Fondation Francqui Stichting

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Best Practice on Road Infrastructure Safety Management

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Presentation Outline

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Background

Background

- Road infrastructure safety may be critical for road safety enhancement, especially in emerging economies.
- Traditional «reactive» approach to road safety (e.g. high risk site management) is becoming ineffective in more advanced countries.
- Moving towards a Safe System approach where the Road Administration has responsibility for the safety of the infrastructure.

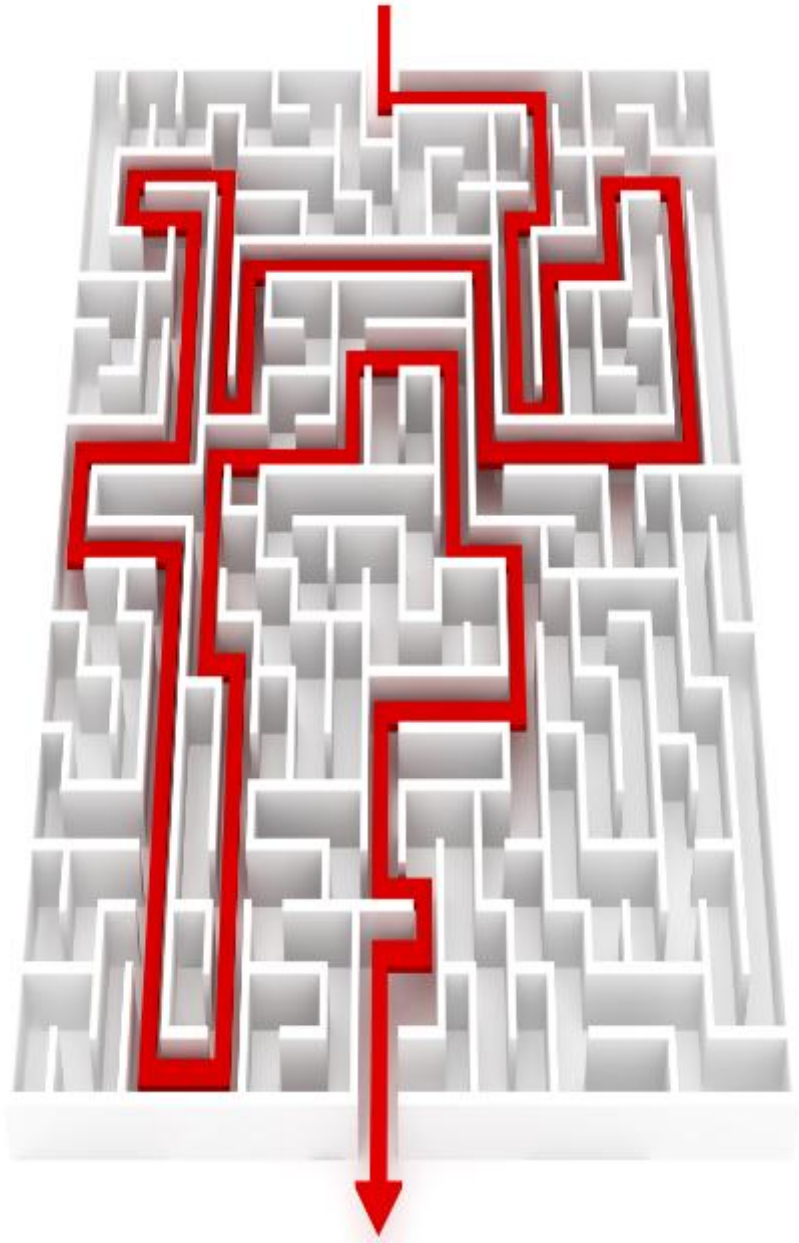
Road Infrastructure Safety Management

- The Road Infrastructure Safety Management (RISM) is defined as:

  the total procedures supporting the road infrastructure management authorities to prevent future road accidents and/or to limit their consequences.

Not all procedures are easy to be implemented

- Terminology
  - e.g. Black Spot? Hazardous Location? High Risk Site?
- Implementation Area
  - Where and when?
- Requirements
  - What tools and data are needed?
- Other barriers…
  - Why they are not used?



Description of RSIM Procedures

- Introduction
- Tools and data needed
- Common practices
- A synthesis:

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

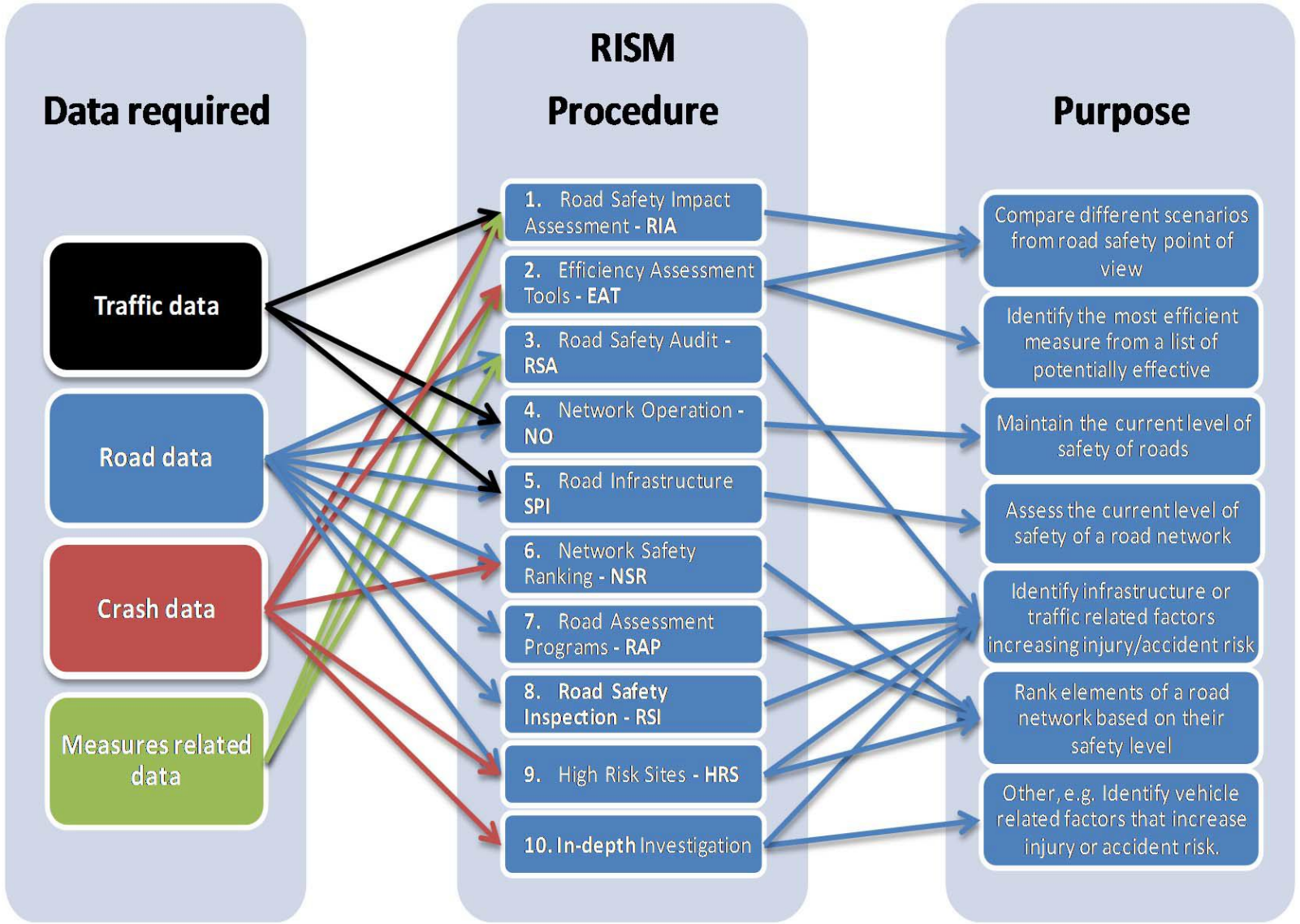
Source: OECD/ITF 2015 – "Road Infrastructure Safety Management"

Targets of RSIM Procedures

- Assessment of the results of specific road safety measures or programs.
- Early identification of new road safety problems.
- Identification of the most hazardous parts of the road network.
- Identification of the most significant contributors to road accidents and injuries.

