B) Assessment of forgiving road safety measures and C) Comparison and Implementation of approaches of self-explaining roads.

The objectives were developed with the concepts of forgiving roadsides and self-explaining roads in mind, focusing on rural roads combined with the most substantive issues of the European road safety goals and the Vision Zero. The analysis of road design for self-explaining roads or forgiving roadsides should look for cost-effective solutions in order to reduce fatal accidents as quickly as possible.

Five research projects were funded by the programme and started in 2009:

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Description of the programme as well as project documents can be downloaded from the following website: http://www.eranetroad.org

At the conclusion of the programme a one day conference was organised to present the findings and recommendations of the five projects. The conference was held on January 13th at Arlanda Airport, Sweden. At the conference two parallel workshops were carried out with focus on the efficient implementation of the findings and recommendations of the projects were discussed

The purpose of this final report is to bring together the findings and recommendations of the projects, based on project final reports or other summaries received from the project coordinators and conclusions from the two workshops carried out at the conference. The report is divided into three parts as follows:

Part 1: Presentation of projects

Project facts, background and objectives, chosen methodologies, outcomes

Part 2: Outcome of workshops at the final conference

Workshop 1 Self-explaining roads: ERASER, RISMET and SPACE

Workshop 2 Forgiving roadsides: IRDES and EuRSI

Part 3: Conclusions

Synergies of the 5 projects

Recommendations for Implementation

Recommendations for further research needs

PART I – Presentation of the projects

1 IRDES – Improving Roadside Design to Forgive Human Errors.

1.1 Project facts

Duration:	15/09/2009 – 15/09/2011
Budget:	EUR 267.713
Coordinator:	Francesca La Torre, Universitá di Firenze, Italy e-mail: francesca.latorre@unifi.it
Partners:	Austrian Institute of technology (AIT), Austria Chalmers University of Technology, Sweden ANAS SpA, Italy The French institute of science and technology for transport, development and networks (IFSTTAR), France
Deliverables:	D02 Final project report D1 State of the art report on existing tools for the design of forgiving roadsides D2 Practical guide for the assessment of treatment effectiveness D3 Forgiving roadside design guide D4 Final report on the survey D5.1 Proceedings of Round Table/Workshop 1 D5.2 Proceedings of Round Table/Workshop 2

1.2 Background and objectives

Each year 43.000 persons are fatally injured in Europe due to road accidents. The previous RISER project has shown that even though 10% of the total accidents are single vehicle accidents (typically run-off-road (ROR) accidents) the rate of these events increase to 45% when only fatal accidents are considered.

One of the key issues of this dramatic increase in the ROR fatality rates is to be found in the design of the roadsides that are often “unforgiving”.

A number of different studies have been conducted in the recent years and design standard development for improving roadside design but still there is a need for:

- A practical and uniform guideline that allows the road designer to improve the forgivingness of the roadside;
- A practical tool for assessing (in a quantitative manner) the effectiveness of applying a given roadside treatment.

The aim of the IRDES project was to produce these two outputs with specific reference to a well identified set of roadside features:

- Barrier terminals
- Forgiving support structures for road equipment

- Shoulder rumble strips
- Shoulder width

1.3 Methodology

WP0 Coordination and management

WP1 Collection and harmonization of studies and standards on roadside design

A literature review covering relevant literature, guidelines and standards dealing with road side treatments was carried out. The goal was to collect and harmonize common standards and guidelines for road side treatments.

WP2 Assessment of roadside intervention

Four studies were conducted on different approaches to analyse the effectiveness of identified treatments, which are:

- The variation of shoulder width
- The removal of unprotected barrier terminals
- The implementation of grooved rumble strips
- Roadside treatments in high risk curves

WP3 Production of a roadside design guide

Based on the results of WP1 and WP2 a practical guide (recommendations) that can be applied in practice in road safety design projects was produced.

WP4 European survey

A European survey has also been performed among the National Road Administrations to identify the treatments used to improve roadside design and their estimated effectiveness.

For the evaluation of the effectiveness of different treatments existing literature has been combined with before/after studies and application of risk assessment models already available in the Partners Research Teams.

WP5 Organisation of Workshops and Round Tables

Two web-based seminars (webinars) were carried out. The first webinar was aimed at presenting the deliverables completed at the time (D1 and D4) and to have an interactive discussion on how to optimise the further development of IRDES. Invited were road laboratories, authorities, operators and owners, fleet operators and governmental organisations dealing with forgiving roadsides.

The second webinar was aimed at presenting the final results of IRDES to the “potential clients”: road operators and managers.

1.4 Outcomes

WP1

Summarizing the literature study, three categories of treatments were proposed:

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

The primary strategy in most countries is stated to be removing obstacles. Providing a so-called safety zone with a certain width allows the drivers to regain control over their errant vehicle and to return to the travel lane or stop.

Especially in the planning phase of a new road, safety zones should be considered. It is recommended to consider the safety zone as a function of the posted speed, side slope and traffic volume. Some guidelines also include the curve radii in their calculations. The calculation method for clear zone widths in the AASHTO Roadside Design Guidelines is the most used worldwide.

If hazardous obstacles cannot be removed from the roadside safety zone, they need to be modified in order to minimize injury or property damage at a crash. There exist a high number of specifications to make obstacle more forgiving. There is however a need for harmonization. For example, there exist numerous different regulations for side slope ratio and ditch characteristics. These need to be harmonized with respect to proper drainage as well as to its forgiving nature.

The third option is to shield obstacles by using road restraint systems (RRS), such as safety barriers and impact attenuators. Detailed requirements of RRS are regulated in the European Norm (EN) 1317. However, this does not give advice on which RRS to use in specific situations. This is handled in specific guidelines such as the RISER documents. Future uniform European guidelines should also include recommendations for kerb-barrier combinations as well as safe motorcycle restraint systems.

It is concluded that the large number of possible treatments to make a road forgiving shows that that there is a large potential of those systems for increasing road safety. A harmonization helps road operators and authorities in their decisions to plan safe roads in respect of run off the road accidents. Common road planning procedures together with Road Safety Audit or Road Safety Inspections on existing roads have to include the specific view on forgiving roads.

WP2

Four treatments were identified for further analyses of effectiveness and for which design guidelines should subsequently be developed:

- The variation of shoulder width
- The removal of unprotected barrier terminals
- The implementation of grooved rumble strips
- Roadside treatments in high risk curves

Due to delays in the modifications of the road no analysis of the variation of shoulder width could be carried out. Only some before treatment measurements were carried out with a tool called Observatory of Trajectories (OT), composed by rangefinder and cameras.

The statistical analysis carried out on typical secondary rural network in Italy shows significant reduction of the number of fatal and injury crashes when the number of unprotected terminals is reduced. A Crash Modification Factor (CMF) was derived as a function of the number of unprotected terminals per km (UT):

$$CMF = e^{0.02381 \times UT}$$

The CMF can be applied to evaluation of different road side features.

The effectiveness of grooved rumble strips on dual carriageways with a comparison between treated and non-treated roads were analysed using statistical methods. The analysis showed a significant reduction of the number of single vehicle accident on roads where Pennsylvanian rumble strips had been implemented.

Treatments of curves were tested by using Vehicle Infrastructure Interaction Simulation on two case studied. In both cases soft shoulders did not show any positive results. The case studies showed that soft shoulders are not appropriate for speeds of 90 km/h and in sharp curves. Hard shoulders showed an ideal vehicle manoeuvre for the extended curves but not for the sharp curve.

A safety barrier showed a positive effect by redirecting the vehicle back to its original trajectory. This was done without any indication of sliding or overturning. When shielding trees with safety barrier the deceleration of the vehicle is lower in an impact and thus the injury risk is decreased.

VIIS (Vehicle-Infrastructure Interaction Simulation) was found to be used as an assessment tool for estimating the effectiveness of forgiving roadside measured in a practical way. It was highlighted that availability of data to create a 3D road model is limited since laser measurement data are not commonly used in road data sets.

WP3

A Roadside Design Guide was developed in the project. The roadside features for which the recommendations were developed were:

- Barrier terminals
- Forgiving support structure for road equipment
- Shoulder rumble strips
- Shoulder width

Each feature is analysed in a separate section of the guide providing

- Introduction
- Design criteria
- Assessment of effectiveness
- Case studied/Examples
- Key references

The results are presented in deliverable D3: Forgiving Roadside Design Guide and are synthesised below.

Barriers terminals

Safety barrier ends are considered hazardous when the termination is not properly anchored or ramped down in the ground, or when it does not flare away from the carriageway and crashes with "unforgiving" safety barrier ends often result in a penetration of the passenger compartment and severe consequences.

Crashworthy terminals can be either flared or parallel, energy-absorbing or non-energy absorbing but in the latter case they have to be properly designed and flared to avoid front hits on the nose of the terminal.
The decision to use either an energy-absorbing terminal or a non-energy-absorbing terminal should therefore be based on the likelihood of a near end-on impact and the nature of the recovery area immediately behind and beyond the terminal. When the barrier length-of-need is properly defined and guaranteed and the terminal is therefore placed in an area where there is no need for a safety barrier protection it is unlikely that a vehicle will reach the primary shielded object after an end-on impact regardless of the terminal type selected. Therefore if the terrain beyond the terminal and immediately behind the barrier is safely traversable a flared terminal should be preferred.

If, for local constraints, the proper length of need cannot be guaranteed or if the terrain beyond the terminal and immediately behind the barrier is not safely traversable, an energy-absorbing terminal is recommended.
Turn-down terminals, or flared-degraded terminals, which have been commonly used in the last years in several counties are now often replaced in new designs by flared terminals with no degradation as the longitudinal slide that arises from the degradation to the ground can lead to an overriding of the barrier.

Additional issues to be considered in the terminals design are:

- The definition of the "length of need";
- The configuration of the terminals in the backfills;
- The configuration of the terminals in the medians;
- The configuration of the terminals adjacent to driveways.

In terms of effectiveness there are no before-after studies available but in WP2 of the IRDES projects a CMF to account for the number of unprotected terminals has been developed and could be used as a reference.

Shoulder rumble strips

Shoulder rumble strips have been proven to be a low cost and extremely effective treatment in reducing single vehicle run off road (SVROR) crashes and their severity.

For rural freeways the Crash Modification Factor (CMF) for the use of milled rumble strips has been estimated combining different studies in:

- 0.89 (which means potential reduction of crashes of 11%) for SVROR crashes, with a standard error of 0.1;
- 0.84 (which means potential reduction of crashes of 16%) for SVROR fatal and injury crashes, with a standard error of 0.1.

For rural two lane roads the Crash Modification Factor (CMF) for the use of milled rumble strips has been estimated combining different studies in:

- 0.85 (which means potential reduction of crashes of 15%) for SVROR crashes, with a standard error of 0.1;
- 0.71 (which means potential reduction of crashes of 29%) for SVROR fatal and injury crashes, with a standard error of 0.1.

