European Road Safety Partnership - Network Wide Road Safety Assessment
KA220-HED - Cooperation partnerships in higher education
Form ID: 2023-1-PL01-KA220-HED-000156844



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EUROPEAN ROAD SAFETY PARTNERSHIP

NETWORK WIDE ROAD SAFETY ASSESSMENT

SPRING SCHOOL – WEIMAR 25-27 MARCH 2026
PROACTIVE APPROACH – RISK ASSESSMENT

GDAŃSK UNIVERSITY OF TECHNOLOGY

Università di Catania

Bauhaus-Universität Weimar

Sveučilište u Zagrebu

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NETWORK WIDE ROAD SAFETY ASSESSMENT

Proactive Approach
Risk Assessment

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Directive 2019/1936/EC

Article 5 Network-wide road safety assessment

- Member States shall ensure that a **network-wide road safety assessment** (**NWRSA**) is carried out on the **entire road network** in operation covered by this Directive.
- Network-wide road safety assessments shall evaluate **accident and impact severity RISK**, based on:
  (**Proactive** - a) primarily, a **visual examination**, either on site or by electronic means, of the design characteristics of the road (in-built safety);
  (**Reactive** - b) an analysis of sections of the road network which have been in operation for more than three years and upon which a large number of **serious accidents** in proportion to the traffic flow have occurred.
- In carrying out the network-wide road safety **assessment**, Member States may take into account the indicative elements set out in **Annex III**.