Road Infrastructure Safety Management

Road Infrastructure Safety Management Procedures



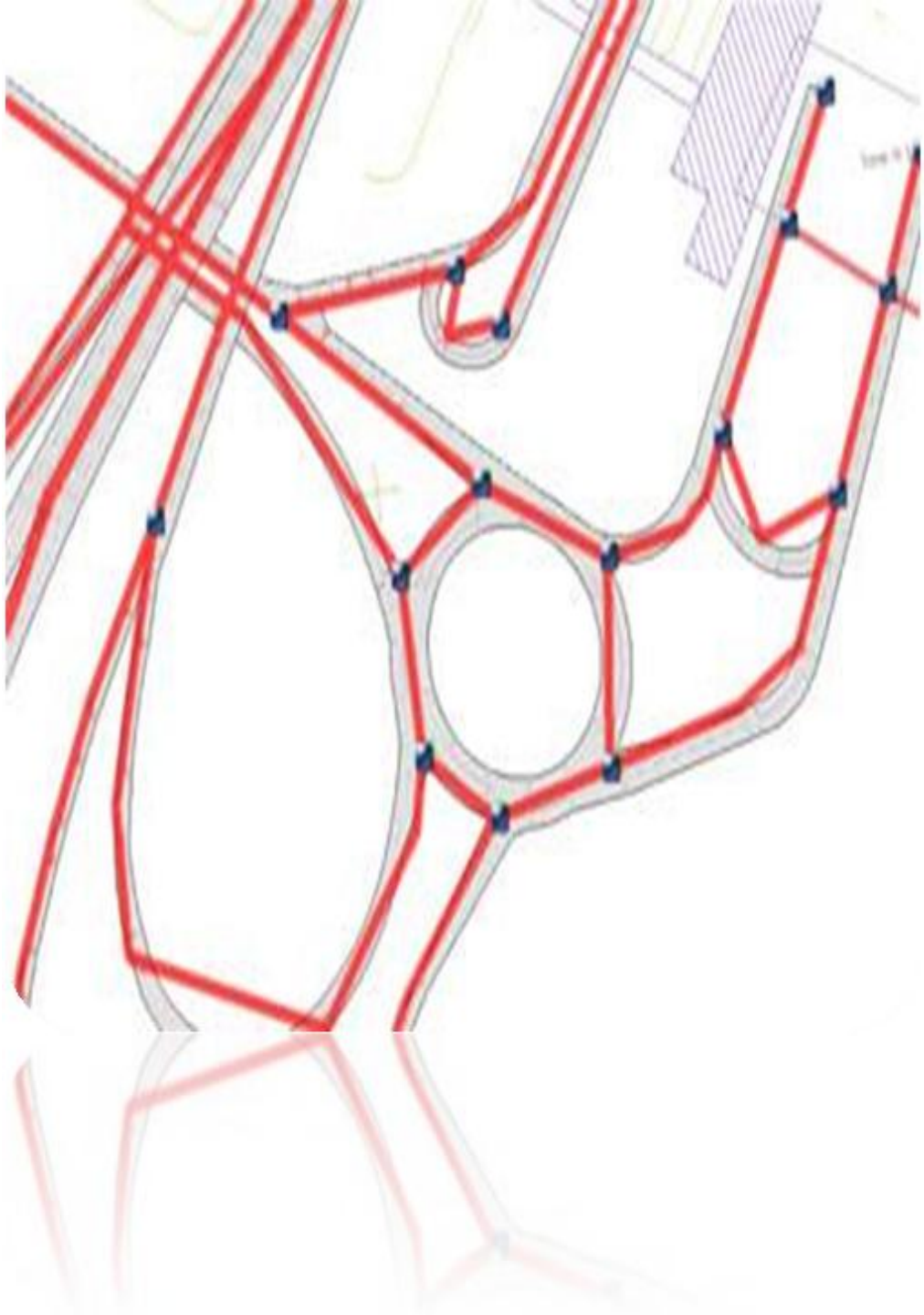
Life-cycle Stages of a Road Infrastructure

Stage 1: Planning & Design

- Road Safety Impact Assessment (RIA)
- Road Safety Measures Efficiency Assessment Tools (EAT)
- Road Safety Audit

1. Road Safety Impact Assessment

- A RIA is a methodology used at the planning stage to assess changes in the network safety level resulting from the introduction of a modification in the road network configuration or operation.
- It requires the estimation of the safety level of a part of the road network.
- Its aim is to compare different implementation scenarios from road safety point of view.



2. Road Safety Measures Efficiency Assessment Tools

- Economic resources for transport in general and for road safety in particular should be distributed in the most efficient way.
- The tools for measuring the efficiency of measures (e.g. cost-benefit analysis) determine the social benefit of an investment in order to set the appropriate priorities.
- The aim is to compare different scenarios from road safety point of view and identify the most efficient measure from a list of potentially effective measures.
- Applied at the planning stage and before a major upgrading of the infrastructure.

3. Road Safety Audit

- A Road Safety Audit (RSA) is commonly defined as a safety check of an infrastructure project, be it a new (section of) road or an intersection, or a substantial modification to the existing network, covering all stages from planning until the initial operation.
- A RSA is a formal, detailed and systematic process that should be carried out by an independent and well-trained auditor (or team of auditors).
- Its aim is to identify infrastructure or traffic related factors increasing injury or accident risk.
- Undertaken during planning, design, construction, pre-opening and early operation stages.

Stage 2: Construction & Pre-Opening & Stage 3: Normal Operation

- Road Safety Audit (RSA)

- Network Operation (NO)
- Road Safety Performance Indicators (SPIs)
- Network Safety Ranking (NSR)

4. Network Operation

- Gradual change in infrastructure and / or traffic characteristics, with consequences on road safety.
- Information on scheduled or unscheduled events that may increase the risk level on the road network.
- The aim of NO is to maintain the current level of safety of roads.
- Undertaken during normal operation of a road and during maintenance.

5. Road Safety Performance Indicators

- The purpose of SPIs is to assess risk factors related to road infrastructure at two levels:
  - the road network level and
  - the road design level (e.g. percentage of road network not meeting design requirements).

- The safety performance of the existing road network during normal operation of the infrastructure is monitored.

6. Network Safety Ranking

- NSR is a systematic road safety ranking and management approach at the level of road networks.

- According to the EU Directive on Road Infrastructure Safety Management (2008/96/EC): *"Network Safety Ranking" means a method for identifying, analysing and classifying parts of the existing road network according to their potential for safety development and accident cost savings."*

- Generally undertaken during normal operation of the road network.