Given the very low standard errors these results can be considered extremely reliable in estimating the potential effect of milled shoulder rumble strips on these type of roads.
For urban freeways and multilane divided highways the analysis data available do not yet allow for a statistically sound evaluation of the effectiveness. For multilane divided highways the following values can be used as a best estimate of the effects of milled shoulder rumble strips: SVROR crashes are expected to be reduced by 22% and SVROR FI crashes by 51% but more statistically sound research is needed.

Different design configurations have been proposed for milled rumble strips:

- a "more aggressive" (and more effective) configuration that can cause higher disturbance to bicycle drivers and to residents in the surrounding. This type of configuration is recommended when there are no residents in the vicinity of the road and when either a 1.2 m remaining shoulder is available or very limited or no bicycle traffic is expected;
- a "less aggressive" configuration that is more "bicycle friendly" and reduces the noise disturbance in the surrounding.

Rumble strips on "noncontrolled-access" highways should include periodic gaps of 3.7 m in length placed at periodic intervals of 12.2 m or 18.3 m to satisfy bicyclists' need to cross the rumble strip pattern without causing them to enter the grooved area. This recommended length is sufficiently long as to permit a typical bicyclist to cross without entering the grooved area, but not so long as to permit a vehicle tire at a typical run-off-road angle of departure to cross the gap without entering the grooved area.

Shoulder rumble strips should not be placed closer than 200 m to an urban area where, if needed, rolled rumble strips could be considered as these produce less noise and do not affect bicycle handling.

Forgiving support structures for road equipment

This section of the guideline addressed the issue of identifying potential hazards in the roadside and defining the most appropriate solutions for making the hazard caused by support structures more forgiving. It is frequent to hear amongst designers and road managers that obstacles in the roadside NEED to be protected with safety barriers. This is a simplistic approach that should be overcome to reach a forgiving roadsides design approach as placing a barrier (with its length of need and its terminals) is not necessarily the most "forgiving" solution and it can be extremely costly as compared to the achieved benefits.

In this Guideline the procedure developed in the RISER Project has been proposed and implemented. This requires to identify if the obstacle can be considered an hazard which means if it is within the clear zone and if it has structural characteristics that can lead to injuries to an errant vehicle impacting against the obstacle. Criteria for identifying the potential hazards are given in deliverable D3.

Support structures that have been tested according to EN12767 standard are considered to be passively safe or "forgiving" but different performance classes are given in the standard and guidelines for selecting the most appropriate performance class in different situations are given in Deliverable D3.
Even though this type of structures have been in place for several years in several countries including most of the northern European counties (Norway, Finland, Sweden) and Iceland, sound statistical analyses of the effectiveness of using "passively safe" support structures in

reducing the severity of crashes were not found. On the other hand several studies can be found that indicate that crashes against these type of structures rarely lead to severe consequences.

A risk assessment of the potential effect of using passively safe lighting columns and signposts has been performed in the UK by combining the likelihood of occurrence of different events that can lead to passenger injuries. The risk associated with the use of “passively safe” o “forgiving” lighting columns resulted almost 8 times lower than the risk associated to conventional unprotected columns. The solution of protecting the column with a safety barrier is still 2 times higher than the risk associated by “passively safe” columns.

Shoulder width

The width of the outer shoulder (right for most of the European countries) is commonly recognised as an important roadside safety feature as it increases the recovery zone that allows an errant driver to correct it’s trajectory without running off the road but the effect of enlarging the outer shoulder width in rural roads is clearly positive for narrow shoulders while for larger shoulders this can be more questionable or even negative. It is therefore recommended that the CMF and predictive functions given in Deliverable D3 are used for estimating the effects of having shoulder width below the national standards. For enlarging the shoulders above the national standards a specific risk assessment should be conducted and additional interventions to prevent the use of the extra width of the shoulder should be considered (such as using different colours).
For rural single carriageway two lane roads and for multilane divided and undivided highways consolidated CMF functions can be found in the recently published Highway Safety Manual while for motorways in open air the effect of the shoulder width is often not found as these road type have usually an outer shoulder width of 2.50-3.0 m that has been shown to be the value above which no effect can be seen in crash reduction. For motorways in tunnels, where shoulder are often more narrow and the confinement affects the drivers behaviour, a specific Safety Performance Function is given to estimate the effect of having a reduced shoulder width.

Given the fact the national standards usually set the criteria for defining the minimum or standard outer shoulder width a “uniform” value was not proposed but the requirements given for rural roads in Austria, France, Italy and Sweden have been compared showing that the these are very similar for Motorways with speed limits of 130 km/h (2.50-3.00 m) while more variability is found in the secondary road network with a speed limit of 90-100 km/h.

WP4

A European Survey was carried out. A questionnaire was distributed to National Road Administrators. Answers were obtained from: Austrian, Belgium, Estonia, Finland, France, Germany, Iceland, Ireland, Italy, Luxemburg, Malta, Poland, Slovenia, Sweden, The Netherlands. From the survey it was found that it was generally agreed that active safety involves all initiatives aimed at preventing accidents, as the run of road of a vehicle, while passive safety involves all measures aimed at reducing the consequences or effects of an accident which is occurring. Type and containment level of safety barriers appeared to be less important: their presence is considered to have an effect.

WP5

Finally, web-based seminars with stakeholders were organized in order to gather input for achieving “practical” guidelines as a result of the IRDES project. Suggestions from the stakeholders were gathered and additional questions were discussed.

2 EuRSI – European Road Safety Inspection

2.1 Project facts

Duration:	01/10/2009 – 31/03/2011
Budget:	EUR 280.034
Coordinator:	Tim McCarthy, NUI Maynooth (NUIM). Ireland e-mail: tim.mccarthy@nuim.ie
Partners:	International institute for Geo-Information Science and Earth Observations (ITC), The Netherlands NAST Consulting, Austria IBI Consulting Group, United Kingdom Pavement Management Systems, Ireland
Deliverables:	D1.1 Final Report detailing Technology, Methodology, Evaluation, Workshop & Recommendations D3.1 Road Safety Inspection Schemes Review D3.2 Risk Assessment Review

2.2 Background and objectives

One of the corner stones in the European road infrastructure directive 2010 revolves around road safety inspection (RSI).

The objectives of the European Road Safety Inspection (EuRSI) project were to address some of the short-comings in current rural-road safety inspection procedures:

- Introduce latest mobile mapping based approaches to help automate route corridor data acquisition and processing.
- Investigate the role of both intrinsic and transient factors together with latest machine-learning techniques for assessing risk from road survey inspections.
- Encourage wider EU stakeholder participation and engagement in adopting a common approach.

2.3 Methodology

There were four main research tasks identified for the project which were:

1) Understand contemporary approaches to RSI in Europe and further abroad

   A report *Road Safety Inspection Review* (Deliverable 3.1) was carried out at the early stages of the project. The objective of this report was to give an overview of the different approaches and methodologies of Road Safety Inspection (RSI) in European countries. The research team carried out a review of existing approaches to RSI using information from reports, published online and through direct contact with road authorities and relevant organisations.

2) Explore new road mapping methodologies using mobile mapping technology

   The research team assembled a new mobile mapping system (MMS) using inertial navigating and GPS instruments, video cameras, LiDAR scanning equipment, and accurate distance measuring sensors. All this equipment was mounted in a van and calibrated for mobile operation. The system was designed to scan the road and roadside area to collect accurate 3D data of the road and roadside features while operating near the road's operational speed.

Data collected in the MMS was used to develop software tools that identified the road and lane edges. The software development also included feature extraction that could identify objects, like poles and signs, and record their position relative to the road as well as on a map.

3) Review various risk assessment methodologies and develop a novel approach to risk assessment within the context of RSI

   Best practice and a contemporary review of published research, methodologies, projects and initiatives regarding road safety factors were collected by the research team. The review was structured and conducted to enable the research team formulate a novel risk assessment framework within the context of RSI along rural road networks. The activities and resulting report were structured into four main sections

   • Review of road safety factors and risk assessment methodologies

   • Understanding the factors and data sources that are relevant to assessing risk within the context of Road Safety Inspection

   • Devising a framework for assessing risk within the context of road safety inspection along rural roads

   • Conclusions & Recommendations

4) Produce software toolkit that would enable end-users carry out risk analysis.

   The major outcome of the project was a tool that combined all the previous activities into a software package. The results of the Risk Assessment Review (D3.2) (activity 3) were used to guide the design, construction of three software applications;

   • LiDAR Processing; Generating road edge geometry automatically from the LiDAR point cloud.

   • Road Feature Classifier; Extraction of road-side features for input to the Risk Analysis tool. Not all the necessary inputs could be extracted from the LiDAR point cloud automatically. The road feature classifier relied on an operator to identify from spatially encoded video these additional inputs.

   • Risk Analysis; A software tool used to compute & visualise risk index score & vehicle safe profile velocity (Vsp)

   The first two software toolkits deal with the lower level road geometry and road side feature extraction whilst the third, Risk Analysis, deals with identifying and explaining risk within the context of an RSI. Risk is always present along road networks; it is not static but changes constantly both spatially and temporally. The software module was developed to demonstrate a novel approach to risk analysis by computing a sample set of static road risk factors and comparing these with a dynamic measure of perceived risk in the form of a safe profile velocity (Vsp).

2.4 Outcomes

The first outcome from the project was the comprehensive review of existing RSI methodologies throughout Europe (Deliverable 3.1). The objective of this report was to give an overview of the different approaches and methodologies of Road Safety Inspection (RSI) in European countries. The research team carried out a review of existing approaches to RSI using information from reports published online and through direct contact with road authorities and relevant organisations. Road safety inspection procedures were described with an emphasis on the steps for conducting RSI including the composition of checklists and the inspection report, the qualification of inspectors and the safety issues which have to be identified during the inspection. The eleven main recommendations are listed below.

Table 1 Key recommendations from Report Road Safety Inspection Review (Deliverable 3.1)

Recommendation	Detail
1	PIARC RSI guidelines definition be used
2	RSA standards could be used as a starting point
3	Two types of RSI (Periodic and Dedicated)
4	Collision data should be used in advance of dedicated RSI
5	Two person RSI teams
6	Four steps to RSI (Preparation, on-site inspection, report & remedial measures)
7	Ensure rota of teams & survey route are interchanged
8	Training for RSI Inspectors
9	Checklist are recommended
10	Road operators should determine the inspection schedule, implement the measures and monitor the results
11	5 year periodic review of Trans-European Road Network

Deliverable 3.2 addressed the current shortcoming in Europe in adopting a common approach to risk assessment. This document covers the topic through a detailed literature survey encompassing both large scale European research projects and smaller contemporary academic papers.

The EU Directive defines four types of instruments which should help to improve road safety including RSI. Within the Article “Safety Inspections” it is stated that the member states shall carry out safety inspections on existing roads in order to identify the road safety related features and to prevent collisions The key benefit arising from EuRSI work is the promotion of a common approach to RSI through the implementation of a trans-national standard where fundamental data capture methodology, measurement, classification as well as hazard identification is the same.

