1\textsuperscript{st} IRTAD sub-group meeting

Safety Performance Evaluation of Road Infrastructure

Amsterdam, 17 October 2012

Best Practices on Cost - Effective Road Safety Infrastructure Investments

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Structure of the presentation

1. Introduction

2. About Cost Effectiveness Assessment of Road Safety Infrastructure Investments

3. Review of Road Safety Infrastructure Investments

4. Selection of Most Promising Infrastructure Investments

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

6. Proposal of Best Practices
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

2. ABOUT COST EFFECTIVENESS ASSESSMENT OF ROAD SAFETY INVESTMENTS

3. REVIEW OF ROAD SAFETY INVESTMENTS

4. SELECTION OF MOST PROMISING INVESTMENTS

5. IN-DEPTH ANALYSIS OF MOST PROMISING ROAD SAFETY INVESTMENTS

6. PROPOSAL OF BEST PRACTICES

REFERENCES
2. About Cost Effectiveness Assessment of Road Safety Infrastructure Investments
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 Long-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

<table>
<thead>
<tr>
<th>Safety effect</th>
<th>Implementation costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Development of motorways</td>
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<td></td>
<td>Development of interchanges</td>
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<td></td>
<td>Increasing curve radii</td>
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<td>Introduction of transition curves</td>
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<td>Superelevation treatment</td>
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<td>Reducing gradient</td>
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<td>Improvement of sight distances</td>
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<td>Increasing lane width</td>
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<td>Introduction of shoulder</td>
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<td>Increasing shoulder width</td>
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<td>Introduction of median</td>
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<td>Increasing median width</td>
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<td></td>
<td>Flattening side-slopes</td>
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<td>Establishment of clear zones</td>
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<td>Low</td>
<td>Creation of speed transition zones</td>
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<td>Weather info VMS</td>
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<td>Congestion info VMS</td>
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<td>Individual info VMS</td>
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<td>Ordinary re-surfacing</td>
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<td>Improving friction</td>
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<td>Implementation of artificial lighting</td>
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<td>Introduction of rail/road grade crossings</td>
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<td></td>
<td>Development of roundabouts</td>
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<td></td>
<td>Junctions staggering</td>
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<td></td>
<td>Junctions re-alignment</td>
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<td></td>
<td>Implementation of traffic lights</td>
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<tr>
<td></td>
<td>Traffic calming schemes</td>
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<td></td>
<td>Development of bypasses</td>
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<td></td>
<td>Improvement of land use rules</td>
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<tr>
<td>Low</td>
<td>Reducing the frequency of curves (horizontal)</td>
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<tr>
<td></td>
<td>Reducing the frequency of curves (vertical)</td>
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<td></td>
<td>Superelevation treatment</td>
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<td></td>
<td>Increasing the number of lanes</td>
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<td>Development of 2+1 roads</td>
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<tr>
<td></td>
<td>Increasing median width</td>
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<td></td>
<td>Individual info VMS</td>
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<td></td>
<td>Improving road surface evenness</td>
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<tr>
<td></td>
<td>Improving road surface brightness</td>
</tr>
<tr>
<td></td>
<td>Junctions re-alignment</td>
</tr>
</tbody>
</table>

- Traffic signs (guide)
- Traffic signs (warning)
- Delineators and road markings
- Raised road markers
- Chevrons
- Post-mounted delineators
- Navigation routing
- Implementation of yield signs
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
<table>
<thead>
<tr>
<th>Source</th>
<th>Measure</th>
<th>Description</th>
<th>Country / Region</th>
<th>Road network</th>
<th>Evaluation period</th>
<th>Evaluation method</th>
<th>Safety effect (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEDR (Questionnaire 2)</td>
<td>Guardrails</td>
<td>France</td>
<td>8</td>
<td>-17</td>
<td>-</td>
<td>-</td>
<td>●</td>
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<td>-18</td>
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<td>-</td>
<td>-</td>
<td>●</td>
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<tr>
<td>CEDR (Questionnaire 2)</td>
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<td>The Netherlands</td>
<td>-</td>
<td>-50</td>
<td>-</td>
<td>-</td>
<td>●</td>
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<td>Spain</td>
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<td>-11</td>
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<td>CEDR (Questionnaire 2)</td>
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<td>-</td>
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<tr>
<td>Elvik and Vaa, 2004</td>
<td>Side slopes</td>
<td>Fallen side slope from 1:3 to 1:4 mostly on two-lane roads</td>
<td>USA</td>
<td>-26</td>
<td>-</td>
<td>-</td>
<td>●</td>
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<tr>
<td>Elvik and Vaa, 2004</td>
<td>Side slopes</td>
<td>Fallen side slope from 1:3 to 1:4 mostly on two-lane roads</td>
<td>USA</td>
<td>-29</td>
<td>-</td>
<td>-</td>
<td>●</td>
</tr>
<tr>
<td>Miaou, 1996</td>
<td>Side slopes</td>
<td>Fallen side slope from 1:3 to 1:4 mostly on two-lane roads</td>
<td>USA</td>
<td>-28</td>
<td>s.s.</td>
<td>-</td>
<td>●</td>
</tr>
<tr>
<td>Elvik and Vaa, 2004</td>
<td>Side slopes</td>
<td>Fallen side slope from 1:4 to 1:6 mostly on two-lane undivided roads</td>
<td>USA</td>
<td>-22</td>
<td>(26-27)</td>
<td>-</td>
<td>●</td>
</tr>
<tr>
<td>Elvik and Vaa, 2004</td>
<td>Side slopes</td>
<td>Fallen side slope from 1:4 to 1:6 mostly on two-lane undivided roads</td>
<td>USA</td>
<td>-24</td>
<td>(26-27)</td>
<td>-</td>
<td>●</td>
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<tr>
<td>Miaou, 1996</td>
<td>Side slopes</td>
<td>Fallen side slope from 1:4 to 1:6 mostly on two-lane undivided roads</td>
<td>USA</td>
<td>-24</td>
<td>s.s.</td>
<td>-</td>
<td>●</td>
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<td>Allare et al., 1996</td>
<td>Side slopes</td>
<td>Fallen side slopes</td>
<td></td>
<td>60 projects</td>
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<td>-</td>
<td>●</td>
</tr>
<tr>
<td>Elvik and Vaa, 2004</td>
<td>Guardrails on embankments</td>
<td>USA, Australia, Sweden</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Elvik and Vaa, 2004</td>
<td>Changing to softer guardrails</td>
<td>USA, Australia, Sweden</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Elvik and Vaa, 2004</td>
<td>Median guardrails on divided highways</td>
<td>USA, G.Britain, France, Sweden, Denmark</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Elvik and Vaa, 2004</td>
<td>Median guardrails on divided highways</td>
<td>USA, G.Britain, France, Sweden, Denmark</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Carlsson et al., 2001</td>
<td>Guardrails</td>
<td>Sweden</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cotthen et al., 1997</td>
<td>Clear zone</td>
<td>Marking of roadside obstacles</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Zeeger et al., 1988</td>
<td>Clear zone</td>
<td>Increase of the roadside clear recovery distance on two-lane rural roads</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ROSEBUD, 2005</td>
<td>Clear zone and guardrails</td>
<td>Setting up guardrails and cutting trees</td>
<td>France</td>
<td>26.5 km of road</td>
<td>1993 - 2003</td>
<td>-</td>
<td>●</td>
</tr>
</tbody>
</table>

s.s: statistically significant
**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
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
• **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)

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

* on target injury accidents

n/a: not available
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.
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.