Stage 4: Maintenance & Renewal

- Network Operation (NO)
- Road Safety Inspection (RSI)
- Road Assessment Programme (RAP)

7. Road Safety Inspection

- Regular, systematic, on-site inspection of existing roads covering the whole road network.
- RSI aims to identify potentially hazardous conditions and deficiencies that can result in severe accidents.
- Generally undertaken during normal operation of a road and may also contribute to error correction and hazard elimination

8. Road Assessment Programme

- A process for the assignment of a score to a road section based on the existence or the absence of essential design features related to road safety.
- Applies to the whole or part of the road network.
- Generally undertaken for identification and correction of errors on the road infrastructure.

Stage 5: Error correction, Hazard Elimination

- High-Risk Site Treatment (HRS)
- Road Safety Inspection (RSI)
- Road Assessment Programme (RAP)
- In-Depth Investigation

9. High-Risk Site Treatment

- Specific road sections where the number of accidents is remarkably high.

- The approach of high risk sites is based on the perception that, in specific sections of the road network, there is a combination of factors leading to an increased number of accidents.

10. In-Depth Investigation

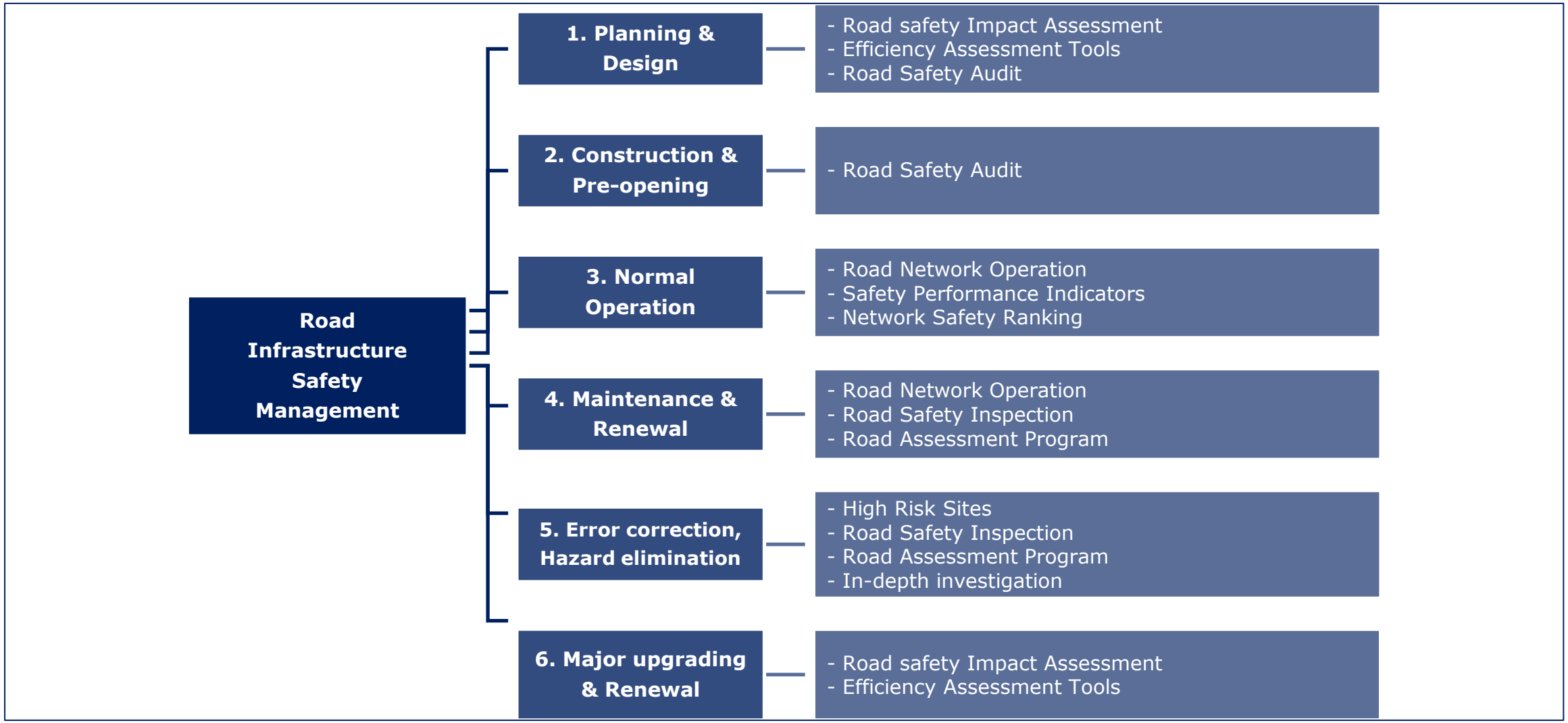
- The In-depth Investigation concerns the collection of all necessary data and the identification of one or more of the following:
  - the cause(s) of an accident,
  - the injuries, the way they were caused and their results,
  - how accidents and injuries could have been prevented.

- Undertaken to identify and remove safety issues emerging from the interaction between human factors and infrastructure.

Stage 6: Major upgrading & Renewal

- Road Safety Impact Assessment (RIA)
- Road Safety Measures Efficiency Assessment Tools (EAT)

Putting it all together



Best Practice on Road Safety Infrastructure Investments

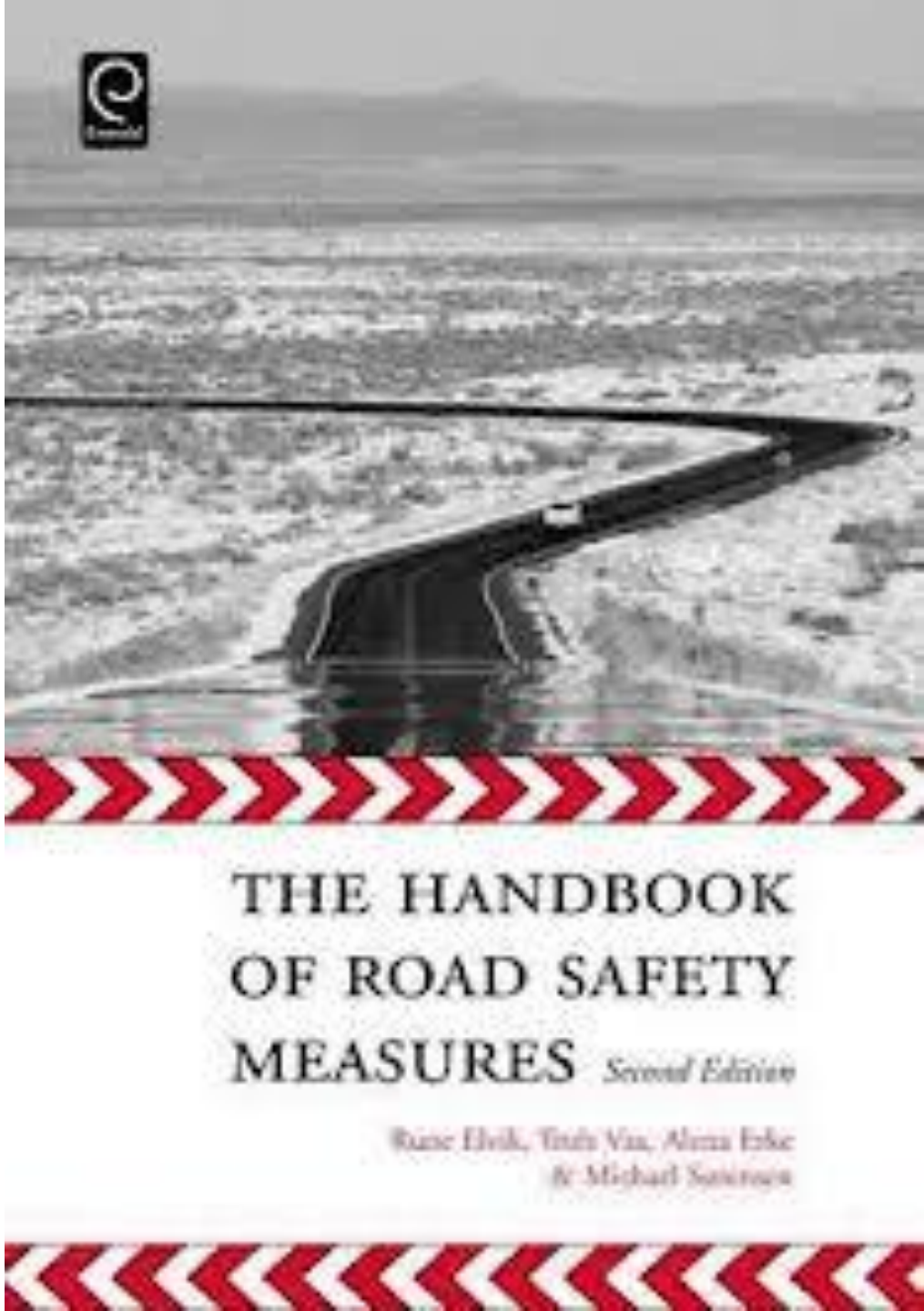
Key Handbooks and Systems (1/8)