The other major outcome involves the description of an indicative rule-based road safety methodology. This forms the basis for a robust and defendable approach, using spatial data acquired through the acquisition of new road side spatial data features or where applicable existing spatial data sources, to allow for RSI on the TERN to be carried out in a safe and repeatable process. At the coarsest level, road safety risk factors are typically attributed to one of three categories. Typically these are describes as behavioural factors, vehicle factors and road factors The EuRSI focuses on the third of these risk factors. These road factors have been further classified into transient risks e.g. traffic, weather etc and static risk, radius of curvature, presence of hard shoulder etc.

Three software applications were developed and data from three separate road surveys were tested in this project. Initial results are promising and indicate a potential new approach in conjunction with RSIs.

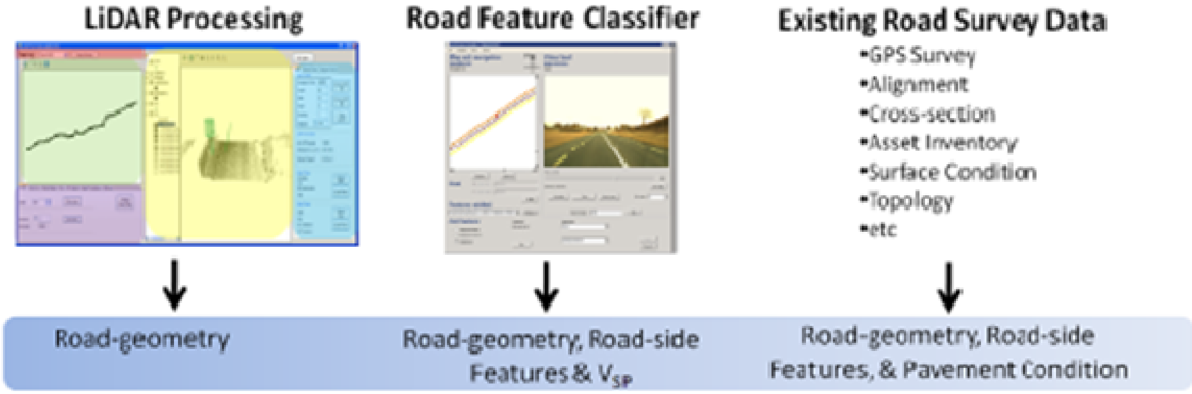


Figure 1 Overview of two of the three software tools developed and their outputs

A fully automated road edge extractor (one of the first published) using LiDAR data was developed. This algorithm was tested extensively on 100kms of road. The types of road edges detected vary from well defined curbs and walls to undefined edges where grass verges define the edge of the road. In all these cases the road edge extractor was implemented without any manual intervention and has successfully extracted the road edge. Additionally over 70% of the traffic signs which have a single pole as their base have been detected over a 40km section of road. Detection rate for telegraph poles and traffic lights was greater than 60%. There was a low detection rate for trees over the same section of road tested. There have been two reasons for this, the first is due to the high concentration of trees in a small area. Secondly combined with the dense foliage at the time of collection, this resulted in poor performance during the coarse classification stage of the pole extraction algorithm in detecting pole-like structures.

Three test-sites were chosen in UK and Ireland. These were surveyed using the mobile mapping system (MMS) at various dates between Nov 2010 and April 2011. Additional datasets relating to road surface condition, collisions and topographical detail was collated for each site.

The Road Feature Classifier was developed to exploit the spatially encoded video captured during the surveys. Along with the GPS data this tool enables both road geometry and road side features to be extracted and output. The user can navigate forwards or backwards through the data-streams using the map or multimedia player controls. In-frame measurements can be carried out and results such as position and feature class type exported and used as input for the Risk Analysis Tool.

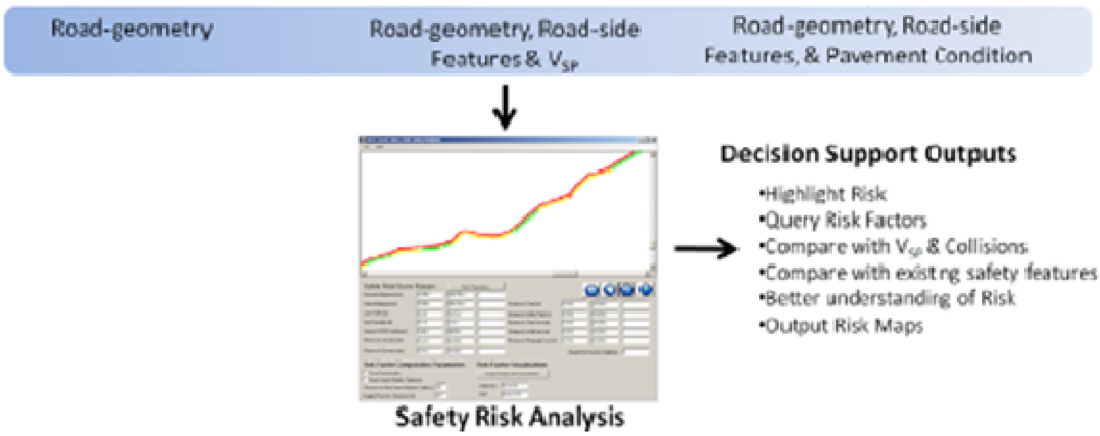


Figure 2 Overview of the Risk Analysis tool and its expected inputs as well as data outputs

The purpose of the Risk Analysis Tool is to take the outputs from LiDAR Processing and Road Feature Classifier and build a risk matrix, based around static road geometry and road side features. An index score can be computed for any sample point along the road network under inspection. A safe profile velocity (Vsp) dataset can also be created and this together with collision data can be compared with the Risk Index Score. This application enables the user to identify areas of risk and understand the factors. These risk maps can be used to carry out a preliminary assessment of risk as part of the RSI process.

The Risk Analysis Tool yields a road risk index score computed using simple rules which can be changed by the end user to suit local or regional conditions. In this application, the model is very simple and is based on sever intrinsic road risk factors (H_{ROC}, V_{ROC}, W, HS, RS, J & E) and five road side hazards (T, TL, DL, WL, UP) which are weighted by factor HW. The Index score is computed as follows:

Road Risk Index $Score_{XY} = (H_{ROC} + V_{ROC} + W + HS + RS + J + E) + (T + TL + DL + WL + UP) / HW$

Where XY : Sample Point X-coordinate, Y-coordinate
H_{ROC} : Horizontal Radius of Curvature
V_{ROC} : Vertical Radius of Curvature
W : Width
HS : Hard-Shoulder
RS : Road Surface (SCRIM)
J : Junction
E : Entrance
T : Large Tree
TL : Tree Line
DL : Drainage Line
WL : Wall Line
UP : Utility Pole
HW : Hazard Weighting

The results show that there is reasonable correlation between perceived risk, indicated by Vsp and Risk Index score in the Irish dataset. On reviewing the accident data the tool also highlights similar sections of road that have apparent higher risk indicated by the index score and Vsp. The correlation between the same three indicators in the UK datasets is not as strong. This is due to the relatively busy traffic on both A628 and A435 that resulted in the survey vehicle slowing down and speeding up. **Note, the Vsp concept was developed after**

survey and data acquisition. Nevertheless there are sections of A628 where correlation is reasonable.

A number of areas have been highlighted for future research. These include, amongst others

- **Risk Index Score** A more rigorous assignment of risk factor parameters and weightings based on road engineering & safety reports
- **Risk Factors** Increase the number of risk factors from present 12
- **Transient Factors** Incorporation of transient risk factors such as weather, illumination & traffic

The research team plan to continue to work on these tools and during the workshop invited feedback from participants who took the opportunity to evaluate the tools and sample data.

3 RISMET – Road Infrastructure Safety Management Evaluation Tools

3.1 Project facts

Duration:	01/10/2009-31/08/2011
Budget:	EUR 334.100
Coordinator:	Govert Schermers, SWOV Institute of Road Safety Research, The Netherlands govert.schermers@swov.nl
Partners:	Dresden University of Technology (TUD), Germany Transport Research Laboratory (TRL), United Kingdom Laboratôrio Nacional de Engenharia Civil (LNEC), Portugal Institute of Transport Economics (TØI), Norway Kuratorium für Verkehrssicherheit (KfV), Austria
Deliverables:	D0.1 Detailed project work plan D1 Data systems and requirements D2 Data requirements for road network inventory studies and road safety evaluations – Guidelines and specifications D3 Overview of evaluation tools for road safety infrastructure management in the EU D4/5 Assessment and applicability of evaluation tools: State-of-the-art in the EU D6.1 Accident prediction models for rural junctions on four European countries D6.2 Applying speed prediction models to define road sections and to develop accident prediction models: A German case study and a Portuguese exploratory study D6.3 Cross-country applicability of evaluation methods: A pilot in Portugal and Germany D7 Guidelines for development and application of Evaluation tools for road safety infrastructure management in the EU

3.2 Background and objectives

The aim of the project has been to develop suitable road safety engineering evaluation tools as anticipated by the ERANET Programme "Safety at the Heart of Road Design" (2009) and furthermore those of the Directive for Road Infrastructure Safety Management (2008). These evaluation tools should allow the easy identification of both unsafe (from accidents or related indicators) and potentially unsafe (from design and other criteria) locations in a road network. With such evaluation tools estimates of potential benefits at the local and the network level can be calculated and potential effects on aspects such as driver behaviour can be estimated. Such tools empower road authorities to improve their decision-making and to implement (ameliorative) measures to improve the road safety situation on the roads.

RISMET is to provide a set of easy to use recommendations and codes of practice for the development and use of comprehensive road safety engineering evaluation tools. These systems based tools consider the relationship between road design, road user behaviour, traffic and road safety. This guide is the second in the set of two developed in RISMET and covers specifically the development and application of evaluation tools that are currently recommended for state of the art road safety management.

The following objectives have applied to this project and to the development of potential evaluation tools for infrastructure safety management:

- To define the minimum data requirements for developing evaluation tools
- To develop and define a uniform methodology for collecting, integrating and analysing road accident, traffic, road geometry and road user behaviour data
- To identify and assess the applicability of existing evaluation tools
- To (further) develop evaluation tools for assessing the efficacy of safety engineering solutions based on the interaction between variables describing the road and traffic environment and road user behaviour.
- To evaluate the applicability of evaluation tools (e.g. APMs, Network safety management tools, Safe and credible speeds etc) in other EU member countries
- To formulate good practice guidelines, incorporating a standardised methodology, for road safety evaluation tools.
- To recommend criteria for benchmarking the safety performance of especially higher order rural roads in Europe

Based on the above influences and objectives, RISMET has had as general objectives the development of appropriate evaluation tools that allow the easy identification of both unsafe (from accidents or related indicators) and potentially unsafe (from design and other criteria) locations on a road network.

3.3 Methodology

RISMET was divided into the following work packages:

WP1 Project management

WP2 Data systems and requirements

An inventory of available data on road accidents, road network geometry, traffic (volumes, speeds, vehicle classification etc.) was carried out. The review includes an assessment of the data (reliability, coverage, cost etc.) and the manner in which it is reported and recorded. The potential application of this data and these systems in view of the (future) development of road safety engineering evaluation tools is addressed.

