



**IRF WORLD ROAD
MEETING 2017**

/ 14-17 NOVEMBER / DELHI / INDIA /

"Safe Roads and Smart Mobility : The Engines of Economic Growth"

**CROSS/
ROADS**

Road Network Safety Management based on Safety Inspection

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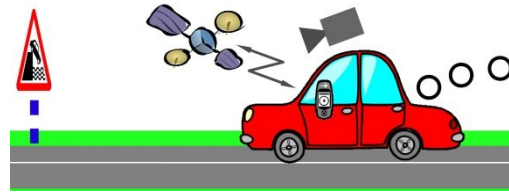
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Presentation Outline

- Introduction and background

- Safety Inspection (SI)



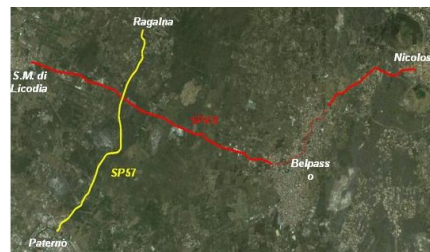
- Risk Index (RI)



- Road Network Safety Management



- Case Study





Road Network in Operation



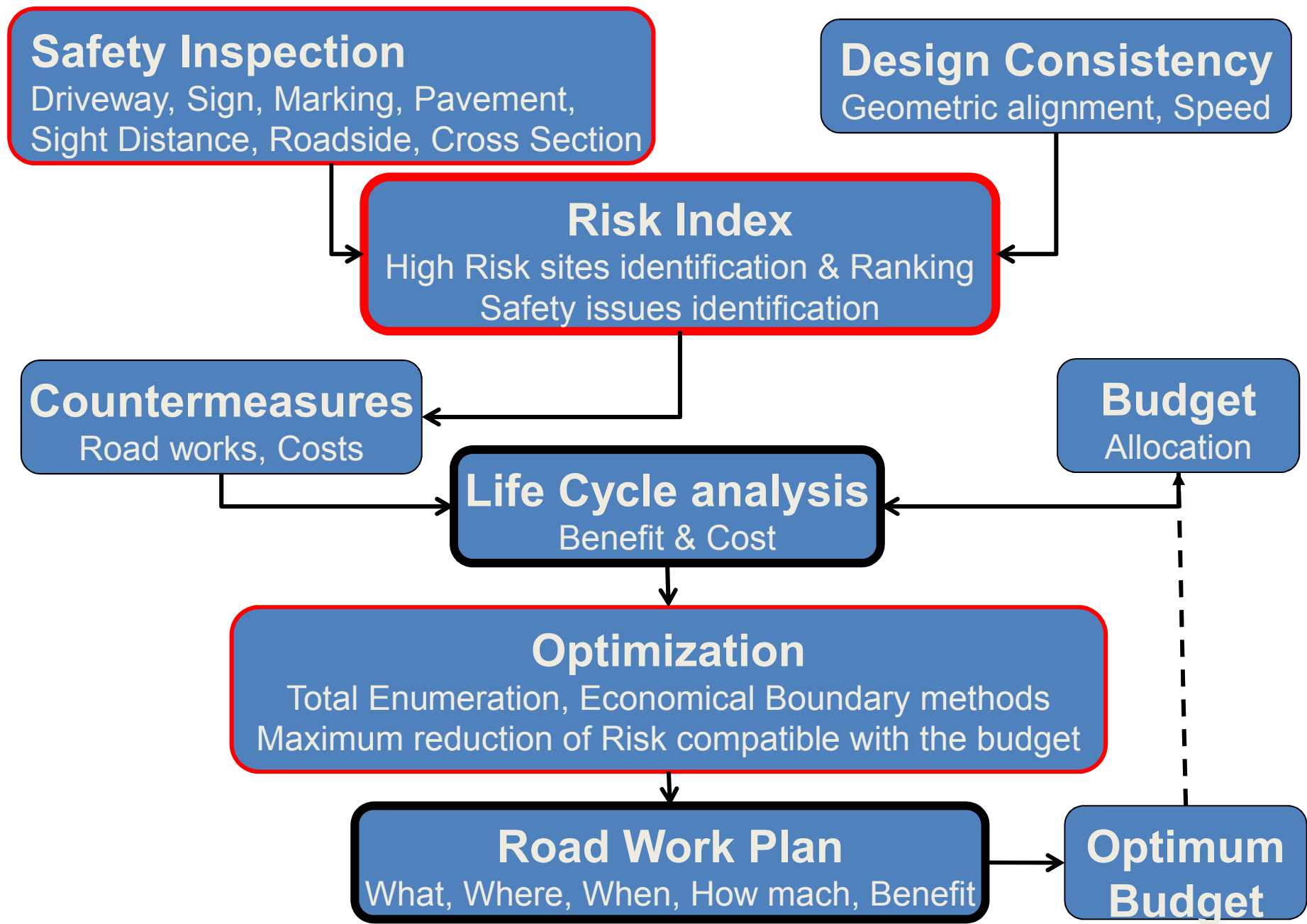
EU Directive states:

*“... Once road sections with a **high accident concentration** have been treated and remedial measures have been taken, **safety inspections** as a preventive measure should assume a more important role.*

Road safety inspection: “an ordinary periodical verification of the characteristics and defects of an operational road that require maintenance work for reasons of road safety”.