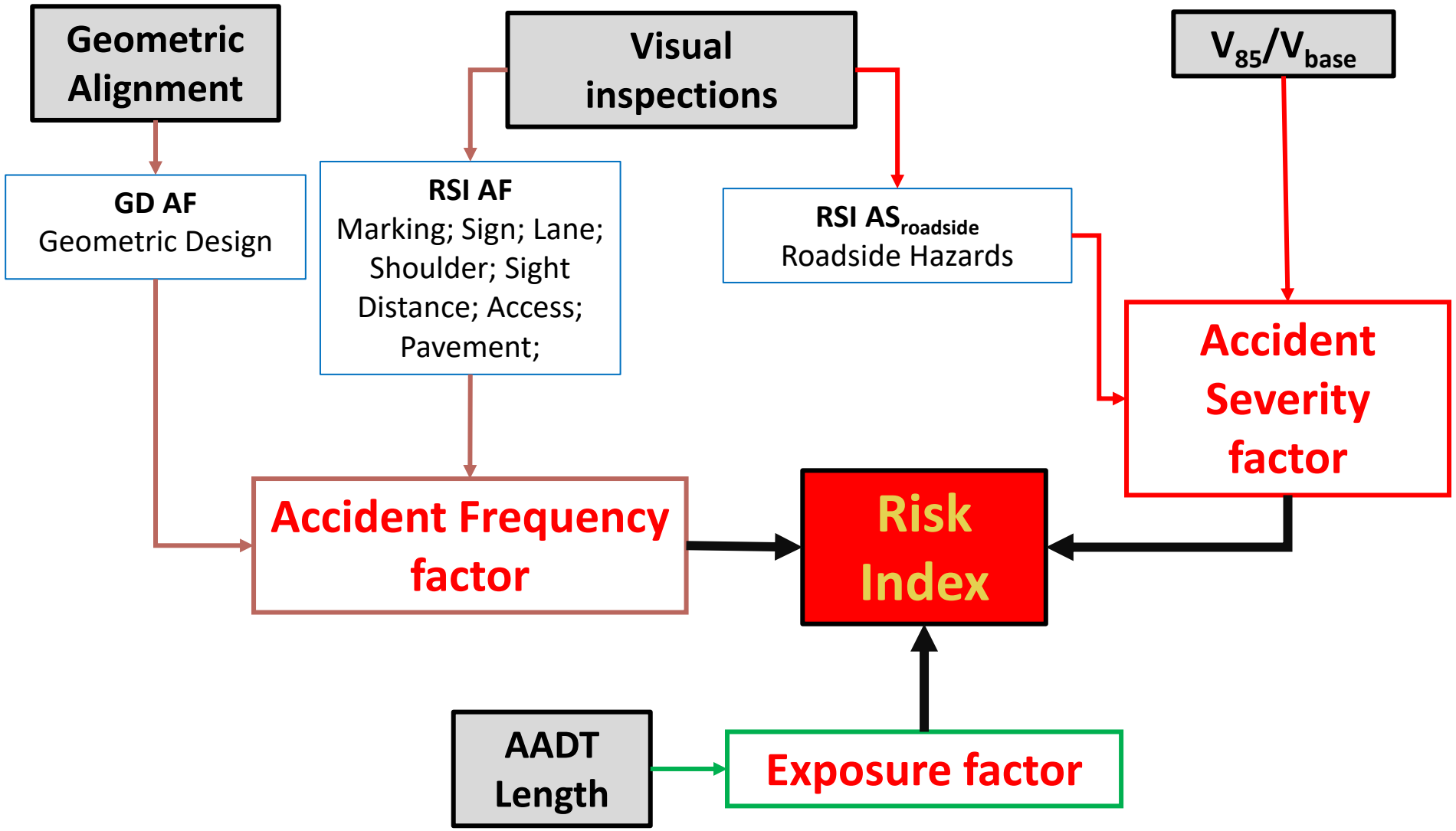
Risk Index: definition

- The Proactive Risk Index (RI) measures the relative safety performance of a road segment
- **RI** is formulated by combining the three components of risk

RISK = Exposure x Likelihood x Severity

1) **EXPOSURE** of road users to road hazards (Exposure factor)
2) **LIKELIHOOD** of a vehicle being involved in an accident (Accident Frequency factor)
3) **SEVERITY** should an accident occur (Accident Severity factor)

Proactive Risk Index: model framework



Risk Index model and formulas

CONTENTS

1) Risk Index model and formulas
2) Pilot studies & validation
3) Example of application
4) References

Risk Index Model

$$\text{Exposure factor} \times \text{Accident Frequency factor} \times \text{Accident Severity factor}$$

$$\text{Exposure factor} = L \times AADT$$

L = length of the segment under consideration (km)

AADT = average annual daily traffic [(1,000 vehicles per day)]

$$\text{Accident Frequency factor} = \text{RSI AF} \times \text{GD AF}$$

RSI AF = Road Safety Inspection Accident Frequency factor

GD AF = Geometric Design Accident Frequency factor

$$\text{Accident Severity factor} = \left(\frac{V_{85}}{V_{base}}\right) \times \text{RSI AS}_{roadside}$$

V_{85} = average 85th percentile of speed along the segment (weighted to element length)

V_{base} = base operating speed for two-lane, local, rural highways (assumed equal to the legal speed limit of 90 km/h)

$\text{RSI AS}_{roadside}$ = Roadside Accident Severity factor of the segment

Exposure Factor

It measures the exposure of road users to road hazards, i.e., how many vehicles travel and how long the trip is.