WP3 Applicability of existing evaluation tools: Review of current practices

A complete as possible overview of engineering tools and applications for the management of road safety of rural roads at the local to network level is provided. This overview concentrates on tools and applications that estimate the road safety (accident) effects (accidents, behaviour, conflicts, perception etc.) of individual or combined engineering improvements (safety improvements/remedial or new). The overview is based on a limited quick scan supplemented by a (internet based) questionnaire survey among European road authorities and engineering practitioners/consultants. The quick scan review makes extensive use of the results of Ripcord-Iserest and similar studies.

WP4 Development of evaluation tools for the future

Existing and potentially new approaches are assessed for applicability in the future safety management of European road infrastructure. This assessment is based on a detailed analysis of current applications and where possible supplemented by a limited number of pilot evaluations using the same country data as input in the different tools to assess their merits. The main focus has been on a detailed study on the application of Accident Predicition Models (APM) as evaluation tools for road infrastructure safety management.

A methodology for the development of APMs is formulated and documented. This includes the strengths and the weaknesses of the available approaches adopted in building such models. The results of the work are documented in separate country research reports. These are one of the primary inputs for the development of a subsequent guideline document

WP5 Guidelines and codes of practice

The results from the different studies conducted in the previous work packages are integrated into the following guidelines:

1. A document providing an overview of the supporting data system, providing a specification of the data requirements, describing a uniform methodology to collect road geometric data and traffic volumes, and providing insights into the use of the various data (sources) in analyses.
2. A document for developing and applying evaluation tools in road infrastructure safety management, with a focus on APMs, for European road authorities. This document is a state of the art[1] outlining all aspects related to the development and application of such tools. The document brings together the knowledge and experience of various countries and presents a common approach for evaluating the effects of road safety engineering measures and treatments.

3.4 Outcome

Improving road safety is and has been a priority in most first world countries with the result that road crashes and resultant traffic injuries have thankfully been declining. However, improvements in road safety have also brought about new challenges for managing the remaining problems. One of these challenges is that the declining number of serious injury crashes means a sparser distribution on the network whereby traditional reactive approaches such as blackspot analysis and remedial treatments are less effective. Consequently there is a need to understand the applicability and suitability of other more pro-active tools and methods for managing road safety.

All road safety management tools require some level of data. These data typically include road accident, traffic, road geometry, vehicle, road user and other related data. The level of details also varies depending on the tool that is being applied. The frequency and manner in

[1] Definition used: The concept of state-of-the-art implies the highest level of development (based on a combination of the level of development and application) of a given tool at the time of the publication and as recognised by the international literature. Certain countries may have country specific tools which for that country are state-of-the-art, but these tools are in the context of these recommendations, not regarded as state-of-the-art.

which such data are collected depend on both the nature of the required analysis and the purpose for which it is intended. In many cases such data are collected incidentally (i.e. for a specific purpose or study) and not applied or used generally whereas others may be collected structurally serving more than one application and purpose.

A guide, based on data that are currently being collected within EU countries was developed. It recommends a minimum set of data that can provide a basis for basic road safety assessments. The guide is intended to stimulate road authorities to collect a minimum set of data needed for conducting road safety evaluations and serves to provide a set of standard definitions for these data.

Furthermore, a questionnaire survey was conducted in order to describe current use of road safety evaluation tools and to assess the applicability, or ease of use, of the tools. A total of 18 countries answered the questionnaire. Between 15 and 17 of these countries were included in statistical analyses designed to uncover the relationship between use of the safety management tools and road safety performance.

The main conclusions of this study highlight the opportunities for further development of the tools for road safety management:

1. Road safety audits, safety inspections and road protection scoring can be further developed by evaluating their effects on safety and their performance in identifying safe and less safe solutions.
2. Network screening should be based on accident models and should apply the techniques developed in the Safety Analyst approach in the United States.
3. Road accident modelling needs to be developed by testing models empirically and by incorporating in them variables describing road user behaviour.
4. The identification and analysis of hazardous road location should employ the Empirical Bayes (EB) approach for identification of hazardous locations and the matched-pair approach for the analysis of factors that may contribute to accidents at hazardous road locations.
5. The state-of-the-art of road safety impact assessment is described in the Highway Safety Manual recently published in the United States. Changes made in current practice should try to bring it closer to the state-of-the-art.
6. Monitoring of road user behaviour should be targeted at about five types of behaviour that make the largest contributions to road accidents and injuries. In most countries, this would include speeding, not wearing seat belts and drinking and driving.
7. Conflict studies, naturalistic driver behaviour studies and in-depth studies of accidents are tools that road authorities may choose to include in their safety management toolbox; none of these tools is essential.

Based on the project objectives and these outcomes, some development work was initiated to further develop and test accident models across country boundaries and to incorporate elements of road user behaviour. In the first instance Accident Prediction Models (APMs) for rural junctions were developed using data from the road networks of Austria, Norway, Portugal and Holland. For the first three countries it was possible to obtain accident prediction models for each country individually. For Holland, however, and due to restrictions on the dimension of the data set, it was only possible to analyse these data together with the other countries data, i.e. analysing aggregated data sets. The data consists, per junction, of injury accident counts, type of junction, traffic control, speed limit and entering major and minor annual average daily traffic volumes. The regression models had the injury accident frequencies as the dependent variable and the remaining variables as explanatory and were fitted using Bayesian statistical techniques with vague or non-informative prior and hyper-prior distributions. These models consisted on the Poisson regression model, hierarchical

Poisson-Gamma and Poisson Log-Normal hierarchical regression model. The Poisson regression model was found to be not appropriate to model the junction data in any of the data sets due to not being able to capture variations and attributes of the data, namely the over-dispersion. The Poisson-Gamma and the Poisson Log-Normal models obtained similar results and in general performed equally well. It was found that accidents occurring at junctions in all countries depend on the junction's entering traffic volume as well as the other explanatory variables considered. This report provides descriptions of the several data sets, equations for the expected injury accident frequencies, per year, on rural road network junctions for Austria, Norway and Portugal and for the conjoint set of the combined data (including Dutch data) as well as posterior means of the expected number of accidents for minimum, mean, median and maximum profiles obtained by the explanatory variables and measurements of model fit together with the major results obtained.

In the second instance APMS were developed and tested using speed prediction modelling as an indicator of road user behaviour. These models have shown that the consideration of driving behaviour is useful and leads to good results. These results are appropriate to be used for accident predictions within road networks. To apply the algorithm, data of good quality are needed. This is especially the case regarding design elements of the horizontal alignment. Based on these data an analysis that uses the developed models can be realised.

When the prediction is applied the results (predicted accident cost rates) must be evaluated. But an evaluation requires a benchmark which makes it possible to decide whether the predicted result is acceptable or not. In Germany, the guideline for network analysis suggests a simple method. Calculated accident cost densities are compared to so-called basic accident cost densities. Basic accident cost densities are derived from network wide analysis of accident occurrence separated by road categories and traffic volume on the evaluated road section. Such an approach is relatively simple and would also be appropriate to evaluate predicted accident cost rates in terms of this study.

A first test of the developed models was conducted for a 42 km long stretch of the Portuguese road IP 04. The investigated road stretch is characterised by a severe accident occurrence. Within the investigated time (2003 – 2005) the considered accidents caused 33 fatalities, at least one per month. However, the application of the models and methodology detected the defined sequence types and predicted model based accident cost rates. To evaluate them, the reference accident cost rates were used and finally the safety critical stretches were indicated. The applicability of the sequence as well as of the developed prediction models was adequately shown. However, the comparison of predicted results to real accident occurrence shows marked differences. There might be numerous reasons for that: the entire road stretch is disproportionally unsafe, the longitudinal profile of this hilly road affects speed choice (a condition which is not frequent in normal roads and also not considered by the speed prediction model) and, the prediction is based on German data which means that a calibration must be done in order to consider national circumstances. Moreover, an accident prediction cannot be equalled to real accident occurrence. A prediction model is rather appropriate to indicate potential safety problems in road design based on the experiences and results of statistical analysis of driving behaviour and road safety. This makes it a tool especially suited to the design or redesign stage of new or existing roads.

The traffic system and cultural dissimilarities are believed to contribute significantly to regional and country differences in road safety performance. Therefore, caution is required when transferring safety management and intervention tools from one region to another.

In the last instance two safety evaluation tools developed at the *Laboratório Nacional de Engenharia Civil* in Portugal and at the Technical University of Dresden in Germany, were applied to a set of road stretches in both countries. The procedures analysed are intended for the detection of inconsistent horizontal curves and dangerous non-intersection sites.

The main questions investigated are related to the direct applicability of both methods outside the region where they were developed. This was investigated by means of a comparison of the detected danger and non-danger zones identified with each method and the corresponding accident rates and by direct comparison of the danger classifications obtained with both methods.

Geometric and traffic data on 42 km of Portuguese roads and 190 km of Brandenburg roads were analysed. Data on traffic and registered accidents refer to a four year period in Portuguese roads (1147 accidents) and a three year period in Brandenburg (126 accidents).

The main conclusions are that both methods need further recalibration to local conditions, in order to fully take advantage of their potential. When properly used, both methods effectively assist road designers in detecting high accident risk sites at the design stage; however, they are not so successful at discarding low accident rate sites from further safety analysis. Despite incorporating variables intended to represent driver behaviour, there is still a considerable percentage of high accident rate sites not being identified as deserving further study and safety improvements in both methods, indicating that their effectiveness may be improved.

The above results were integrated into the final deliverable of the project, namely a guide for the development and application of evaluation tools for road safety infrastructure management in the EU. The guide provides a state of the art reference document in which the following tools are described and discussed:

1. Road safety audits
2. Safety inspections (as per the EU Directive)
3. Network screening (referred to as network safety management in EU Directive)
4. Accident modelling
5. Road protection scoring
6. Identification and analysis of hazardous road locations
7. Impact assessment of investments and road safety measures (referred to as road safety impact assessment in EU Directive)
8. Monitoring of road user behaviour
9. Conflict studies
10. In-depth analyses of accidents

The guide is intended for road authorities and road safety engineering practitioners.

4 SPACE – Speed Adaption Control by Self Explaining Roads

4.1 Project facts

Duration:	01/01/2010 – 31712/2011
Budget:	EUR 314.730
Coordinator:	Leif Sjögren, Swedish National Road and Transport Research Institute, Sweden leif.sjogren@vti.se
Partners:	Transport Research Laboratory (TRL), United Kingdom Belgian Road Research Centre (BRRC), Beligium Centrum Dopravniho Vyzkumu (CDV), Czech Republic Forum for European Highway Research Laboratories (FEHRL), Belgium Kuratorium für Verkehrssicherheit (KfV), Austria
Deliverables:	D1Self-Explaining Roads Literature review and Treatment Information D2 Methods to evaluate international SER measures D3 Self explaining road treatments - Report from expert workshop D4 Report on driving simulator experiment D5 Comparison of methods (Technical note) D6 Final report

4.2 Background and objectives

A significant reduction in casualties can only be achieved by taking action on all three elements of the safe road system: driver, vehicle and road. Improving road infrastructure safety can be achieved by making roads forgiving and self-explaining. Self-explaining roads reduce crash likelihood and forgiving roads mitigate the severity of the outcome of a crash.