*“Regular **inspections** are an essential tool for preventing possible dangers for all road users, including vulnerable users, and also in case of roadworks”*

Safety Management of road network using SI



SAFETY INSPECTION Practice - Technics

Safety – Accuracy - Equipment Cost – Productivity
Pros - Cons!

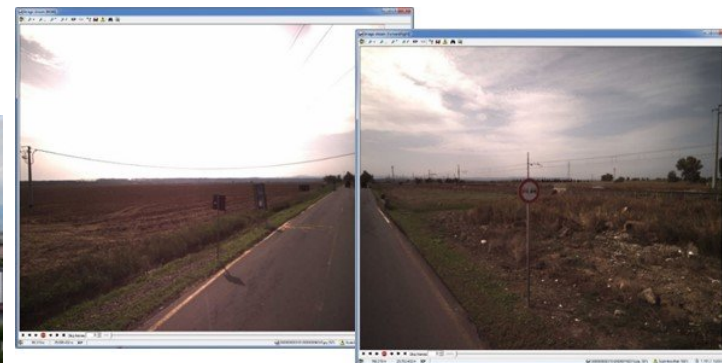
In field inspection by hand



In field Inspection Supporting tools



Virtual Inspection Automated



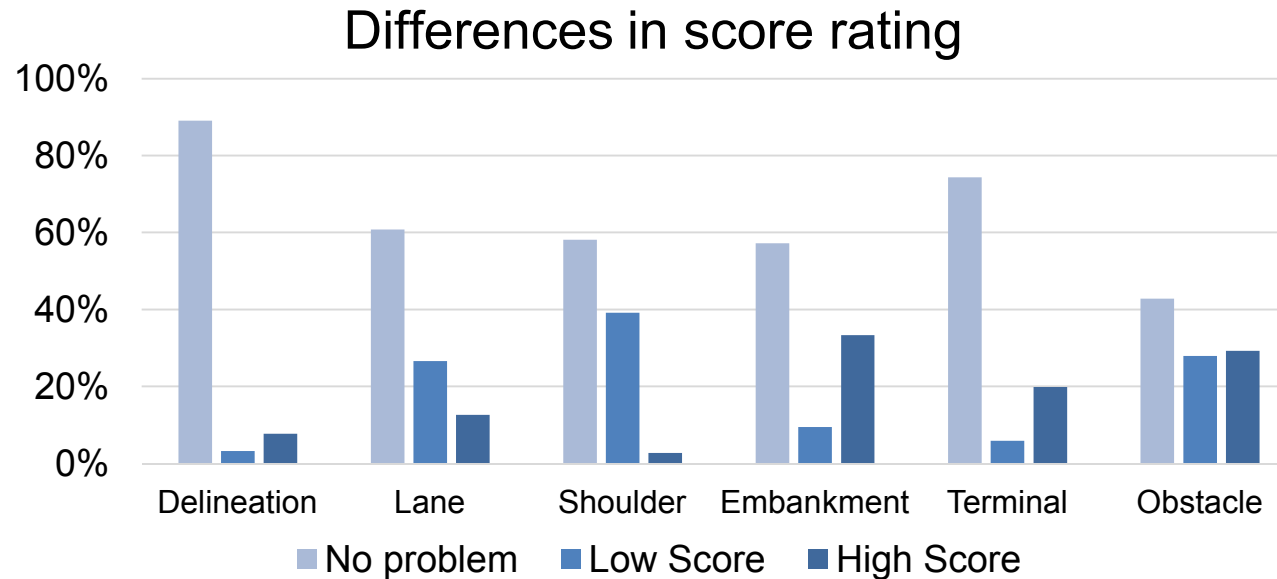
Front
view



Rear
view

In field vs. Digital vision for safety issues scoring

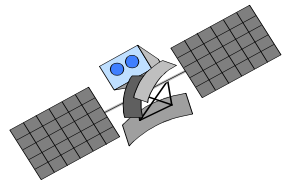
k statistics and p-values of agreement between the two procedure



Safety issues	k	Significance
Roadside: embankments	-0.073	0.032
Roadside: dangerous terminals and transition	-	Insignificant data
Roadside: obstacles	0.118	0.012
Cross section: lane width	-0.043	0.376
Cross section: shoulder width	0.175	0.000
Delineation: chevrons	0.108	0.022

[note: not in the paper; preliminary un-published results]