EXPOSURE = L × AADT

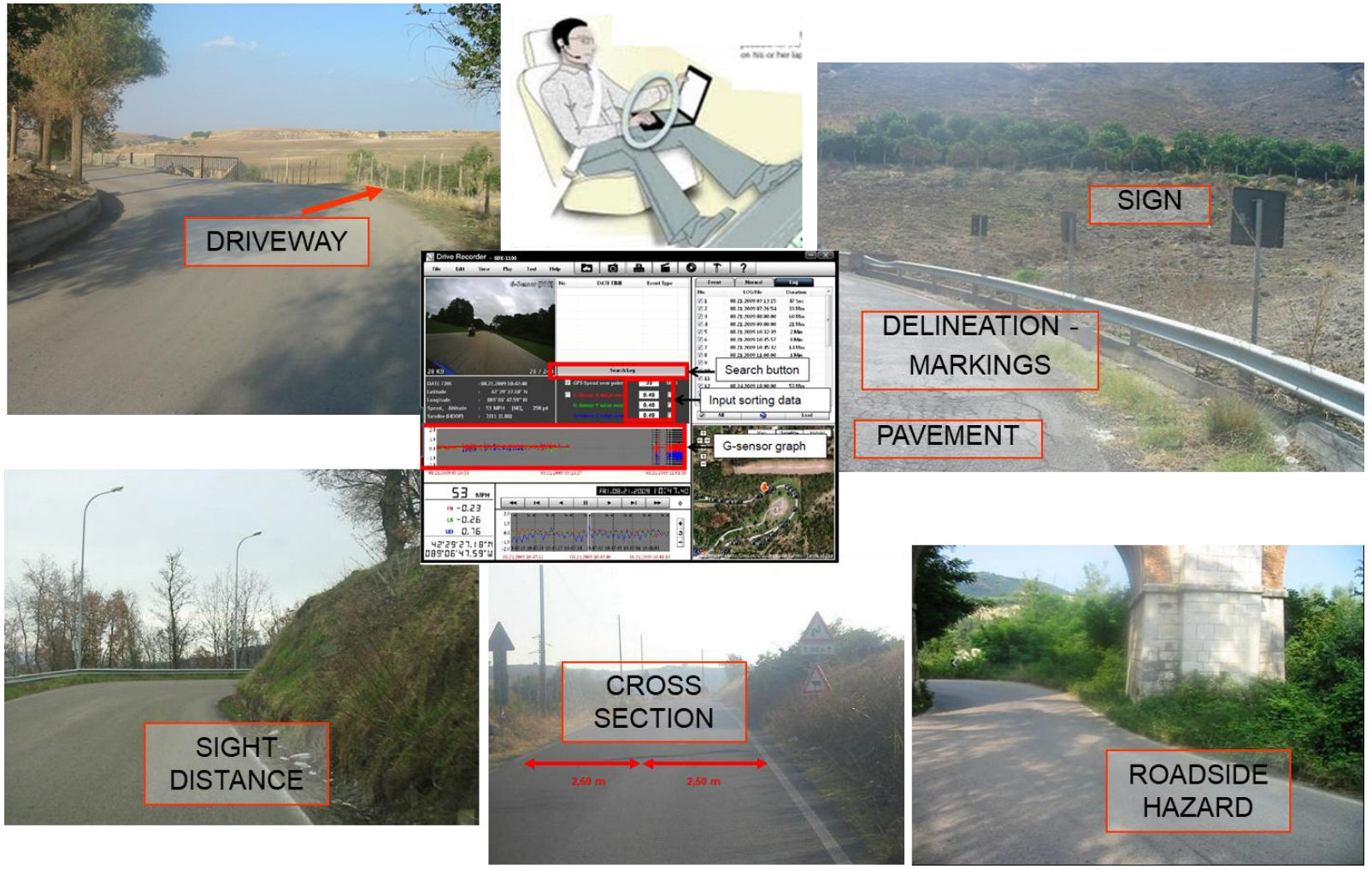


L = Length of the segment under consideration (km)

AADT = Average Annual Daily Traffic (veh/day)

Visual Inspection

Examples of Safety Issues identified by Visual Inspection



Safety Issues and *data sources*

1) Sign, Marking, Access, Sight distance, Roadside Hazard

Visual Inspection

2) **Pavement**

Road Inventory/Visual Inspection

3) Cross-section

Road Inventory/Visual Inspection

4) Horizontal alignment Design Consistency

Road Inventory/Network Map

Visual Inspection

MODULE FOR FRONT-SEAT INSPECTOR								
Roadside					Accesses		Alignment	
Embankments	Bridges	Dangerous terminal and transitions	Trees, utility poles and rigid obstacles	Ditches	Dangerous accesses	Presence of accesses	Inadequate sight distance on horizontal curve	Inadequate sight distance on vertical curve

MODULE FOR BACK-SEAT INSPECTOR								
Markings		Cross sections		Pavement		Signs	Delineation	
Edge lines	Center lines	Line width	Shoulder width	Friction	Unevenness	Warning signs, regulation signs	Chevrons	Guide posts and barrier reflectors

