International Traffic Safety Data and Analysis Group

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Safety Performance Evaluation of Road Infrastructure

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Best Practices on Cost - Effective Road Safety Infrastructure Investments

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Structure of the presentation

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1. Introduction

The Need for the Assessment of Road Safety Investments

Road Safety is a typical field

with high risk of important investments not bringing results

Objective

To provide Road Directors a Best Practice Guide to assist them in their strategic initial choices for infrastructure related investments aiming to improve road safety, through:

- gathering available information in an exhaustive literature review,
- organizing & comparing existing experience based on the investments effectiveness,
- identifying and analysing the most promising sets of investments,
- suggesting the conditions for the optimum implementation of the selected investments.

This Best Practice Guide does not replace the subsequent necessary specific studies for the selection, design and implementation of the measures suitable for each specific case.

Methodology

1. INTRODUCTION

REFERENCES

2. About Cost Effectiveness Assessment of Road Safety Infrastructure Investments

Investments Assessment - A Complex Task

Economic appraisal: important tool in the hands of decision makers but also a complex issue:

- difficulties in isolating the safety effect of a specific investment;

- difficulties in aggregating information/data due to high diversification of the investments;

- difficulties in comparing information/data among countries
    - differences in road traffic environments
    - differences in the actual investment costs among the countries
    - differences in methodologies of safety effect calculation

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.

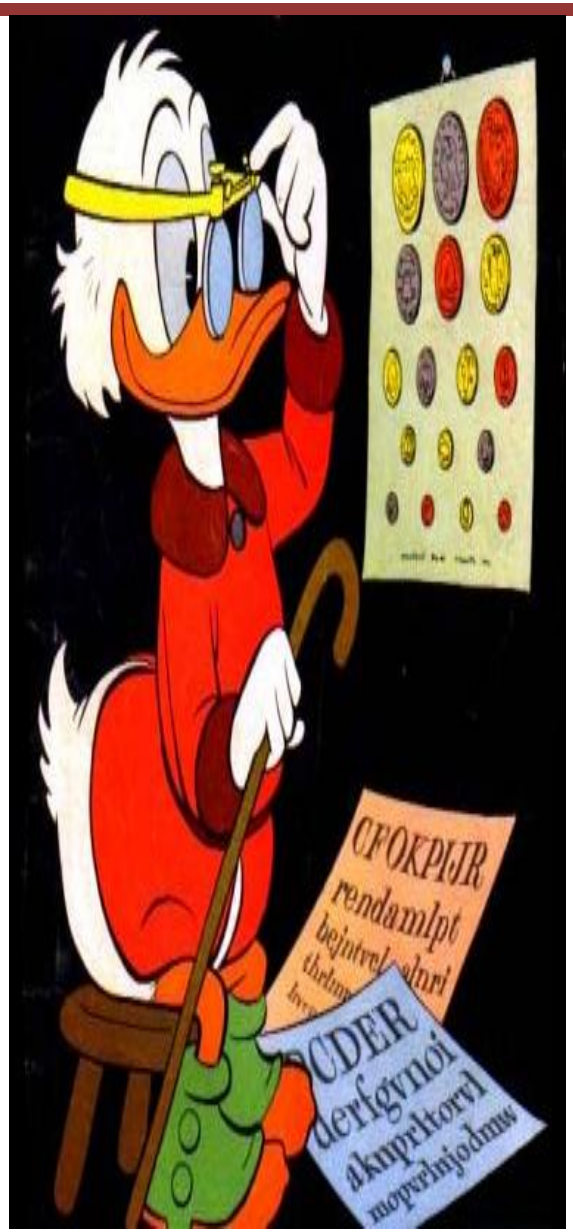
- Definition of suitable **units of implementation** for the investment.

- Implementation costs: **social costs** of all means of production (**labour** and **capital**) employed to implement the investment.

3. Review of Road Safety Infrastructure Investments

Investments Selection Criteria

1. Investments that are **mainly related to road infrastructure**.
2. Investments which are **common among EU countries** and **frequently implemented**.
3. Balance between investments of different **size, implementation cost and scale of implementation**.
4. Investments must be **comprehensive and concise**. A complete description of the basic components for the efficiency assessment of the investment should be available.
5. Investments for which adequate information was **impossible or very difficult to be obtained** are not retained in this Guide, independently of their ad-hoc implementation and assessment in specific cases.