- The Handbook of Safety Measures (2004, 2009)

- State-of-the-art summaries of current knowledge on the effects of 128 road safety measures:
  - policy instruments
  - road design, equipment, maintenance, traffic control
  - vehicle design, protective devices, inspection
  - driver training and regulations,
  - public education & information,
  - police enforcement and sanctions,
  - post-crash care

- Formal techniques of meta-analysis were used.

- A systematic framework was used to assess the validity of the studies.



Key Handbooks and Systems (2/8)

- The ROSEBUD Handbook (2006)
  «Examples of assessed road safety measures»

- The handbook includes information about various assessed road safety measures.
  - User related
  - Vehicle related
  - Infrastructure related

- The assessment methods used are cost effectiveness analysis (CEA) or cost-benefit analysis (CBA).

- According to the Benefit-Cost ratio, measures are ranked as poor, acceptable and excellent.

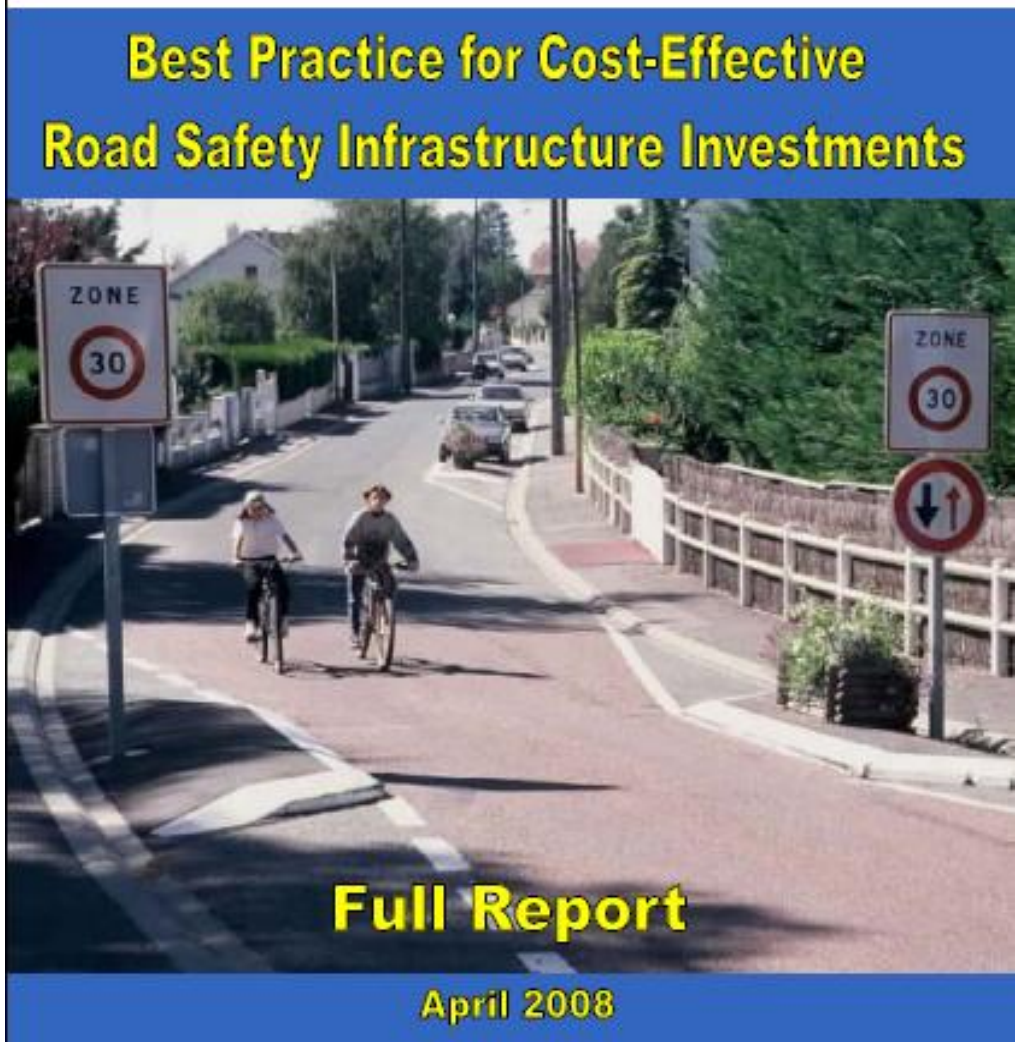
Key Handbooks and Systems (3/8)

- The SUPREME Handbooks (2007)
  "Best practices in road safety"
- Handbook of measures at country level
- Handbook of measures at European level
  - Best practice (B/C ratio available)
  - Good practice (sound theoretical basis)
  - Promising practice (new measures)
- Nine thematic areas
  - Education, campaigns, driver training
  - Rehabilitation and diagnostics
  - Vehicles
  - Infrastructure
  - Enforcement
  - Statistics and in-depth analysis
  - Institutional organisation
  - Post-accident care

Key Handbooks and Systems (4/8)