Visual Inspection

- Checklists are filled in by two inspectors for both directions of the road, with a step of 200 m (two-lane rural roads)

- A score (S_{Jk}) is assigned at each item (k) considered in the Safety issue (J), ranked as:
  - high problem: score equal to **(2)**
  - low problem: score equal to **(1)**
  - no problem: score equal to **(0)**

Accident Frequency factor (AF)

formula

- For each safety issue j the related Accident Frequency factor (AFj) is computed

$$AF_j = 1 + WS_j \times \Delta AF_j \times P_j$$

ΔAFj = estimated relative increase in accident risk due to the issue j

Pj = proportion of accidents typologies affected by the issue j

WSj = Average Weighted score

Accident Frequency factor
average weighted score

- Average Weighted Score of each safety issue j (WS_j), ranging from 0 to 2, is computed

$$WS_j = \frac{1}{2 \times m_j} \sum_{k=1}^{m_j} S_{kj}$$

S_{kj} = score of the detailed Item k in the safety issue j

m_j = number of detailed issues associated with the issue j

2 = factor to take both directions into account

Accident Frequency factor

related accident typologies

accident risk ΔAFj

j	Safety Issue	Related Accidents	ΔAF (%)
1	Accesses	All	1.35
2	Cross section	Run off the road Head-on Sideswipe	0.15 – 1.00 f(AADT)
3	Delineation	All	0.30
4	Markings	All	0.20
5	Pavement	All	0.10
6	Roadside	Run off the road	2.00
7	Sight distance	All	0.50
8	Signs	All	0.20

Type of accidents	Pj (%)
Head on	17,8
Side on	13,6
Rear end	7,6
Run off the road	57,6
other	4,2
All	100

Accident Frequency factor
overall estimation

- The cumulative influence of all the safety issues j is assessed by a multiplicative composition

- Accident Frequency factor from the visual safety Inspection (RSI) is computed as:

$$\text{RSI AF} = \prod_{j=1}^{\ell} \text{AF}_j$$

ℓ = number of safety issues, equal to 8 in the model

Accident Frequency factor
Geometric Design

$$GD\ AF = 1 + S_{GD} \times \Delta AF_{GD} \times P_{GD}$$

S_{GD} = score of the safety issue GD

ΔAF_{GD} = **7** : relative increase in accident risk due to GD

P_{GD} = proportion of accidents affected by GD

S_{GD} scores:

Curved Elements		Tangents		Related Accidents
Good	0.4	Overall Standards Check	0.0	Run off the road
Fair	1.0	Minimum Length	0.2	Partially (50%):
Poor	2.0	Maximum length	0.2	Head-on
				Same direction and opposite direction sideswipe

Geometric Design Accident Frequency factor

- Curves
  - Design consistency evaluation
- Tangents
  - Minimum critical tangent lenght
    - V_d = 60 km/h ⇨ TL_{min} = 50 m
    - V_d = 80 km/h ⇨ TL_{min} = 90 m
    - V_d = 100 km/h ⇨ TL_{min} = 150 m
  - Maximum critical tangent lenght
    - $TL_{max} = 22 \times V_d$ (e.g. V=100 km/h → TL_{max}=2200 m)

Geometric Design Accident Frequency factor

- Design consistency evaluation
  - A consistent highway design ensures that successive elements are coordinated in such a way as to produce harmonious and homogeneous driver performances along the road
  - Practice highlights that an alignment with inconsistencies requires drivers to handle speed gradients in order to drive safely on certain alignment elements

Geometric Design Accident Frequency factor

- Design consistency evaluation
  - Design consistency evaluates an the Safety defining three design classes: **poor**, **fair**, **good**.

operating speed consistency, related to the difference in V_{85}, between two successive geometric elements

GOOD	FAIR	POOR
$V85_{i+1}$-$V85_i \leq 10$ km/h	$10<V85_{i+1}$-$V85_i \leq 20$ km/h	$V85_{i+1}$-$V85_i > 20$ km/h