Reference Documents

- CEDR Reports of Roads (*Most Effective Short-, Medium- and Lon-Term Measures to Improve Safety on European Roads*).
- CEDR O7 Questionnaire 1 and Questionnaire 2.
- European and National projects (ROSEBUD, PROMISING, VESIPO, etc.).
- Key publications:
  - R.Elvik, T.Vaa - The Handbook of Road Safety Measures,
  - PIARC - Road Safety Manual,
  - NHTSA - Highway Safety Manual
- An important number of scientific papers, Reports and national studies

Infrastructure Categories & 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

Infrastructure Categories & Investment Areas

- A complete list of 56 examined road safety investments
- Classified according to 15 investment areas, into 4 groups (motorways, rural roads, junctions, urban areas).
- Applied on simple road sections, on bend sections and on junctions, but also in more than one infrastructure elements.

Preliminary review of each road safety investment:

- Description of the investment
- Safety effect of the investment
- Other effects (mobility, environmental etc.)
- Investments costs
- CEA/CBA results

4. Selection of Most Promising Infrastructure Investments

Preliminary Selection of Most Promising Investments

Implementation costs		Safety effect: High	Safety effect: Low
	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

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.

Most Promising Investments for Further Analysis

- **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**

5. In-Depth Analysis of Most Promising Road Safety Infrastructure Investments

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

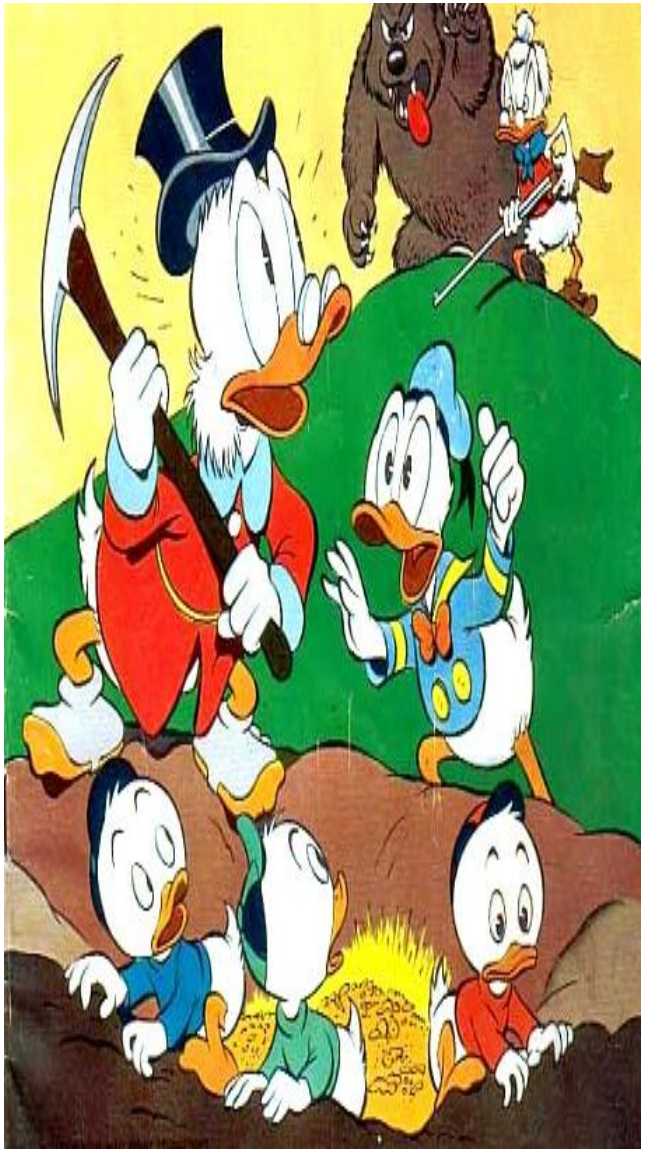
Strengths:
- Significant safety effects on the number of accidents with casualties, but also on accident severity
- Validated cost-effectiveness
- High acceptability by road users