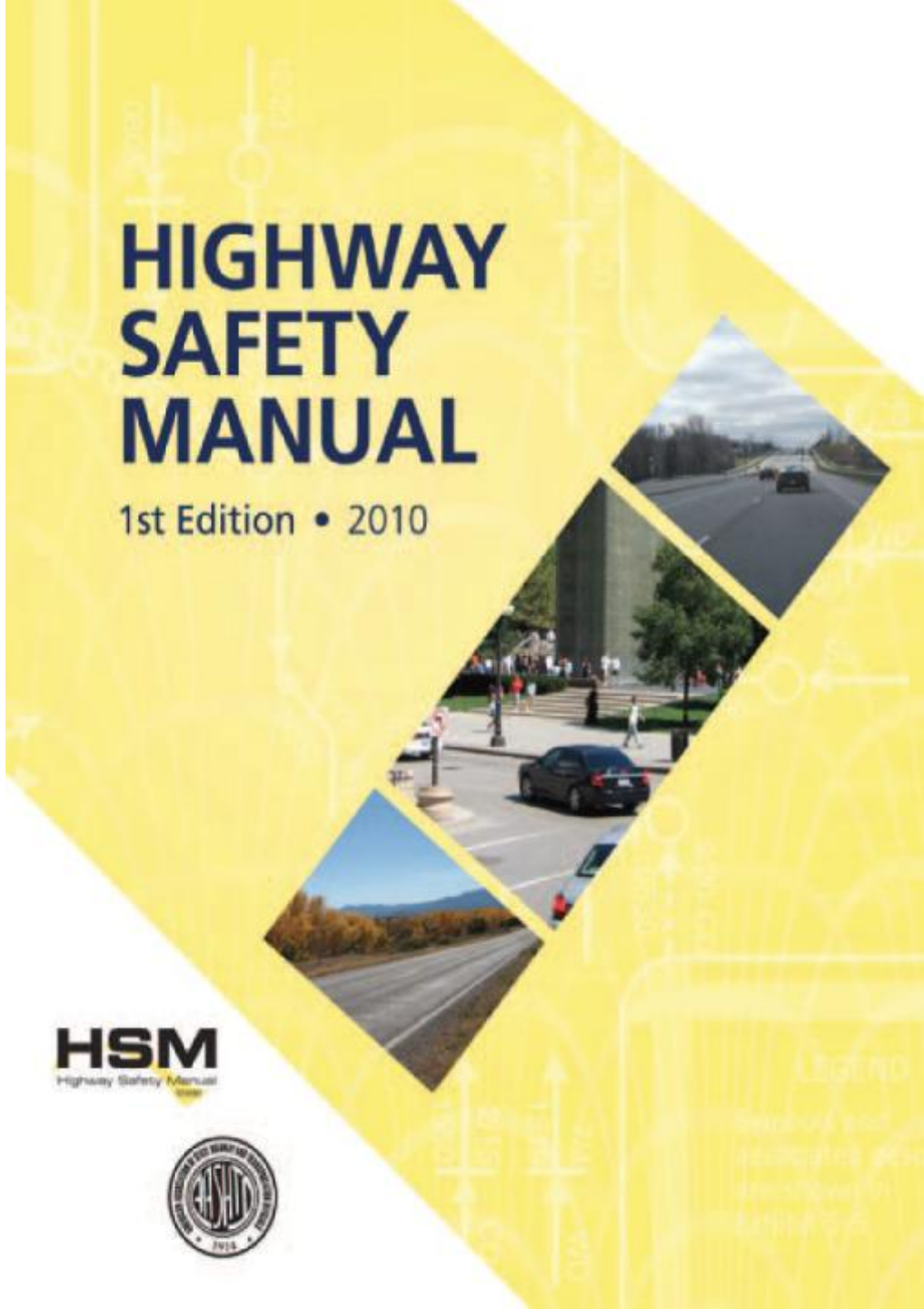
- The CEDR Report (2008)
  «Best Practice on Cost Effective Road Safety Infrastructure Investments»
- A review of 56 road infrastructure investments (literature and national CEDR questionnaires)
  - motorways, rural roads, urban areas
  - Simple road sections, bends, junctions
- Five most promising investments were identified:
  - Roadside treatment
  - Speed management
  - Junctions layout
  - Junction traffic control
  - Traffic calming
- Safety effects, Other effects (mobility, environmental etc.), Investments costs, CEA/CBA results, Strengths and weaknesses, implementation barriers.

CEDR
Conférence Européenne des Directeurs des Routes
Conference of European Directors of Roads



Key Handbooks and Systems (5/8)

- The AASHTO Highway Safety Manual (2010 & 2014)
- Provides information and methodologies on measuring, estimating and evaluating roadways in terms of crash frequency and crash severity, applicable to:
  - rural two-lane highways,
  - rural multilane highways,
  - urban and suburban arterials,
  - at-grade intersections,
  - motorway segments,
  - interchange ramp segments
  - interchange ramp terminals (crossroads)
- Quantitative estimation of the safety performance of roadways, as well as of potential infrastructure countermeasures.



Key Handbooks and Systems (6/8)

- Highway Safety Manual Complementary Systems:
  - FHWA CMF Clearinghouse

    A searchable online database of approximately 7.000 Crach Modification Factors used to estimate the effectiveness of infrastructure countermeasures

  - Tatum SPF Clearinghouse

    A searchable online database of Safety Performance Functions

  - FHWA Interactive Highway Safety Design Module (IHSDM)

    A decision-support tool that provides estimates of a highway design's expected safety and operational performance, checks existing or proposed highway designs against relevant design policy values, and assists in economic analyses

Key Handbooks and Systems (7/8)

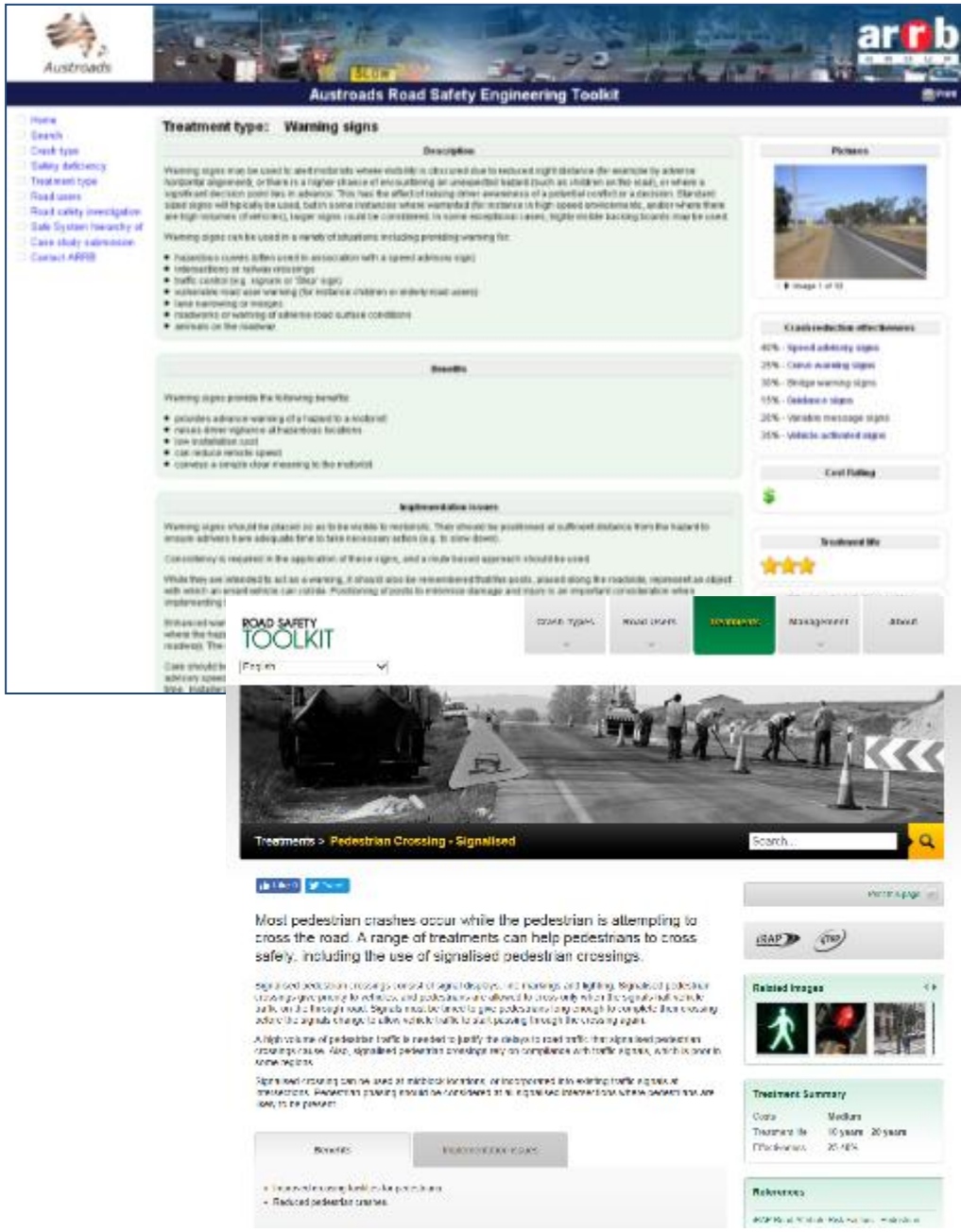
- The Austroads Road Safety Engineering Toolkit