Accident Severity factor

Formula

- The Accident Severity factor for is computed as

$$Accident_Severity_factor = \left(\frac{V_{85}}{V_{base}}\right)^{n} \times \text{RSI AS}_{roadside}$$

V_{85} = average 85th percentile of speed along the segment (weighted to element length)

V_{base} = Safe speed for two-lane, local, rural highways (assumed equal to the posted speed limit)

n = 1 (can be increased to enhance severity vs. frequency)

$\text{RSI As}_{roadside}$ = Roadside Accident Severity factor of the segment

Roadside Accident Severity factor

Formula

$$\text{RSI AS}_{\text{roadside}} = 1 + \text{WS}_{\text{roadside}} \times \text{P}_{\text{roadside}} \times \text{DAS}_{\text{roadside}}$$

$\text{WS}_{\text{roadside}}$ = weighted score of the roadside safety issue

$\text{P}_{\text{roadside}}$ = proportion of accidents related to the roadside issue, equal to the proportion of run off the road accidents

$\Delta\text{AS}_{\text{roadside}}$ = estimated relative increase in accident severity due to the issue j (2)

$$WS_j = \frac{1}{2 \times 5} \sum_{k=1}^{5} weight_k \times S_k$$

S_k = score of the roadside safety items k

Weight_k = relative weight of the roadside safety item k

5 = Number of detailed safety issues

Roadside Accident Severity factor

K	Detailed Safety Issue	Relative Weight
1	Embankments	**3**
2	Bridges	**5**
3	Dangerous terminals and transitions	**2**
4	Trees, utility poles and rigid obstacles	**2**
5	Ditches	**1**

RISK Index

$$RI = Exposure_factor \times Accident_Frequency_factor \times Accident_Severity_factor$$

$$RI = [L \times AADT] \times [RSI\ AF \times GD\ AF] \times \left[\left(\frac{V_{85}}{V_{base}}\right)^{n} \times RSI_{AS_{roadside}}\right]$$

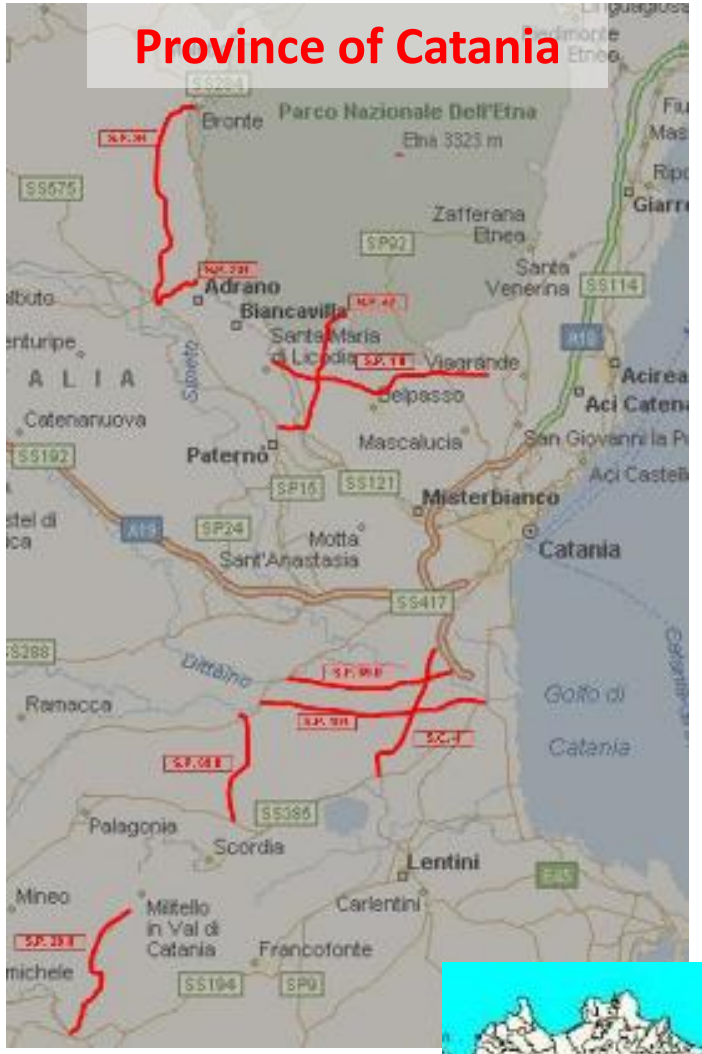
Safety Iusses	Related Accident	Pj	ΔAFj	m_j
Accesses	All	1,000	***1,35***	***2***
Cross section	Run off the road head On Side On	0,890	***1,00***	***2***
Delineations	All	1,000	***0,30***	***2***
Markings	All	1,000	***0,20***	***2***
Pavement	All	1,000	***0,10***	***2***
Alignment	All	1,000	***0,50***	***2***
Signs	All	1,000	***0,20***	***1***
Roadside	Run off the road	0,576	***2,00***	***5***
Geometric Design	RoR + 50% head On Side On	0,733	***7,00***	***1***