Safety Inspection Software Tools & Vehicle Equipment



TABLET 1

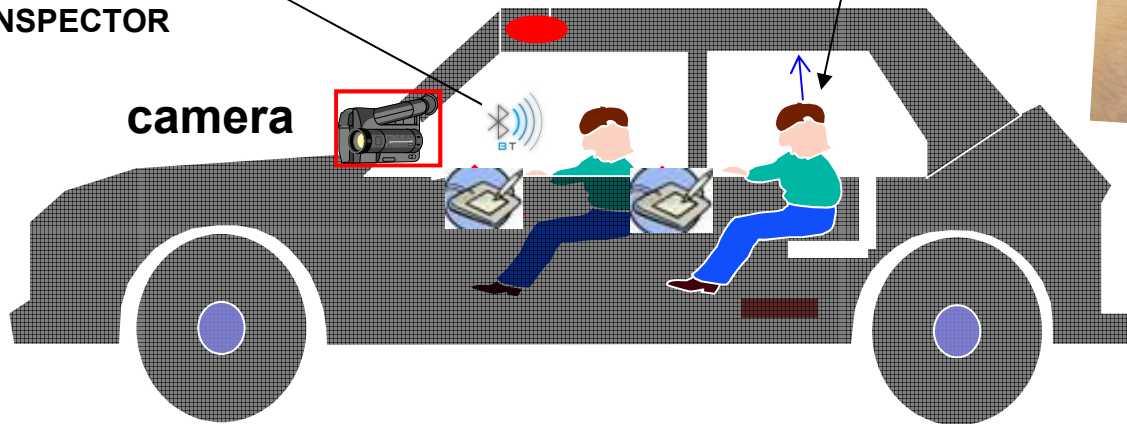
FRONT SEAT INSPECTOR

camera



GPS

TABLET 2
BACK SEAT INSPECTOR



Front Seat Inspector

StreetSheets

S.P. 57 (Sheet 0) (0-100) Stop

✓ Calibration complete

Satellite: Excellent

GPS: connected

Time: [Progress Bar]

Roadside

- Embankments (0, 1, 2)
- Bridges (0, 1, 2)
- Dangerous terminals and transitions (0, 1, 2)
- Trees, utility poles and rigid obstacles (0, 1, 2)
- Ditches (0, 1, 2)

Accesses

- Dangerous accesses (0, 1, 2)
- Presence of accesses (0, 1, 2)

Alignment

- Inadequate sight distance on horizontal curve (0, 1, 2)
- Inadequate sight distance on vertical curve (0, 1, 2)

Active Sheets: 0 Next Sheet



Tablet

Android App

Inspection and GPS Data are stored and synchronized with video recording in both directions

Check list automatically change after reaching the fixed length of the section (eg. 200 m). Inspector can fill, stop, review, insert notes during the inspection.

3 Scores

0 = no problem

1 = Low Score

2 = High Score

Rear Seat Inspector

StreetSheets

Sample 12345 (Sheet 0) (0-200) Stop

✓ Calibration complete

Satellite: Excellent

GPS: connected

Time: [Progress Bar]

Markings

- Edge lines (0, 1, 2)
- Center line (0, 1, 2)

Cross section

- Lane width (0, 1, 2)
- Shoulder width (0, 1, 2)

Pavement

- Friction (0, 1, 2)
- Unevenness (0, 1, 2)