Two-lane rural roads generally have lower geometric design standards and are not as well maintained as motorways. The accident rates for those rural roads are much higher than higher order roads. There are frequent occurrences of head-on and run-off-the-road accidents. These are often linked to high speeds, dangerous overtaking manoeuvres, driver inattention, design constraints, sight restrictions and road side obstacles. The self-explaining road and the forgiving road side are two cited concepts deemed to be able to reduce the number of accidents on rural roads.

The objective of SPACE was to identify solutions that offer the greatest potential safety gains through a state of the art review, international expert panel review, interactive visual tools and driving simulator experiments. The aim was to develop tools that can identify unsafe or non-explaining areas of the network and that are able to estimate the potential safety benefits of a road safety measure. These tools should be able to register change in driving behaviour and also explain why this or these changes occur. The developed tools should then be used for evaluation of different measures aiming to provide a self-explaining road. Other aims are to determine the speed adaption and situational awareness benefits of different self-explaining design measures. A comparison of different approaches should finally lead to recommended common strategies.

4.3 Methodology

The following steps were carried out in SPACE:

WP1: State of the art and review of experiences

A state of the art review and collection of experiences detailing the collision prevention and injury mitigation effects of passive and active road safety for implementation on rural roads will be completed. This will include a review of the results and recommendations from earlier and on-going EU projects as well as the current scientific literature. The review will, in addition, extend to recent national experiences and case studies where self-explaining measures have been implemented. The review will be completed using the partners' extensive knowledge sources including libraries and international scientific source databases, along with questionnaires given to expert contacts. The literature review will aim to find the following information for each treatment type:

- Effectiveness for collision reduction
- Effectiveness for injury mitigation
- Cost of countermeasure per site or per km as appropriate
- Maintenance cost and treatment life of the measure
- Differential impact on different road user types: pedestrians, bicyclists, motorcyclists, car occupants and heavy vehicle drivers)
- Differential impact according to age, experience and gender
- Relative impact at differing levels of behavioural and speed compliance (different countries)

WP2: Selection of promising measures

The identified potential self-explaining measures will be evaluated in this step. The knowledge of the costs and benefits of these measures will inevitably vary. The purpose is to identify those measures that have the greatest safety potential, but are relatively unknown in terms of their impact on driver behaviour. The measures that are selected will then be examined in more detail in the work packages that follow.

The following selection criteria will be applied:

- *mainly used for rural roads?*
- *the degree of trans-national applicability*
- *performance in different weather and lighting conditions*
- *Impact on different roads user types e.g. heavy goods vehicle and two wheelers*
- *The degree of impact on other road users*
- *divided into types of infrastructure such as plain roads, tunnels and bridges*
- *the degree of authority acceptance (easy to install, low budget and degree of maintenance)*
- *road user awareness (classified by the measures aim on visibility, sound or sense* or a combination of these)

Once the limitations and requirements are established the pre-selection of measures will be done. The goal is to select the 5-10 most promising measures fulfilling the requirements.

WP3: Stakeholder and expert workshop
This phase will make use of a stakeholder and expert workshop to make the final selection of measures to be evaluated in a driving simulator experiment. At the workshop, scenarios will be presented. Expert opinion will be gathered via questionnaires and a voting procedure. The scenarios will, among other factors, present different national solutions to the same problem. The scenarios can be presented on a big screen or at individual computer screens, photos and videos.

This will end in a selection of measures that will be studied and evaluated in the following driving simulator experiment. Since driving simulator experiments are costly, the number of tests that can be achieved within the project is limited. The goal is to test 2 or 3 measures.

WP4: Driving simulator studies (VTI)
VTIs moving base driving simulator will be used for evaluation of the selected scenarios based on the outcome from WP3. The evaluation will focus on effectiveness and user acceptance. For this type of evaluation the most relevant approach is to focus on relative comparisons between different scenarios. With this in mind the simulator will be a useful tool to select the most promising measures in order to find the self-explaining road that gives the correct signals to the driver that makes him/her to have correct expectations on the road and in the final end select optimal speed. The evaluation will be done with a within subject design with a balanced order for two different driver categories (novice drivers and experienced drivers) but also for gender (half men). In total 30 participants can be used. The selection of participants will be defined after discussions in the consortium. The discussions will deal with how to do a correct statistical selection to also include drivers from other countries to meet the transnational approach. Each driving session will last for 45 minutes, with a maximum of 8 scenarios. This will determine the influence of each measure across participants with different driving experiences and levels of speed compliance. The aim of this work package is to quantify the impact of each tested solution on driving behaviour.

WP5: Management, dissemination and exploitation

4.4 Outcomes

The literature review carried out as part of this study demonstrates that the term “self-explaining road” has been in use since the 1990s. It was also apparent that the term SER means different things to different people and there is a clear need for guidelines on how SER can be used and what types of treatments might create safe, driving conditions where road design fits the expectations of the road users.

The SPACE project aimed at developing a modern and practical definition of Self-Explaining roads and the following definition was used:

“Theeuwes and Godthelp (1992) suggested that roads are self-explaining when they are in line with the expectations of the road user, eliciting safe behaviour simply by design. This definition is largely theoretical and, where it is practically applied, it is based on road categorisation principles. In practice the term SERs has been widely adopted and has evolved to include many aspects of innovative highway engineering, including the concepts of intuitive and understandable design, consistency, readability and psychological traffic calming.”

A state-of-the-art literature review on the development of the concept of self-explaining roads over time was carried out so that potential self-explaining treatments could be identified and evaluated. The reviewed treatments were suitable for higher volume rural, single carriageway roads. In total 72 individual treatments were identified by the project team. These were grouped according to the type of road section on which they might be applied: curves, transitions, intersections and links. The treatments, including road attributes and design, that were considered to have an influence on speed are shown below for each type of road section:

Curves

- Chevron Signs/ Marker Posts
- Lining
- Vehicle Activated Signs (VAS)
- Surface Treatments
- SLOW markings
- Transverse Rumble Strips
- Optical Bars
- Visibility and sight distance
- Alignment

Transitions (changes in type or function of road)

- Physical measures (e.g. build outs, islands, median treatments)
- Signing and lining treatments (e.g. edge markings, hatching, dragons teeth)
- Surface treatments (e.g. coloured textures and/or surfaces, transverse rumble trips, optical bars)

Intersections

- Additional or enhanced signing
- Lining/roadway markings
- Surface treatments
- Layout and junction type
- Visibility

Links (straight sections of the road in between intersections and transitions)

- Lane width
- Number of lanes in each direction
- Surface quality and treatment
- Illusory lane width markings
- Median and edge treatments
- Barriers
- Shoulder
- Repetitive road side objects

Two methods to evaluate the treatments were devised. The first involved consultations with experts in a series of workshops conducted across Europe to obtain their feedback on the likely impacts of different SER treatments. Secondly, some selected treatments were tested in a driving simulator study conducted in Sweden.

Expert workshops

The SER treatments addressed in the workshops were limited to two types of road sections: curves and transitions.

The participants of the workshops organised in Belgium, Czech Republic, Sweden, Ireland, and Austria were experts on road safety, regional and municipal road administrators, and representatives of stakeholder organisations such as automobile clubs, national motorcycle drivers associations and national organisations of transport companies.

The same questionnaires and the same video and photo material were used at all workshops. During the morning sessions the participants discussed the definition of SER treatments and gave their vision on the conditions that make a SER treatment efficient or not. During the afternoon sessions a series of examples of SER treatments were presented and the participants gave their comments on the examples.

Conclusions arising from the workshops include the following:

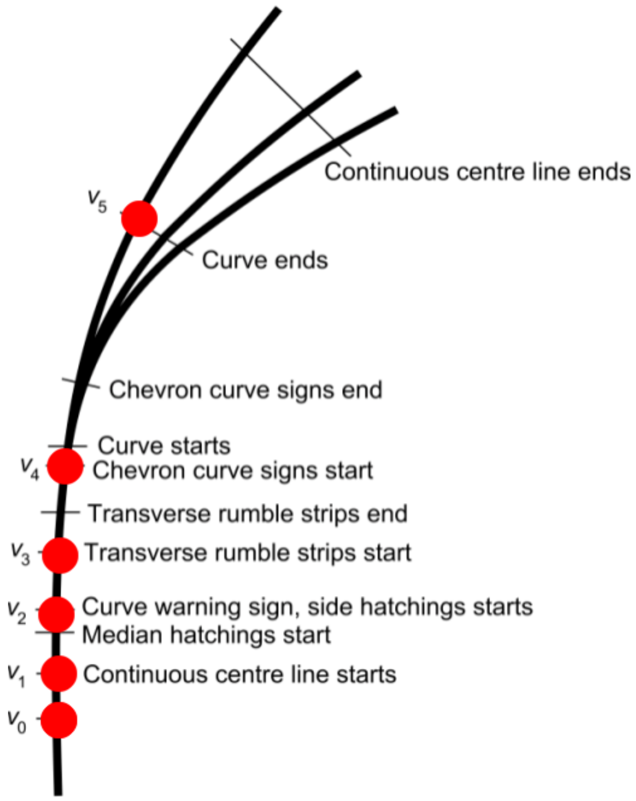
- Single treatments are less effective than a combination of treatments
- Definition of SER is different for existing roads and newly planned or constructed roads.
- Video sequences a useful method for expert evaluation
- In terms of the long term effect and cost-effectiveness, different circumstances for the video sequences are not that useful.

Driving simulator study

Following on from the workshops, a number of speed reducing treatments before curves identified by experts as being useful but requiring further analysis were chosen for the driving simulator study.

Figure 3 The driving simulator at VTI used for the study in SPACE

The drivers were divided into two groups. One group was exposed to (consistent) treatments corresponding to the severity of the curve, i.e. slight curve – low treatment level, moderate curve – medium treatment level and severe curve – high treatment level. The other group experienced inconsistent treatments by being exposed to all nine possible combinations of curve severities and treatment levels. The low level treatment was using a curve warning sign, the medium level was using a curve warning sign and chevrons curve signs and the high level treatment was a combination of curve warning sign, chevrons curve signs, median and side hatchings and transverse rumble strips.



v0: 350 m before curve starts (reference)

v1: 290 m before curve starts (continuous centre line starts)

v2: 215 m before curve starts (warning sign + side hatching starts)

v3: 140 m before curve starts (transverse rumble strips starts)

v4: 20 m before curve starts (first chevron sign)

v5: 280 m after curve starts (curve ends)

Figure 4 Illustration of the curves of different severities and the position of the different treatments. The red dots indicate where speed is registered.