Pilot studies & validation

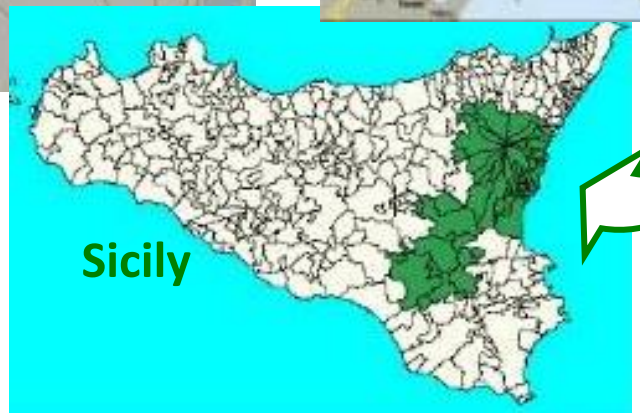
TEST & VALIDATION

ITALY

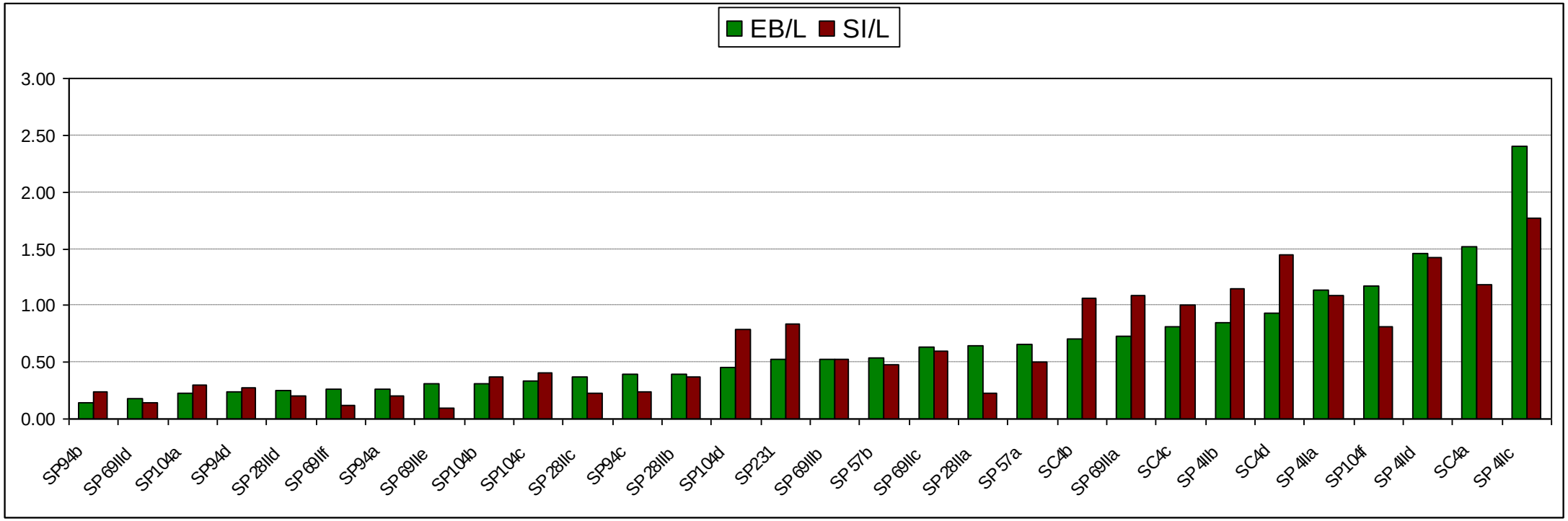
Section	Road Name	Length (km)	AADT (veh/day)	Observed Injury Accidents	Model Predicted Accidents	EB Estimate
1	SP 4II	3.463	4100	5	3.01	3.92
2	SP 4II	2.782	4100	2	2.64	2.37
3	SP 4II	0.639	4100	3	1.09	1.54
4	SP 4II	2.740	5200	5	3.13	4.00
5	SP 57	4.505	1800	5	1.91	2.99
6	SP 57	1.399	1800	0	0.94	0.75
7	SP 69II	3.084	5500	1	3.50	2.26
8	SP 69II	6.425	1800	5	2.36	3.41
9	SP 69II	3.115	1800	3	1.53	1.97
10	SP 69II	5.328	600	1	0.93	0.94
11	SP 69II	1.038	600	0	0.35	0.32
12	SP 69II	1.456	600	0	0.43	0.38
13	SP94	5.628	900	2	1.30	1.49
14	SP94	7.636	900	0	1.56	1.09
15	SP94	1.817	900	1	0.66	0.71
16	SP94	2.988	900	0	0.89	0.71
17	SP104	6.854	1200	1	1.81	1.54
18	SP104	2.409	1200	0	0.97	0.76
19	SP104	2.220	1200	0	0.92	0.73
20	SP104	2.874	2900	0	2.08	1.31
21	SP104	2.094	2900	4	1.72	2.46
22	SP231	3.887	3500	1	2.87	2.04
23	SC4	1.175	4500	2	1.69	1.79
24	SC4	1.814	4000	0	2.01	1.28
25	SC4	2.165	4000	1	2.23	1.76
26	SC4	1.146	4000	0	1.52	1.07
27	SP 28II	1.260	1100	2	0.61	0.82
28	SP 28II	3.347	1100	2	1.10	1.32
29	SP 28II	2.580	1100	1	0.94	0.96
30	SP 28II	5.273	1100	1	1.45	1.32