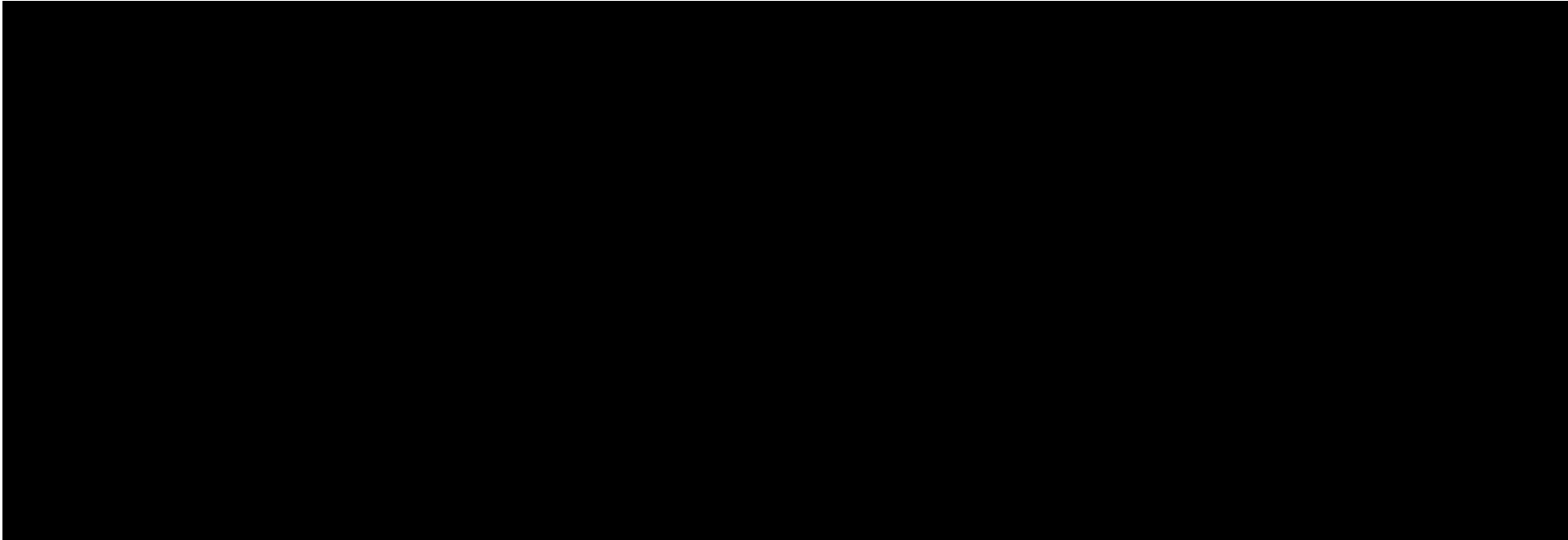
Signs

- Warning signs, regulation signs (0, 1, 2)

Delineation

- Chevrons (0, 1, 2)
- Guideposts and barrier reflectors (0, 1, 2)

Active Sheets: 0 Next Sheet



Example of Safety Issues Ranking



- EMBANKMENTS

- **High Score Problem**

- Unshielded or shielded with ineffective barriers embankments ($h > 5$ m)
 - Unshielded or shielded with ineffective barriers embankments with great slope ($h > 3$ m)
 - Embankments shielded with low containment safety barrier with great slope ($h > 3$ m)
 - Dangerous obstacles in the bottom

EMBANKMENTS
High Score Problem



Example of Safety Issues Ranking

- EMBANKMENTS

- **Low Score Problem**

- Unshielded or shielded with ineffective safety barriers embankments with great slope ($1 < h \leq 3$ m)
 - Embankments shielded with low containment safety barrier ($h > 3$ m) if high commercial vehicles traffic is present
 - Embankments shielded with discontinuous barriers ($h > 3$ m)

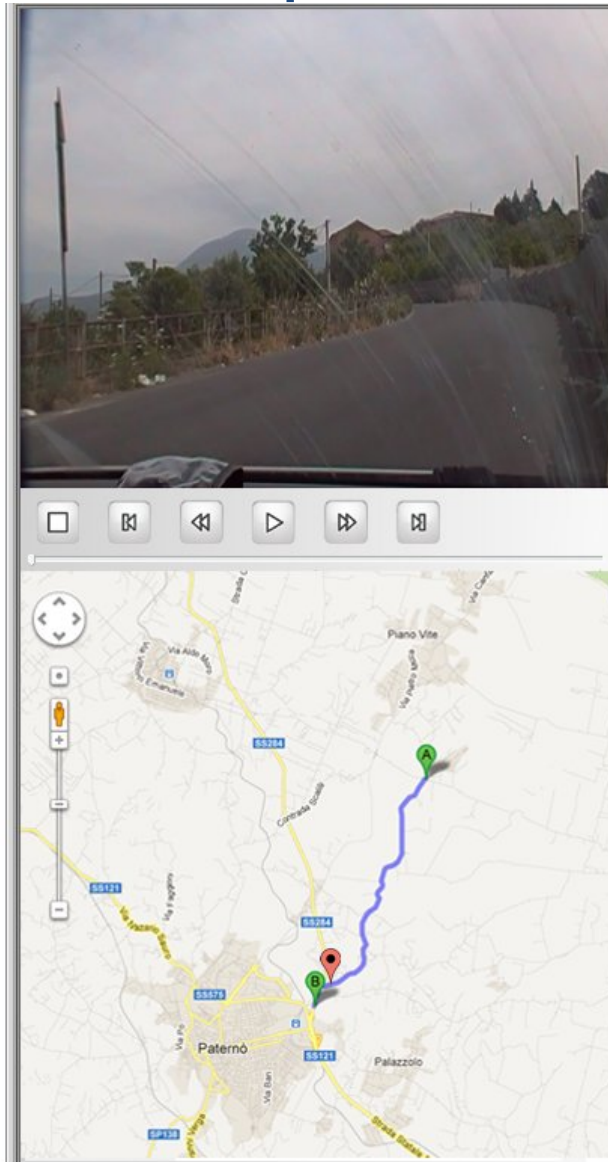
EMBANKMENTS **Low Score Problem**



In the Office

After in field Safety Inspection, Checklists are reviewed in the office by the Inspection Team (Review software)

- Sheet 1
- Sheet 2
- Sheet 3
- Sheet 4
- Sheet 5
- Sheet 6
- Sheet 7
- Sheet 8



Sheet 2 (200 - 400)

Roadside

- Embankments 0 1 2
- Bridges 0 1 2
- Dangerous terminals and transitions 0 1 2
- Trees, utility poles and rigid obstacles 0 1 2
- Ditches 0 1 2

Accesses

- Dangerous accesses 0 1 2
- Presence of accesses 0 1 2

Alignment

- Inadequate sight distance on horizontal curve 0 1 2
- Inadequate sight distance on vertical curve 0 1 2



Road Safety Ranking & Management

Why can't the Road Agencies select always the best solution recommended by Inspectors and can't they apply the best treatments in all the sections at high risk in the network?