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

Example: Roadside Treatments - Best Practices

- **Roadside treatments** have very positive safety effects
- However, they are not always cost-effective, given that certain treatments present high implementation costs (**clear zones** and side slopes treatments)
- The maximum safety effect may be further increased when various roadside treatments are combined (e.g. clear zones + guardrails)
- **Side slopes**: the steeper the initial slope, the higher the safety effect
- All types of **guardrails** are cost-effective, especially when steel guardrails are implemented along the embankment on rural roads.
- Minimum safety effect of guardrails concerns either wire median guardrails or any type of guardrails implemented on roads with an Average Annual Daily Traffic lower than 3,000 vehicles



6. Proposal of Best Practices

Comparative Overview of Most Promising Investments (1/2)

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

Comparative Overview of Most Promising Investments (2/2)

- 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.

Cost-Effectiveness vs. Safety Effects

- Overall cost-effectiveness is **not always in accordance** to the safety effect of an investment.

- Roundabouts have very high safety effects, which are not directly reflected in the B/C ratios available.
- The B/C ratios of lighting treatments are higher than those of roundabouts, although the safety effects of lighting treatments are much less impressive.
- In this case, a comparison of B/C ratios only might lead to the misleading conclusion that lighting treatments are more efficient than roundabouts.

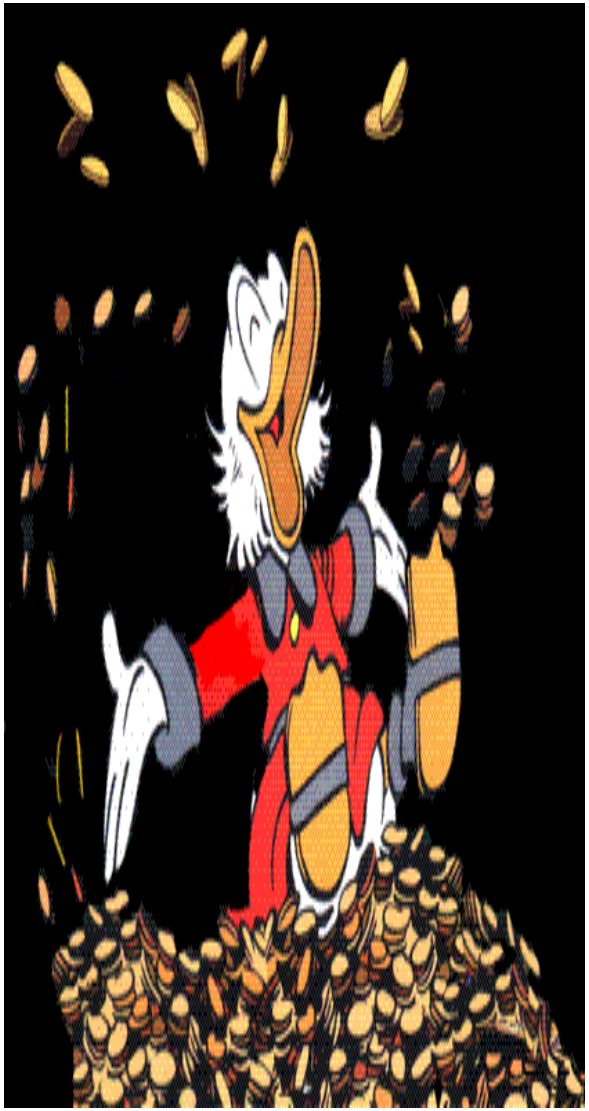
- **It is recommended that Benefit / Cost ratios and safety effects are always examined jointly**, in order to identify the optimal solution for a specific road safety problem in specific conditions and with specific objectives.

Conclusions (1/2)

- The in-depth analysis revealed the **range of safety effects, implementation costs and eventual cost-effectiveness** that can be expected with the most promising investments.

- Given that only statistically significant and well-documented results where taken into account in the above synthesis, the degree of uncertainty is minimized.

- These best practice examples could be optimally used as **an overall guide towards a more efficient planning of infrastructure investments.**



Conclusions (2/2)

- The above ranges of results may not apply in any application of these investments.
- It is always possible that particularities of the setting, the context and the implementation features may bring more or less different results in a different case.
- **Thorough analysis on a case-specific basis** is always required, in order to optimize the implementation of the investment in different countries or areas, according to the extent of the implementation, the implementation period and the specific national or local requirements.