The conclusion from the simulator studies is in short:

Consistent use of “level of treatment” according to the severity of curves is important to make drivers adapt their speed appropriately.

5 ERASER - Evaluations to Realise a common Approach to Self-Explaining European Roads.

5.1 Project facts

Duration:	01/01/2010 – 31/12/2011
Budget:	EUR 287.280
Coordinator:	Rob Eenink, SWOV Institute for Road Safety Research, The Netherlands e-mail: rob.eenink@swov.nl
Partners:	Dresden University of Technology (TUD), Germany
	Kuratorium für Verkehrssicherheit (KfV), Austria
	Transportation Research Laboratory (TRL), United Kingdom
	Lund University, Department of Technology and Society, Sweden
Deliverables:	D1 SER and SER Approaches: State-of-the-art
	D2 Road user pilots in different European countries
	D3/4 Road authority pilot and feasibility study
	D5 Dissemination kit

5.2 Background and objectives

ERASER deals with the comparison and implementation of approaches of self-explaining roads (SER). The project mainly aims to bridge the gap between fundamental knowledge concerning self-explaining roads and the practical, hands-on knowledge that road authorities require to make their roads safer by applying the concept of self-explaining roads.

The objective of the ERASER project was to develop a support tool for road authorities. The tool should essentially be a check-list that road authorities can use to determine to which extent their roads are self-explaining, but should also contain information concerning design elements that can help to make roads more self-explaining.

5.3 Methodology

The following steps were carried out in ERASER:

WP1 SER and SER approaches; State-of-the-art: Definition, comparison and evaluation of existing self-explaining road approaches in Europe

Self-explaining roads were developed to increase inherent road safety by taking into account the nature of human perception and information processing. However, to increase road safety, self-explaining roads per se are not enough. Additionally, the entire road categorization has to be self-explaining. With traditional road categorization being the result of historical developments and sometimes dating back to the time when traffic safety was no major concern, this will not always be the case.

In order to allow a common and modern state-of-the-art approach of self-explaining road categorization to be developed in Europe, the current practice of road categorization must be reviewed and compared with respect to their self-explaining properties. To achieve this aim, the following steps were carried out:

- Description of the background of road categorization
- Summarizing how road categorization impacts road design
- Definition of self-explaining roads. The definition of Theeuwes and Godthelp was adopted:

  “Traffic systems having self-explaining properties are designed in such a way that they are in line with the expectations of the road users. The [...] "Self-Explaining Road" (SER) is a traffic environment which elicits safe behaviour simply by its design.”(Theeuwes & Godthelp, 1995, p. 217)
- Explaining commonalities and differences between the SER approach and other approaches.
- Understanding how a road can be made self-explaining by introducing psychological concepts (in particular influencing speed behaviour).
- Explaining how an entire road network is made self-explaining. The crucial aspect is that road users correctly perceive the road category they are driving on and the behaviour expected from them on this category. Two principles were identified which support this aspect:

  • homogeneity within and
  • heterogeneity between road categories.
- Identify criteria needed to decide whether these principles are met. Propose a methodology how these criteria can be applied in a practical evaluation of the SER quality of a given road and road network.
- Overview of the current practice of European roads. It was found that very few countries (The Netherlands, Denmark, Germany) actually apply or are developing SER approaches to road categorization. However, despite being largely in line with SER principles there are still weaknesses to be found. Whether such weaknesses in SER design affect behaviour will prototypically be tested in WP 2 of the ERASER project.
- Make an attempt to develop and introduce an ideal self-explaining road categorisation. This ideal can serve as basis for the evaluation of existing approaches but can also be used to develop a coherent SER classification for Europe.

It is concluded that road categorizations differ widely in Europe and that only few countries are implementing or developing categorizations following SER standards. However, even those are at a starting point with none fully meeting SER criteria. It is thus concluded that additional empirical validations have to be performed in order to draw final conclusions. These empirical steps mainly have to deal with the question of whether designs which can formally be distinguished are also distinguishable by the road users – which is a prerequisite for a road categorization to become self-explaining.

WP2 Road user pilots in different European countries: Testing the self-explaining nature of roads; the effects of combinations of road features in different European countries.

Road safety can benefit from roads that are designed in a way that is self-explanatory for drivers. Indicating an appropriate driving speed is a main issue in self-explaining road design. Previous research has focused on the impact of different design elements on speeding behaviour, but it is less clear how universal these effects are. This was the focus of an online questionnaire study for the ERASER ERANET-roads project on self-explaining roads. It was conducted simultaneously in 6 European counties (N=307): Austria, Germany, the Netherlands, Great Britain, Ireland and Sweden. In total, 24 pictures of rural roads were presented; each a different combination of road width, separation of driving direction, vegetation of the roadside environment and the number of lanes per direction. Participants indicated their own driving speed as well as a safe speed limit on these roads. Results indicated that there are particular road features whose effects could be considered relatively self-explaining in the purest sense as they are similar for all countries (road width and vegetation). Effects of other road features, (lanes and type of separation) differed per country. This implies that extra communication (e.g. in an information campaign) or complementing roads with more self-explaining features, might enhance the desired speed behaviour.

Also in this project, a system for automated video analysis was used to collect the actual driving speed data for validation purposes. Two sites at a 2+1 road in southern Sweden were filmed using several cameras in order to be able to cover longer sections (200 and 100 m respectively). The video analysis system was adjusted so that the data from each individual camera could be connected into continuous speed profiles. Comparison with the questionnaire answers for the same road design showed good correspondence between the stated and actual driving speeds.

WP3/4 Road authorities pilot/Feasibility study

This workpackage aimed at developing a decision support tool for road authorities. This decision support tool should provide road authorities with the necessary background to develop and implement self-explaining road (SER) categories. It should also incorporate a model to infer safe and credible speed limits.

A feasibility check with road authority target groups (at CEDR meeting) was conducted to ensure that developed tool is accepted by the road authorities.

WP5 Dissemination

5.4 Outcomes

The main outcome of the ERASER project is a draft version of a tool to help European road authorities make decisions to improve the safety and “self-explainingness” of their roads (http://www.swov.nl/enquete/Eraser/Tool.php).

For this tool, the concept of SERs has been taken forward in relation to speed: the design of a road can provide explicit cues to road users about what the speed limit might be. It is suggested that various characteristics of a road may act as accelerators or decelerators, i.e. they give the road user the impression of a faster or slower road. A SER will have characteristics which are in line with the speed limit on the road and the speed limit will therefore be credible.

The following credibility features have been identified:

Accelerators

- Open road environment
- Wide road
- Straight road stretches
- High quality road surface

Decelerators

- Dense road environment
- Narrow roads
- Short road stretches
- Physical speed reducers
- Low quality road surfaces

The aim of the tool is, however, not just to make the roads and their speed limits more credible or self-explaining, but also to ensure that speed limits are safe. The tool is based on the "safe system" approach, which is an approach that already has been adopted in Sweden and the Netherlands. The table below shows "safe" speeds adopted from Sweden.

Table 2 "Safe speeds" for different types of infrastructure and traffic (adopted from Sweden)

Types of infrastructure and traffic	Maximum safe travel speed (km/h)
Locations with possible conflicts between cars and pedestrians	30 (20 mph)
Intersections with possible side collisions between cars	50 (30 mph)
Roads with possible frontal collisions between cars	70 (40 mph)
Roads with no possibility of side or frontal collision (only collision with structure)	>100 (>60 mph)

The tool that has been developed requires that road characteristics are entered and, based on this the tool calculates what would be a "safe speed" (i.e. survivable) and assesses whether the speed limit is credible.

The tool has been developed to be used on rural roads. A prerequisite was also that the tool should not require intensive data collection. The tool is furthermore to be used on a road-by-road basis rather than across a whole network.

The tool is summarised in the figure below (copied from ppt-presentation shown at the final seminar 13th January 2012).

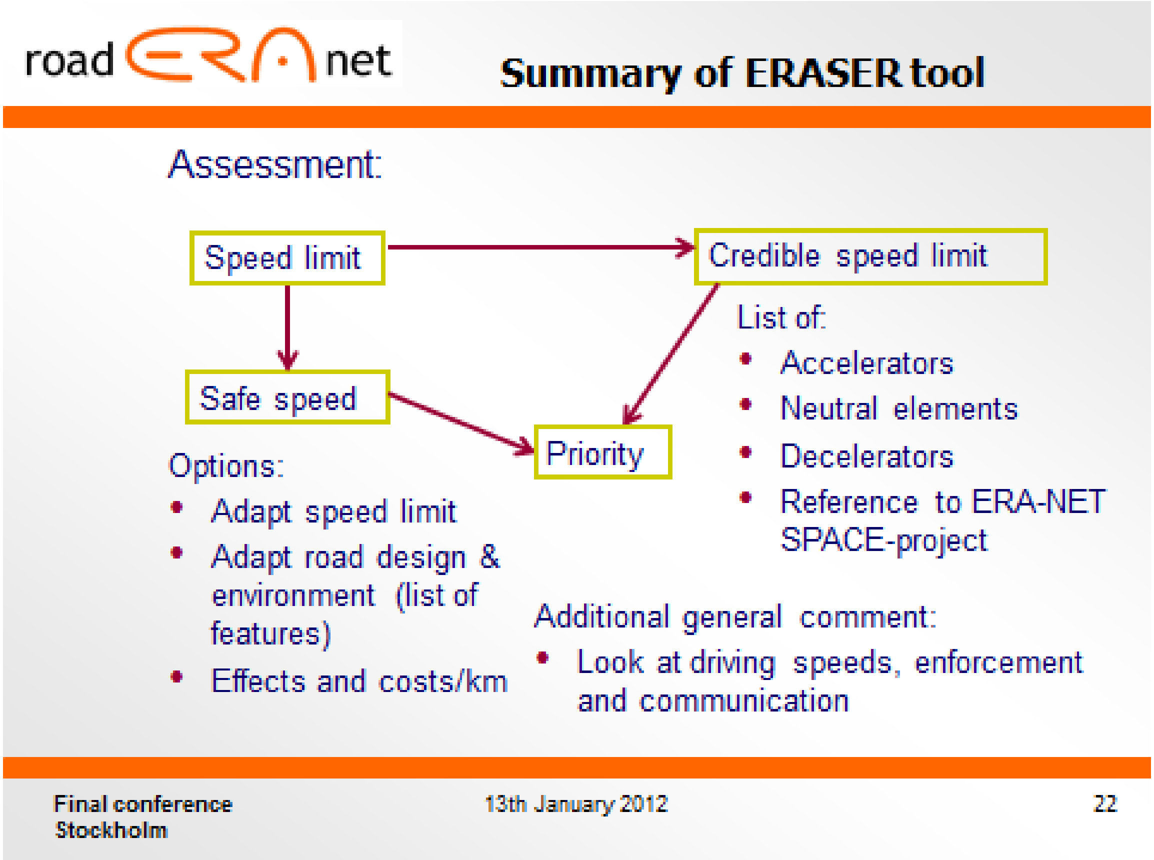


Figure 5 Illustration of the developed tool

To illustrate the output from the tool it was used on the road A595 in Cumbria, UK(?) The results given by the tool are shown in the figures below (copied from ppt-presentation shown at the final seminar 13th January 2012).