  Information on 67 road infrastructure treatments, including:
  - relevance to specific crash types,
  - addressing specific road safety deficiencies, and
  - affecting particular road user groups.

  Information for each treatment includes:
  - key benefits
  - implementation barriers
  - crash reduction effectiveness
  - cost rating
  - treatment life estimation
  - reference to technical papers, studies and guides

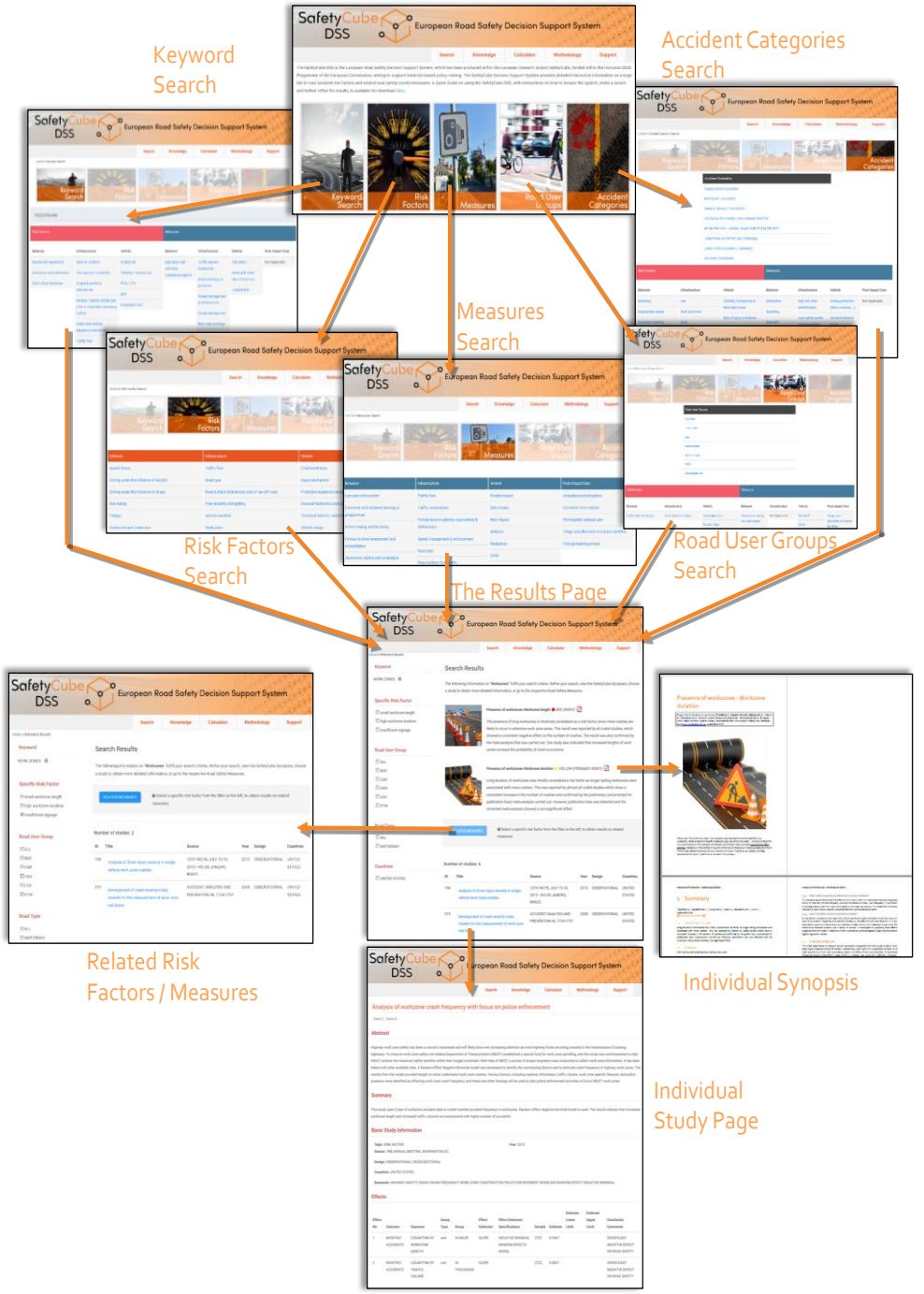
- The iRAP Road Safety Toolkit

  Information on 42 road infrastructure treatments and how these are related to specific crash types or affect particular road user groups.



Key Handbooks and Systems (8/8)

- The European Decision Support System (DSS) developed within the SafetyCube, EC Horizons 2020 Project (2018)
- The main contents of the SafetyCube DSS concern:
  - road accident risk factors and problems
  - road safety measures
  - best estimate of effectiveness
  - cost-benefit evaluation
  - all related analytic background
- More than 270 studies on infrastructure related risk factors have been coded.
- Approximately 3.500 effects were found for the examined risk factors.
- 37 synopses have been authored for inclusion in the DSS (including 5 original meta-analyses)
  (some of the original 50 topics factors were merged)



Efficiency Assessment Methodologies

- Cost-effectiveness analysis:

$$\text{Cost-effectiveness} = \frac{\text{Number of accidents prevented by a given measure}}{\text{Unit costs of implementation of measure}}$$

- Cost-benefit analysis:

$$\text{Benefit-cost ratio} = \frac{\text{Present value of all benefits}}{\text{Present value of implementation costs}}$$

- Safety Effect:
  - Expected reduction in target accidents/casualties following the implementation of a treatment, given in the form of a percentage.
  - Estimation of the safety effect: "Before-after studies"

Accident And Implementation Cost

- Accidents cost calculation includes three major cost items:
  - Material damage costs.
  - Generalized costs, including administrative costs.
  - Human costs, based on the Value of Statistical Life and the loss of quality of life.
- Definition of suitable units of implementation for the investment.
- Implementation costs: social costs of all means of production (labour and capital) employed to implement the investment.

Key Infrastructure Investment Areas

- Motorways:
  - Development of motorways
  - Interchanges
- Rural roads:
  - Horizontal Curvature treatment (various individual investments)
  - Cross-section treatment (various individual investments)
  - Roadside treatment (various individual investments)
  - Traffic Control and Operational Elements (various individual investments)
  - E-Safety systems
  - Road surface treatment (various individual investments)
  - Lighting treatment
  - Rail / road crossings treatment
- Junctions:
  - Roundabouts
  - Junctions layout (various treatments)
  - Traffic control at junctions (various individual investments)
- Urban areas:
  - Urban traffic calming schemes
  - Bypasses
  - Improvement of land use rules

CEDR - Preliminary Selection of Most Promising Investments

- Investment areas and individual investments with high safety effect and low implementation cost are the most interesting.
- High cost/high safety effect investments are also considered, due to increased safety effect.
- Low cost/low safety effects investments are only exceptionally considered in specific cases (i.e. minor and local road safety issues).
- High cost/low safety effect investments should only be considered under certain circumstances.