We have not enough money!



After assessment

We need to rank and prioritize

Safety Risk Index



EUROPEAN RESEARCH PROJECT

IASP: “Identification of Hazard Location and Ranking of Measures to Improve Safety on Local Rural Roads”

$$\text{Risk Index} = \underbrace{\text{Exposure} \times \text{Frequency}}_{\text{Crash Number}} \times \underbrace{\text{Severity}}_{\text{Crash Severity}}$$

Exposure: exposure of road users to road hazards (Traffic volume, Segment Length)

Frequency: likelihood of crash occurrence (**Safety Inspection (SI)**: Sign, Marking, Delineation, Cross section, Pavement, Driveway, Sight Distance + **Design Consistency**: horizontal alignment)

Severity: crash consequence (**SI**: Roadside Hazard + **Operating Speed**)

Safety Index – Model Structure

$$\text{RISK} = \text{Exposure} \times \text{Frequency} \times \text{Severity}$$

$$\text{RI} = L \times \text{AADT} \times \text{RSI AF} \times \text{GD AF} \times \left(\frac{V_{85}}{V_{\text{base}}} \right) \times \text{RSI AS}_{\text{roadside}}$$

EXPOSURE

L = length of the segment under consideration [km];

AADT = average annual daily traffic [vehicles per day];

FREQUENCY

RSI AF = Safety Inspection factors (Cross Section, Accesses, Sight distance, Delineation, Signs, Markings, Pavement);

GD AF = Geometric Design Consistency factor;

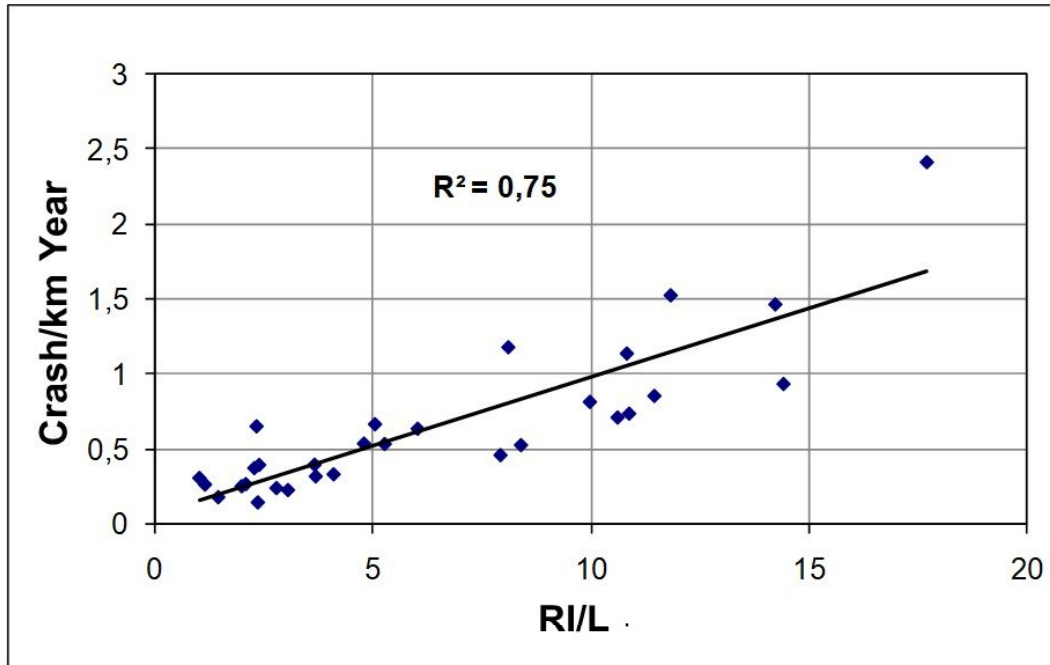
SEVERITY

V₈₅ = average 85th percentile of speed along the segment (weighted to element length);

V_{base} = base operating speed for two-lane local rural roads (assumed equal to the design/posted speed);

RSI AS_{roadside} = Roadside Accident Severity factor (SI)