Figure 6 Foto of road A595 on which the tool is demonstrated

Results

The speed limit of your road= 60 km/h (40 mph)
The calculated safe speed limit=40 km/h (25 mph)
The speed limit is credible

Evaluation details

The speed limit is higher than the current safe system standards allow for.
You might decrease the speed limit to 40 km/h (25 mph).
Effectiveness: 5-10%
Cost indication: low

Alternatively, you might adapt the failing design elements of the road, which are:

- Access restriction recommended for vulnerable road users.
  Effectiveness: 0-25%
  Cost indication: medium-high

- Obstacle free zone should be > 2.5m or safety barrier.
  Effectiveness: 20-75%
  Cost indication/km: low-medium

- Shoulders should be present and well paved, or be unpaved for more than 1m.
  Effectiveness:
  Cost indication/km:

- Level junctions should have speed reducing measures (e.g. plateaus).
  Effectiveness: 30-70%
  Cost indication/km: low-high

Credibility

Decelerators

- The road is smaller than 4.5m

Credible road features

- No access restrictions
- No separation of driving directions
- Dense or semi-open road environment
- Straight stretch of road is shorter than 180m

Accelerators

- No physical speed reducers at (all) junctions

When available, speed data can be a usefull additional source of information. Be aware that speed is influenced by more factors than road design alone.
More information about measures that can be taken, can be found in this document of the SPACE-project .

Urgency

The urgency of taking action on your road is: Moderate

Figure 7 Output from tool used on road A595.

PART II – Outcome of workshops at the final conference

1 Workshop 1: ERASER, RISMET and SPACE. Moderator: Lars Ekman, the Swedish Transport Administration

1.1 Résumé of the discussions

The moderator launched the workshop by putting some open questions to the participants of the workshop:

"I am a traffic planner at the regional level. Try to convince me what I should change. What do we need to do that we have not done before? What should we stop doing?"

The discussions during the workshop came to focus on three different subjects/areas:

a) Availability and quality of data needed for the assessment of measures intended to make roads more self-explaining
b) Barriers against applying new knowledge
c) Prerequisites for self-explaining roads

a) Availability and quality of data

It was discussed that data of good quality is needed as a basis to motivate the choice of design (curvature, road width, etc.). This is true not least if you want to deviate from the present design guidelines. If you have to go underneath the guidelines for the design good quality data is needed to support these decisions.

The so called "2+1-roads" (median separated roads) that have been introduced in Sweden were mentioned as a good example where safety has actually been improved by deviating from the standard guidelines.

A conclusion from these discussions is that making the road authority's and other data more available and user friendly would be desirable.

One comment was also that different persons taking part in the planning process use different data. It was suggested that one should try to make a uniform set of data that anyone could use.

b) Barriers against applying new knowledge

The limited amount of money available was brought up as one major problem for adding self-explaining measures. Design and Build contracts where mentioned as an example where the design and budget has already been fixed and are difficult to change retrospectively.

It was commented that this is not a new problem, it is a general problem and depends on how new roads are decided on. When the decision is taken the budget is fixed. But it is a long process to plan, design and build a new road during which lots of things can happen and not least new knowledge can turn up. However, politicians are not likely to increase the budget and most certainly not unless there is a strong motive such as great improvements for traffic safety.

An example from the Netherlands is that they are about to raise the speed on motorways. But as this is known to have negative consequences for the safety, there is a budget for improving the safety on these roads. Thus, if the consequences of certain measures can be shown it is easier to motivate an increased budget.

It was, however, concluded that one problem is actually lack of knowledge of the consequences of different measures and changes of design. Rather fundamental research is needed and there is also a need for better data to be able to do the research. This brings us back to the discussions during the workshop on the importance of the availability to good quality data.

Another barrier against applying new knowledge on a European level mentioned was what was called “cultural differences”. For example road markings are designed and used very differently in different countries. Harmonizing the use of road markings as one measure to achieve SERs would be a very long process.

c) Prerequisites for self-explaining roads

There were some discussions on the definition of SERs during the workshop, although one would have expected that this should have already been determined in the projects. At least it seems as if there is no clear consensus between the projects.

Most discussions implied that on a SER the driver understands what the safe speed is from the design of the road. Understanding how to influence human behavior is therefore important, for example identifying so called decelerators and accelerators. Speed signs are not sufficient to make drivers drive the correct/safe speed and should maybe not even be needed on a truly SER. According to some this should maybe also apply for road markings.

SERs is, however, not only about speed and safety (safe speeds). It is important that the driver understands what kind of traffic and which categories of road users that can be expected, for example on-coming traffic, heavy vehicles, cyclists, pedestrians, etc.

Categorization of roads and certain road segments (such as severity of curves) where the categories are distinctly different from one and another is important for the development of SERs. The different categories should be clearly recognized by the road users/drivers and should also not be too many as this may cause confusion.

Another conclusion was that in order to be successful in the development of SERs it is necessary to harmonize across Europe.

A question that was raised by the moderator was where the projects think their input will be primarily, in the early stage of the planning process for new roads or on existing roads.

The conclusion was that the projects all have focused primarily on existing roads. It was also concluded that the approach is very different depending on if it is a new road or an existing road. You have to come in at a very early stage of the planning process to ensure that the final road will be self-explaining. On existing roads only limited treatments can be done, but even small measures will improve roads to be more self-explaining.

2 Workshop 2: IRDES and EuRSI

Moderator: Robert Thomson, VTI

2.1 Résumé of the discussions

The session began with a short presentation by the moderator. The presentation identified the main research and application areas and links between the two projects. Five main discussion points were identified for the remainder of the session:

- Project results and contributions to state of the art
- Synergy developed between the projects
- Practical application of the results by end users

    - How? Who?
  - Barriers to implementing the results
  - Opportunities and needs for future development

The resulting discussions suggested that these five areas could be reorganized into:

a) Project results and synergies between projects

b) End user applications and barriers to implementations

c) Opportunities and needs for further development

Results:

a) Project results and synergies between projects

The PEB members present in the workshop were asked how they viewed the results of the projects. As a whole, the project program was judged a success with good output. The results had different levels of usefulness depending on the country. For example the focus on rural roads created limited value for some countries since motorways were not included. Another comment was that the total output was less than for national project. This was based on a comparison between one specific project where a national sponsor closely follows the activities in contrast to a ERA-NET program with 5 projects but limited possibility for sponsors to follow and direct project activities. Closer contact with project and end user during project could have improved the output. Since several projects were awarded, ERA-NET also provided a “scanning” possibility for the funding countries in several topics to establish state of the art.

More coordination among the projects and the ERA-NET organisers could have been incorporated in the initial project negotiations. The project managers indicated that more interaction between the projects would have been valuable. It was said that it would have been done but it did not happen. Meetings in beginning and end recommended. The idea of “Bottom up approach” was suggested as it is better to join from the start instead of at the end.

A specific interaction between projects was identified. EuRSI and IRDES were focused on different areas of roadside safety. Data that was needed in IRDES (GIS data, roadside data sorted and catalogued, automated collection methods) was part of the EuRSI approach. Conversely, the risk issues and relevance of roadside features in EuRSI was well understood by the IRDES consortium.

Accessibility of data was limited for IRDES in some cases. There are legal issues in some countries that restrict data availability. In some cased data to conduct safety evaluations of countermeasure effectiveness was not available. Road network information in the databases can be different and not possible to match (node & link vs GPS coordinate). In other cases the type of barrier, traffic volume etc. is available in some databases (i.e. for the accident site within GIDAS data in Germany) but it is not available in other countries.

Practically vs scientific research: The group recognized the rationing of resources and research must address both activities today. Research budgets are limited so ERA-NET is a good tool to combine research and applied research.

b) End user applications and barriers to implementations

The project managers and PEB agreed that a greater end user benefit would be achieved if the Project Managers and PEB had interactions while deliverables were in progress. Most deliverables were finalized (in terms of work effort) before the PEB comments were submitted. PEB comments that could improve the results were too late to implement.

The IRDES project tried to use online surveys but this was not successful and not recommended for further work. Webinars were deemed more successful where interactions between the researchers and end users were direct and dynamic.

The projects could confirm there is still a need to adapt results to reflect specific countries and their individual needs. Existing guidelines are often lacking in specific examples and direct advice. Language issues can limit penetration of international research, especially if the PEB is not able to push results out in their organizations. WEBINARS were identified as a useful project tool and can be extended at the national level. The example of a previous project (RISER) could be important to consider. If one explores all different options there can be too much general information for specific applications in a country. The separation of guidelines vs standards was brought up. Guidelines are best practice and can be a power to improving national and international standards.

The IRDES project identified how general guidelines can be difficult to apply at a national level. Legal issues are often a barrier. It is important to bring the local practitioners into the project as the PEB may not always be the best reference group. Important to translate information to local level to reach the practitioners and get their feedback. Webinars may be the best way to go between regional, national, and international levels.

A specific example of what is not yet available for the end user was highlighted in IRDES: Road Restraint Systems (safety barriers) could not be addressed in the project, but were a general guideline from RISER. However, assessment of different safety barriers could not be provided in RISER nor IRDES. Steel barriers are different in different countries but legal issues limited data exchanges and analyses in IRDES. Experience indicates that some data is available need further work to solve this problem.

c) Opportunities and needs for further development

The consensus was that there were many topics in the two projects that warranted further work. It was stated that well defined project plans are needed to make sure the project follows a logical and focused scope. It is critical to have early discussions regarding the outputs of the previous and parallel projects.

Follow up projects should take forward the best parts of the completed projects. Not enough time and resources were available to pull together the results of the different projects within the awarded resources. One participant commented that it is not always the best to start new research topics before the existing results have been thoroughly reviewed.

Information from existing and previous projects could be made more accessible with a single information portal. Better and clearer links for projects and information are requested by both researchers and end users. EuRSI promoted a common internet portal could be developed. There was not enough time to discuss this topic regarding usefulness, previous success, format, etc. for these infrastructures.

The closing comments of the workshop identified that a project activity and consortium is just developing into a knowledge and practical resource at the end of the project. At this time the funding is often terminated and the project group is disbanded. The comment “Ready to go but no petrol in the tank” was used to describe this. As a proposal program funding could be reserved and then allocated to select 1-2 main research activities after the project or program is finished.

Harmonization of data collection and data transfer between research areas and countries are still a barrier to research. There is still a need to develop better harmonization of data elements.

PART III – Conclusions

1 Synergies between the projects

1.1 General recommendations on how to improve synergy effects

From the discussions at the workshops it was identified that more coordination among the projects and the ERA-NET organisers could have been incorporated in the initial project negotiations. The project managers indicated that more interaction between the projects would have been valuable. It was said that it would have been done but it did not happen. Meetings in beginning and end are recommended in order to obtain synergies between projects.