		Safety effect	
		High	Low
Implementation costs	Low	Implementation of guardrails Replacing guardrails with softer ones Changing from unrestricted speed to speed limit Reducing speed limit Creation of speed transition zones Traffic signs (regulatory) Traffic signs (warning) Rumble-strips Implementation of artificial lighting Improving existing lighting Protection of rail/road level crossings Junctions channelization Implementation of stop signs Improvement of existing traffic lights Traffic calming schemes Improvement of land use rules	Traffic signs (guide) Traffic signs (warning) Delineators and road markings Raised road markers Chevrons Post-mounted delineators Navigation routing Implementation of yield signs
	High	Development of motorways Development of interchanges Increasing curve radii Introduction of transition curves Superelevation treatment Reducing gradient Improvement of sight distances Increasing lane width Introduction of shoulder Increasing shoulder width Introduction of median Increasing median width Flattening side-slopes Establishment of clear zones Creation of speed transition zones Weather info VMS Congestion info VMS Individual info VMS Ordinary re-surfacing Improving friction Implementation of artificial lighting Introduction of rail/road grade crossings Development of roundabouts Junctions staggering Junctions re-alignment Implementation of traffic lights Traffic calming schemes Development of bypasses Improvement of land use rules	Reducing the frequency of curves (horizontal) Reducing the frequency of curves (vertical) Superelevation treatment Increasing the number of lanes Development of 2+1 roads Increasing median width Individual info VMS Improving road surface evenness Improving road surface brightness Junctions re-alignment

CEDR - Most Promising Investments

- Roadside treatments
  (clear zones, guardrails)
- Speed limits
- Junction layout
  (roundabouts, re-alignment, staggering, channelization)
- Traffic control at junctions
  (traffic signs, traffic signals)
- Traffic calming schemes
- Lighting treatments

Example: Roadside Treatments - Investments

- Flattening side slopes
- Establishment of clear zones
- Installation of guardrails along the embankment
- Replacement of guardrails (CEN standards)
- Median guardrails on divided highways
- Median guardrails on undivided highways
- Combination of guardrails installation and roadside obstacles removal

Example: Roadside Treatments - Safety Effects

Source	Measure	Description	Country / Region	Road network				Evaluation period	Evaluation method		Safety effect (%)										
				Urban	Rural	Highways	Number of sites		meta-analysis	before/after	Best estimate	95% conf.int.	run-offroad, head-on and sideswipe accidents	single vehicle run-off accidents	single vehicle accidents with trees	all accidents	fatal accidents	injury accidents	Damage-only accidents	fatalities	Injuries
CEDR (Questionnaire 2)	Guardrails		France				8				**-17**	-				●					
CEDR (Questionnaire 2)	Guardrails		France				8				**-18**	-								●	
CEDR (Questionnaire 2)	Guardrails		The Netherlands				-				**-50**	-				●					
CEDR (Questionnaire 2)	Guardrails		The Netherlands				-				**-50**	-									●
CEDR (Questionnaire 2)	Guardrails		Spain				-				**-11**	-				●					
CEDR (Questionnaire 2)	Guardrails		Spain				-				**-49**	-								●	
CEDR (Questionnaire 2)	Guardrails		Spain				-				**-26**	-									●
Elvik and Vaa, 2004	Side slopes	Flatten side slope from 1:3 to 1:4 mostly on two-lane roads	USA		●		-	-	●		**-42**	(-46;-38)						●			
Elvik and Vaa, 2004	Side slopes	Flatten side slope from 1:3 to 1:4 mostly on two-lane roads	USA		●		-	-	●		**-29**	(-33;-25)							●		●
Miaou, 1996	Side slopes	Flatten side slope from 1:3 to 1:4 mostly on two-lane roads			●		-	-	●		**-28**	s.s.		●							
Elvik and Vaa, 2004	Side slopes	Flatten side slope from 1:4 to 1:6 mostly on two-lane undivided roads	USA		●		-	-	●		**-22**	(-26;-18)						●			
Elvik and Vaa, 2004	Side slopes	Flatten side slope from 1:4 to 1:6 mostly on two-lane undivided roads	USA		●		-	-	●		**-24**	(-26;-21)							●		●
Miaou, 1996	Side slopes	Flatten side slope from 1:4 to 1:6 mostly on two-lane undivided roads			●		-	-	●		**-24**	s.s.		●							
Allaire et al., 1996	Side slopes	Flatten side slopes			●		60 projects	-	●		**(-3;-50)**	-		●				●			
Elvik and Vaa, 2004	Guardrails	Setting-up guardrails along embankments	USA, Australia, Sweden		●	●	-	-	●		**-44**	(-54;-32)					●				
Elvik and Vaa, 2004	Guardrails	Setting-up guardrails along embankments	USA, Australia, Sweden		●	●	-	-	●		**-47**	(-52;-41)						●			
Elvik and Vaa, 2004	Guardrails	Changing to softer guardrails	USA, Australia, Sweden		●	●	-	-	●		**-41**	(-66;+2)					●				
Elvik and Vaa, 2004	Guardrails	Changing to softer guardrails	USA, Australia, Sweden		●	●	-	-	●		**-32**	(-42;-20)						●			
Elvik and Vaa, 2004	Guardrails	Median guardrails on divided highways	USA, G.Britain, France, Sweden, Denmark			●	-		●		**-43**	(-53;-31)					●				
Elvik and Vaa, 2004	Guardrails	Median guardrails on divided highways	USA, G.Britain, France, Sweden, Denmark			●	-		●		**-30**	(-36;-23)						●			
Carlsson et al., 2001	Guardrails	Wire median guardrails on undivided highways	Sweden			●				●	**-23**	-									●
Corben et al, 1997	Clear zone	Marking of roadside obstacles	Australia	-	-	-	-	-		●	**-23**	s.s.						●			
Zeeger et al., 1988	Clear zone	Increase of the roadside clear recovery distance on two-lane rural roads (between 1,5m - 6,2m)					-	-		●	**(-13;-44)**	s.s.	●								
ROSEBUD, 2005	Clear zone and guardrails	Setting-up guardrails and cutting trees	France		●		26,5 km of road	1993 - 2003		●	**-95**	(-59;-99)			●						

s.s: statistically significant

Example: Roadside Treatments - Summary (1/2)

Investment: Roadside treatment

Network: Mainly interurban / rural

Maximum safety effect: Installation or replacement of guardrails seem to have higher safety effects, as well as their combination with other roadside works.

Minimum (or negative) safety effect: Flattening side slopes, especially from 1:4 to 1:6 on two-lane undivided roads seem to have the lower safety effect, which is though very significant (-24% ; -22% reduction).