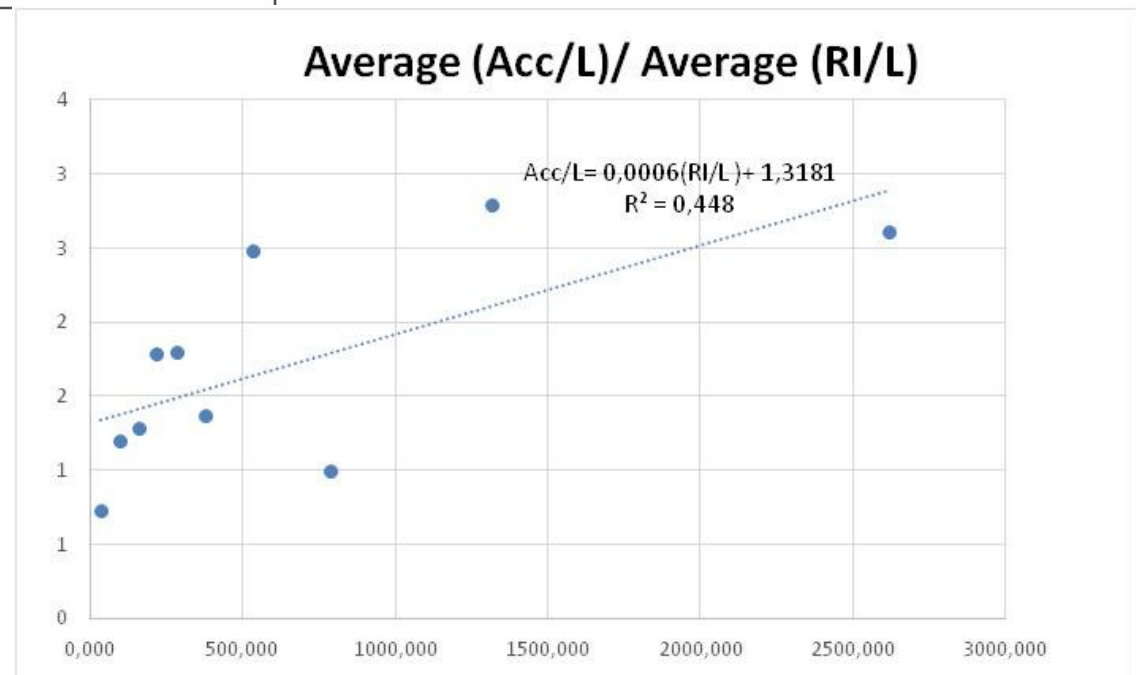
Model Validation & International Transferability