From the comprehensive overview of the concrete outcomes from the 5 projects, 1 on forgiving roadsides (FR), 2 on road infrastructure safety management (RISM) and 2 on self-explaining roads (SER), below it can be concluded that there is a rather large overlap between the work that has been carried out.

Two prototype tools have been developed, one Risk Analysis tool (EuRSI) for assessing the “forgivingness” of roadsides and one tool for assessing the “self-explainingness” of roads and calculating the safe speed (ERASER) Both these tools could most certainly be further developed by using the knowledge gathered, and recommendations given, in the other projects. It could even be considered if the tools should be combined into one tool since the road should be both forgiving and self-explaining. The configuration of the roadside has an influence not only on the “forgivingness” but also on the “self-explainingness”.

Synergies between the results of the projects could be gained by forming a project with the coordinators of the 5 project with the specific task to create just that.

1.2 Forgiving roadsides: IRDES

Outcomes of IRDES:

1. Practical guide for the assessment of treatment effectiveness.
2. Forgiving Roadside Design Guide.
   The road side features for which the design guideline has been developed are:
   a. Barrier terminals
   b. Forgiving support structures for road equipment
   c. Shoulder rumble strips
   d. Shoulder width

1.3 Road infrastructure safety management: EuRSI and RISMET

Outcomes of EuRSI:

Key recommendations from comprehensive review of existing Road Safety Inspection (RSI) methodologies throughout Europe

Recommendations for RSI through the implementation of fundamental data capture methodology, measurement and classification

Three prototype software applications were developed and data from three separate road surveys were tested. Initial results indicate a potential new approach to timely data acquisition in conjunction with RSIs.

1. A fully automated road edge extractor using LiDAR data
2. A Road Feature Classifier was developed to exploit the spatially encoded video captured during the surveys. Along with the GPS data this toll enables both road geometry and road side features to be extracted and output.
3. A Risk Analysis Tool takes the outputs from LiDAR Processing and Road Feature Classifier and offers a possibility to build a risk matrix, based on static road geometry and road side features. An index score can be computed for any sample point along the road network under inspection. A safe profile velocity (Vsp) dataset can also be created and this together with collision data can be compared with the Risk Index Score. This application enables the user to identify areas of risk and understand the factors. These risk maps can be used to carry out a preliminary assessment of risk as part of the RSI process.

Outcome of RISMET:

A guide based on data that are currently being collected within EU countries. It recommends a minimum set of data that can provide a basis for basic road safety assessments. The guide is intended to stimulate road authorities to collect a minimum set of data needed for conducting road safety evaluations and serves to provide a set of standard definitions for these data.

A second guide for the development and application of evaluation tools for road infrastructure safety management in the EU. The guideline provides a state-of-the-art reference document in which the following tools are described and discussed:

1. Road safety audits
2. Safety inspections (as per the EU Directive)
3. Network screening (referred to as network safety management in EU Directive)
4. Accident modelling
5. Road protection scoring
6. Identification and analysis of hazardous road locations
7. Impact assessment of investments and road safety measures (referred to as road safety impact assessment in EU Directive)
8. Monitoring of road user behaviour
9. Conflict studies
10. In-depth analyses of accidents

The guide is intended for road authorities and road safety engineering practitioners.

1.4 Self-explaining roads: SPACE and ERASER

Outcome of SPACE:

Conclusions and recommendations for two different methods for evaluating SER treatments

1. Expert workshops using

   a. Questionnaires
   b. Video and photo material
2. Driving simulator

From the results of the driving simulator study specific recommendations for SER treatments at curves were given, i.e. choice of treatment (level) depending on severity of curve.

Outcome of ERASER:

A prototype tool to help European road authorities make decisions to improve the safety and "self-explainingness" of their roads has been developed. The tool requires that road characteristics are entered and, based on this the tool calculates what would be a "safe speed" (i.e. survivable) and assesses whether the speed limit is credible.

2 Recommendations for Implementation

The project managers and PEB agreed that a greater end user benefit would be achieved if the Project Managers and PEB had interactions while deliverables were in progress. Most deliverables were finalized (in terms of work effort) before the PEB comments were submitted. PEB comments that could improve the results were too late to implement. In order to transfer the results into recommendations for implementations further work needs to be carried out. This could be gained by forming a project with the specific task to create just that.

A number of guides and recommendations have been developed by the projects. It is important that the members of the PEB make these guides/recommendations known and available to the European road authorities. However, these are rather comprehensive reports that are maybe not to be expected to be read by practitioners. To facilitate the dissemination of the recommendations and guides presentation material, such as power point presentations, could be prepared. This should be material suitable to be used for the education of practitioners.

Factsheets from each project could be prepared showing the most important outcomes (as was done in ERASER) in order to facilitate the dissemination of the project results.

In addition the tools developed could be further tested in demonstration projects. In order to ensure that recommendations for implementation is provided as an outcome from the demonstration project this could be a more highlighted part of the aim of the project. Furthermore, dissemination before the end of the project on this particular aspect is recommended as a requirement for running the project.

Table 3 Overview of the guides and tools developed in the projects and recommendations for implementation

Project	Guide (report)	Tool (software)	Recommendations for implementation
IRDES	Practical guide for the assessment of treatment effectiveness Forgiving road side design guide		Educational material Handbook with a more condensed content
EuRSI		LIDAR processing – road edge geometry Road feature classifier Risk Analysis tool	Further development is required and tests in demonstration projects are recommended
RISMET	Data requirements for road network inventory studies and road safety evaluations – Guidelines and specifications Guidelines for development and application of Evaluation tools for road safety infrastructure management in the EU		Handbook with a more condensed content Educational material
SPACE	Two methods for evaluating SER treatments: Expert workshops Driving simulator		The driving simulator can be used to demonstrate different SER treatments to road authorities and practitioners. See also below.
ERASER		Decision support tool for road authorities (speed management)	A functionality and usability check has been done with road authorities within the project. Further tests in a demonstration project are recommended. One suggestion is: The ERASER tool is used on an existing road. The effects of the improvements suggested by the tool are then demonstrated/tested in a driving simulator.

3 Recommendations for further development and research

There are many topics in the projects that warrant further work. Follow up projects should take forward the best parts of the completed projects. Not enough time and resources were available to pull together the results of the different projects within the awarded resources. The results from the projects provide a valuable basis for further research. Recommendations for further research have been reported by the 5 projects, and are briefly summarized below. No obvious additional recommendation has been identified by the authors of this report.

It was identified that a project activity and consortium is just developing into a knowledge and practical resource at the end of the project. At this time the funding is often terminated and the project group is disbanded. The comment “Ready to go but no petrol in the tank” was used to describe this. As a proposal program funding could be reserved and then allocated to select 1-2 main research activities after the project or program is finished.

Harmonization of data collection and data transfer between research areas and countries are still a barrier to research. There is still a need to develop better harmonization of data elements.

Recommendations from the FR project:
In the IRDES project the following roadside features and their benefits and characteristic features are described and discussed:

- Barrier terminals
- Shoulder rumble strips
- Forgiving support structures for road equipment
- Shoulder width.

Recommendations from the RISM projects

The EuRSI project highlights a number of areas for future research. These include, amongst others

- **Risk Index Score:** A more rigorous assignment of risk factor parameters and weightings based on road engineering & safety reports
- **Risk Factors:** Increase the number of risk factors from present 12
- **Transient Factors:** Incorporation of transient risk factors such as weather, illumination & traffic
- **Sampling.** Should risk be computed over a linear/areal range rather than discrete point sources, highlighting change e.g. straight/curve transition
- **Safety Interventions** These should be also measured, scored and integrated with risk, VSP and Collisions in order to develop a more comprehensive approach to prioritising remedial measures
- **Safe Profile Velocity VSP** This technique should be improved to ensure adherence to average driving profile under good conditions and low driver work-load. This methodology should be checked for quality including accuracy, & repeatability. Acceleration should also be examined in more detail to decide best approach in including this variable to producing a more comprehensive figure. VSP could also be used to normalise the search tolerance distances used to identify location of risk factors
- **Visualisation** More comprehensive integration of risk factor data inputs, Risk Index Score, VSP, Collisions, geocoded imagery (MMS), topographical maps & existing safety interventions. This would present a more comprehensive picture of the road environment.

A further suggestion from the EuRSI project is to develop an online pan-European Road safety Risk Analysis Platform

- Migrate risk analysis and associated data handling tools to an online Web based system enabling road authorities across Eu-27 to share data and expertise, collaborate, use latest toolsets and encourage a common approach through adoption of standards
- Explore new safety advisory services (in-car or wireless) using these datasets and incorporating real-time weather and traffic information and so, contribute to adoption of new Eu ITS directive.

The RISMET project recommends the following research for the future to further develop evaluation tools:

1. Road safety audits, Road safety inspections and Road protection scoring – monitor and evaluate the effect of measures
2. Network screening – adopt Safety Analyst approach
3. Road accident modelling – test models empirically, incorporate road user behaviour
4. Blackspot safety management - employ Empirical Bayes for identification and the matched-pair approach for the analysis of contributing factors
5. Road safety impact assessment – The Highway Safety Manual (AASHTO, 2012) reflects state of the art. Current practice to adopt this.
6. Monitoring of road user behaviour – target a maximum of five types of behaviour affecting safety (incl. speeding, not wearing seatbelts and drinking and driving)
7. Conflict studies, naturalistic driver behaviour studies and in-depth studies of accident are optional tools in the safety management toolbox, none are essential.

Recommendations from the SERs projects:

In the SPACE project expert workshops were used for evaluating SER treatments. It was concluded that it is important to have written guidelines and a specified framework for how the workshops should be conducted in order to be able to compare results. However, the guidelines and background material used for the workshop concept can be further developed. For instance it should be possible to use the same animated graphical scenarios as those developed for the driving simulator experiments. This provides the possibility to evaluate future not yet built environments and SER treatments in two steps. The first step is the expert workshop where a “larger number” of designs/treatments are evaluated and the most promising are chosen for evaluation in the second step, the driving simulator study.

According to the ERASER project applying the principle of SERs on an entire road network requires road categorisation that follows the two basic principles regarding design and expected behaviour.

- Heterogeneity between road categories
- Homogeneity within road categories

Traditionally, however, other aspects are considered when categorising roads and there is no harmonisation in road categorisation over Europe. The current practice of road categorisation in Europe therefore needs to be reviewed

The best example of a self-explaining road category today is the modern motorway. Its design is recognizable at first sight, it differs from all other road categories and the visual appearance is actually quite similar throughout Europe.

However, to develop the principle of SER categories further knowledge is required. Empirical research has to be carried out to enhance knowledge on how specific design elements influence the drivers' expectations and behaviour, i.e. the self-explaining nature of different road categories.

Furthermore, feedback from road authorities on functionality and usability of the ERASER tool resulted in the following suggestions for future development:

- Development of two different tools – one that remains simple and has relatively straightforward data needs, and another that allows greater precision through intensive data input
- Include more speed comparisons
- Include network wide approach (at present the tool works on a road-by-road basis)