Max B/C ratio: 32:1, considering only safety effects

Min B/C ratio: 8,7:1, considering only safety effects

Implementation costs per unit:

- Installation of guardrails: 32.500 - 220.000€ per km, depending on the type
- Installation of guardrails and other works: ~1.000.000€ in total

Example: Roadside Treatments - Summary (2/2)

Other effects:

- Negative effects on environment in some cases
- Slight increase on average speed

Strengths:

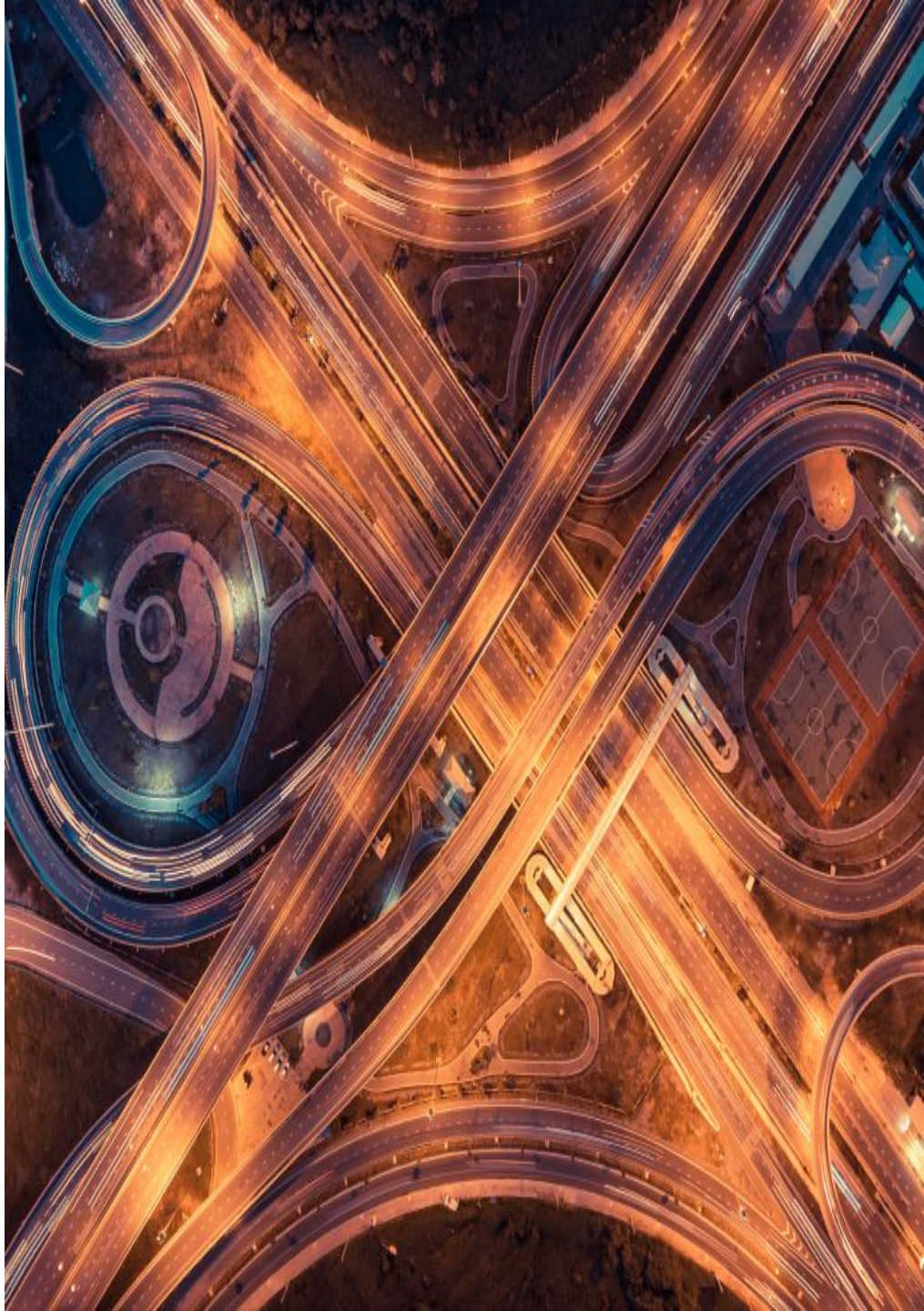
- Significant safety effects on the number of accidents with casualties, but also on accident severity
- Validated cost-effectiveness
- High acceptability by road users

Weaknesses:

- Relatively high implementation cost
- Side effects to the surrounding environment/landscape
- Slight increase in the number of damage-only accidents in some cases

Implementation barriers:

- Long and complicated administrative and financial procedures



Comparative Overview of Most Promising Investments

- Important interrelations exist between the six most promising investments.
- Roadside treatments, junction layout treatments and speed limit interventions could be considered as a main set of most promising investments in interurban and rural roads.
- Traffic calming, junctions layout, traffic control and lighting treatments may be considered as a main set of most promising investments in urban areas.
- There may seldom be a single answer to a specific road safety problem; a set of infrastructure interventions will be required.
- The safety effects of the most promising investments cannot be guaranteed; efficient planning and implementation of an investment is required.

Investment	Sub-investment	Safety effect (%) *		Implementation cost (€)		Benefit / Cost ratio	
		Min	Max	Min	Max	Min	Max
Roadside treatment	Clear zones	-23		*n/a*	*n/a*	< 1:1	*n/a*
	Side-slopes	-22	-42	*n/a*	*n/a*	< 1:1	*n/a*
	Guardrails	-30	-47	35,000 per km	220,000 per km	8:1	32:1
Speed limits	Introducing speed limits	-22		300 per km		> 1:1	*n/a*
	Reducing speed limits	-9	-67	300 per km		> 1:1	*n/a*
Junctions layout	Roundabouts	-11	-88	650,000 per junc.	1,300,000 per junc.	2:1	3:1
	Re-designing junctions	-17	-50	785,000 per junc.	*n/a*	3:1	
	Channelizations	+16	-57	65,000 per junc.	1,650,000 per junc.	< 1:1	2.5:1
Traffic control at junctions	STOP sings	-19	-45	250 per sign	700 per sign	< 1:1	6.8:1
	Introducing traffic signals	-15	-36	60,000 per junc.	*n/a*	< 1:1	8:1
	Upgrading traffic signals	+60	-37	*n/a*	*n/a*	< 1:1	8.6:1
Traffic calming	Area-wide traffic calming	-8	-50	1,300,000	3,000,000	2:1	4:1
Lighting treatment	Installing lighting	-28		26,500 per km	57,500 per km	7:1	9:1
	Increasing lighting level	-32		30,000 per km	32,500 per km	2.5:1	4:1

* on target injury accidents
n/a : not available

Conclusions

Conclusions (1/3)

- RISM procedures are effective and efficient.
  - *RIAs and EATs provide better information to policy makers in order to make better decisions.*
  - *RSAs and RSIs have shown positive cost-benefit-ratios, up to 99:1.*

- Road Authorities are key players for improving road safety.

- Road design standards cannot guarantee road safety in all conditions.
  - *Design standards are important to keep up with nominal safety. Substantive safety must be considered in design process to care for safety in principle.*

Conclusions (2/3)

- Success factors for the implementation of a RISM procedure are:
  - adequate level of investment
  - a supporting regulation
  - road safety data.

- A critical requisite is an adequate institutional management capacity to support the development and implementation of effective interventions.

- Several tools supporting road infrastructure safety management are already available.

Conclusions (3/3)

- Each country has specific needs and has to cope with specific barriers to the implementation of RISM as different conditions exist.
- Road safety performance monitoring helps to achieve safety target of road authorities.
  - A target should be defined and progress toward the safety target should be monitored.
- Road infrastructure should be improved with the development of self-explaining roads to guide drivers to adopt appropriate behaviours.

Fondation Francqui Stichting

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