Italy - 2005

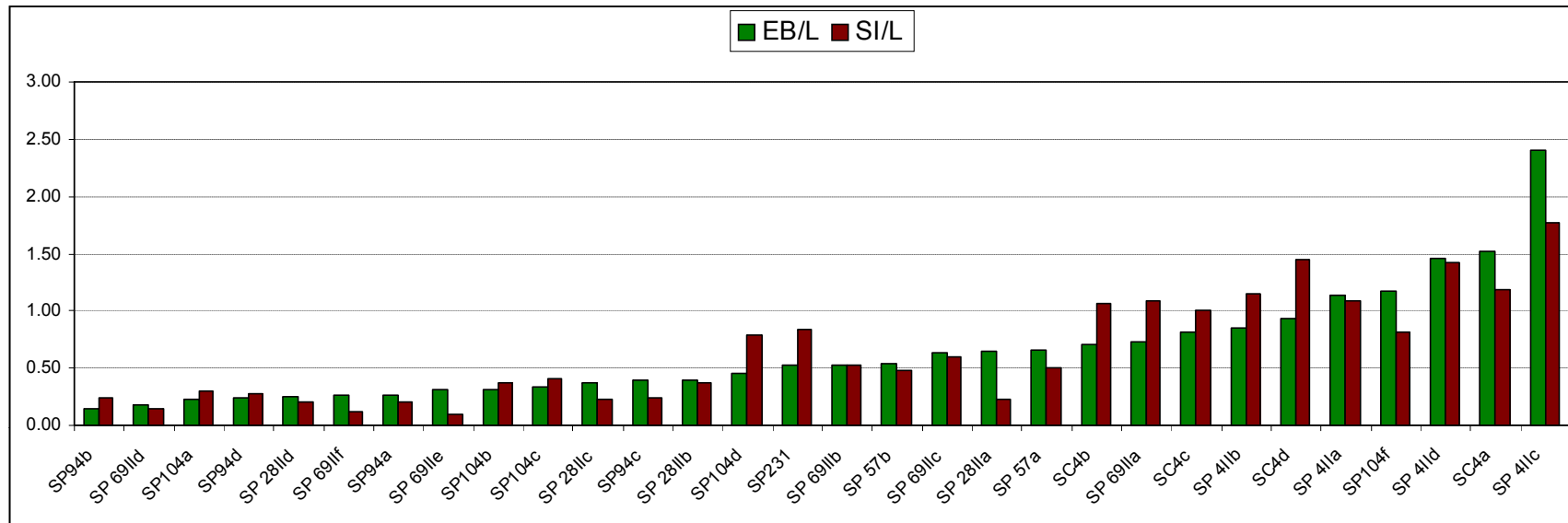


Poland - 2015



VALIDATION OF THE PROCEDURE

Comparison between crash rank vs. Risk Index rank



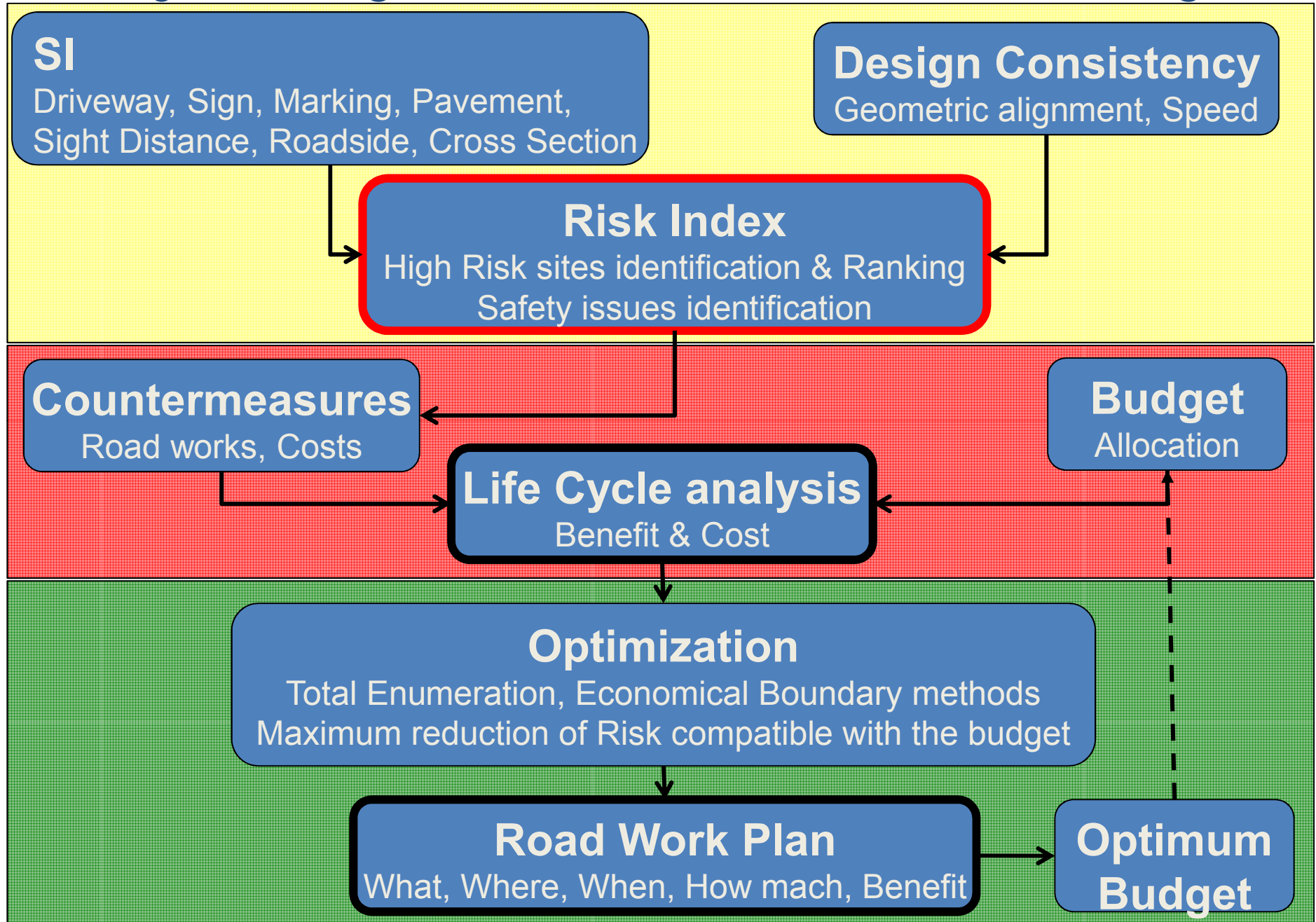
Statistics

(Spearman rank correlation)

$\rho = 1 - 6 \times \sum D_i^2 / [N \times (N^2 - 1)]$ Spearman's rank correlation coefficient

$\rho = 0.87 \div$ level of significance $> 99\%$

Safety Management of road network using SI



PROJECT LEVEL: Roadwork Plan

when - where - what - how much - benefit

Year	Section	Length (km)	Intervention	Cost	SI _{network}	ΔSI _{network}
0	2	0.60	I.1 - I.3 - A.1 - A.4	€ 37000		
0	4	0.60	B.3 - B.2 - D.1 - D.2 - H.1	€ 41978	161.5	39.7 (-19.7%)
0	5	0.60	B.3 - D.1 - D.2 - H.1	€ 27559		
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1	3	0.38	B.2 - B.3 - D.1 - D.2 - H.1	€ 20756		
1	7	0.60	B.2 - B.3 - D.1 - D.2 - H.1	€ 15745	144.0	62.8 (-30.4%)
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1	24	0.55	I.1 - A.4 - A.1	€ 12750		
2	1	0.60	I.3 - A.1	€ 36414		
2	11	0.60	B.2 - B.3 - D.1 - D.2 - H.1	€ 16758	134.5	77.1 (-36.4%)
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2	28	0.60	B.1 - B.3 - D.1 - D.2 - H.1	€ 58160		
3					136.4	80.7 (-37.2%)
4					141.9	81.6 (-36.5%)
5					145.6	83.9 (-36.6%)
6					145.8	87.8 (-37.6%)
7					148.2	87.7 (-37.2%)
8					151.0	87.3 (-36.6%)
9					151.0	89.7 (-37.3%)

Budget = 1 ML €
(77 ML ?)



B/C = 3/1

Total Risk after 10 years if optimal solution is applied: 151.0 (- 37.3%)

Benefit = 15 severe crashes less (1 fatality + 26 injured people) = 3 ML €

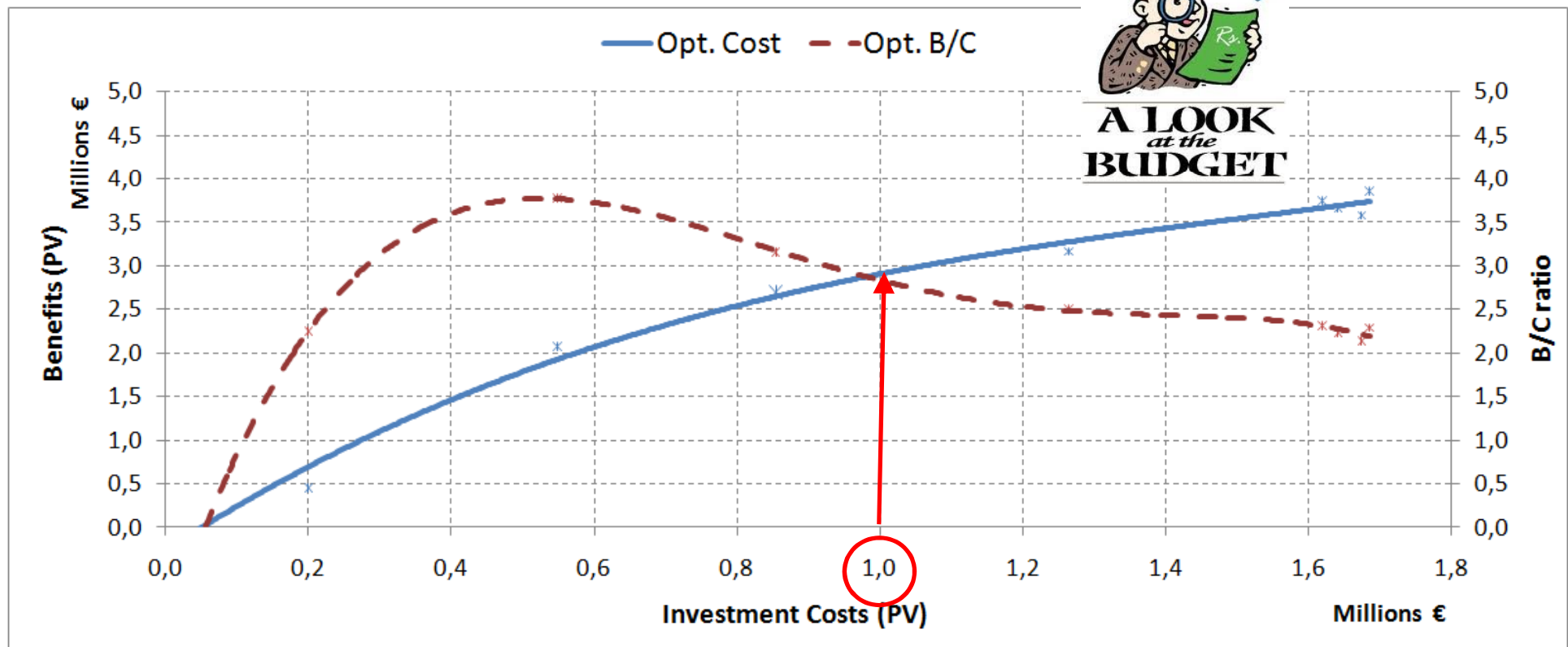
PROGRAM LEVEL

Optimum budget allocation

By varying the budget it is possible to analyze the expected benefits and benefit/cost ratio in the management period (10 years)



**A LOOK
at the
BUDGET**



Remarks & Recommendations

- # EU Directive and International practice require the establishment and implementation of procedures for the Safety Management of Road Network and Safety Inspections by the Road Agencies
- # Digital images can support SI, but in field identification and ranking are also useful. Software tools and low cost equipment can improve quality, productivity and inspectors' safety during in field SI.
- # SIs for their qualitative nature are not able to define a priority ranking and a management program for maximizing the benefit/cost ratio of treatments at network level
- # Risk Index makes it possible to rank sections and to identify the countermeasures that produce the greatest benefits in terms of safety
- # Using the optimization process the best countermeasures under budget constrains can be selected and different management policies compared
- # Clear model structure of RI based on the state of the art and published references facilitate the international transferability of the procedure

Thank you for your attention !



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