VALIDATION OF THE PROCEDURE
Comparison between Risk rank and accident rank



Statistics

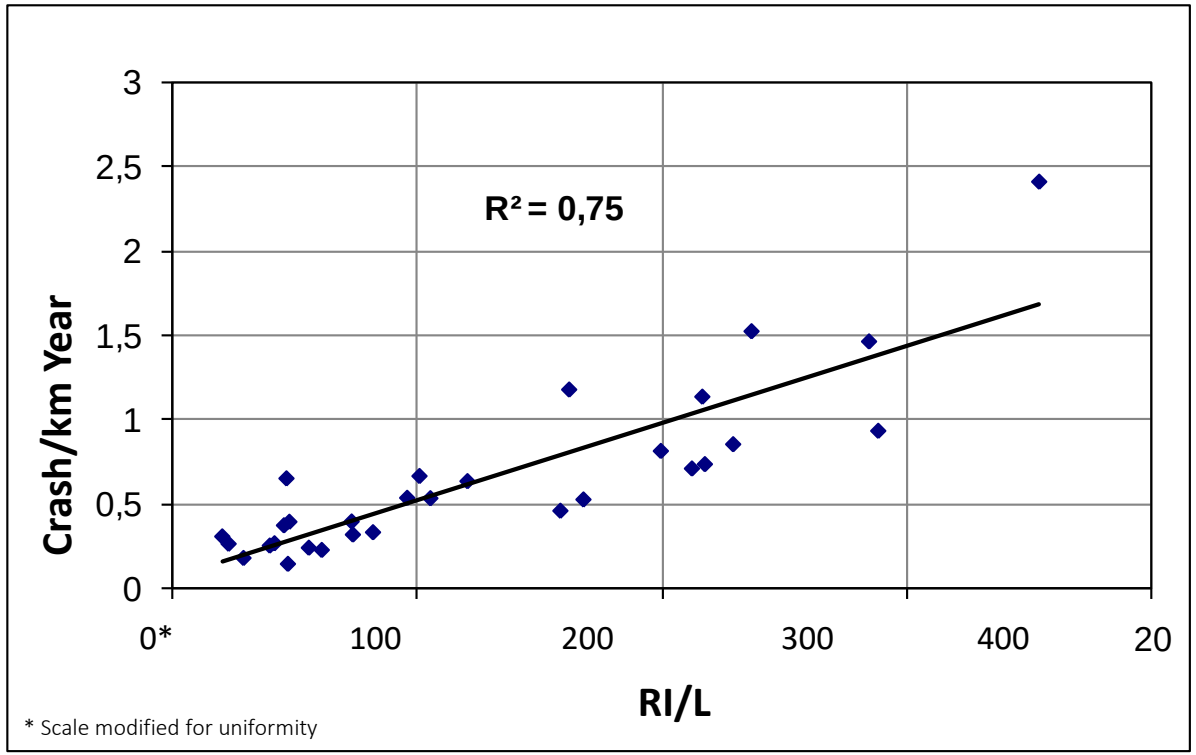
(Spearman rank correlation)

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

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

Risk Index is a surrogate measure of safety

Experimental studies highlighted a significant correlation between RI and crash data (EB)
(R^2=0.75, p-value < 0.001)

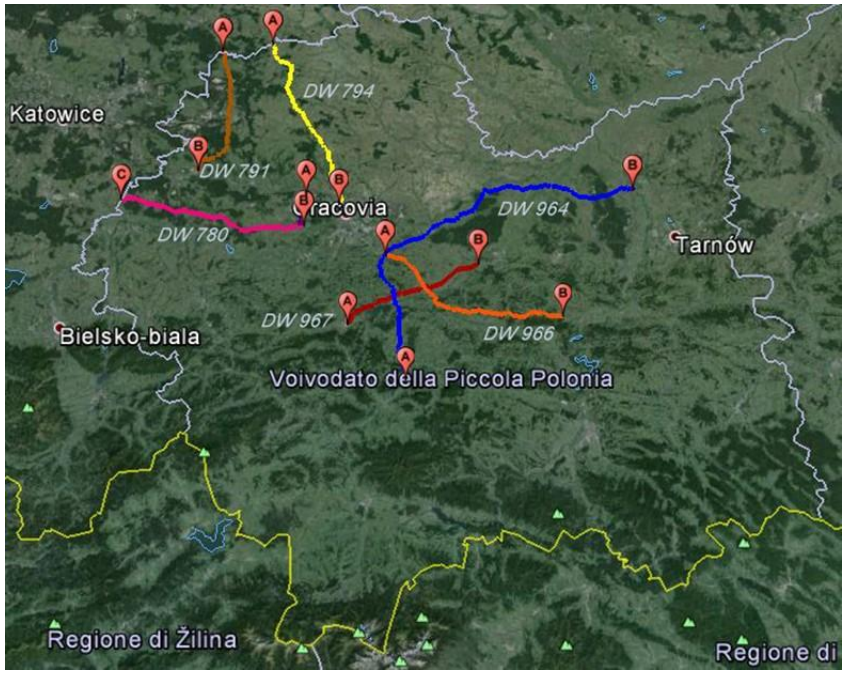


Source: Cafiso S., La Cava G., Montella A. (2007). Safety Index for Evaluation of Two-Lane Rural Highways. Transportation Research Record 2019, 136-145

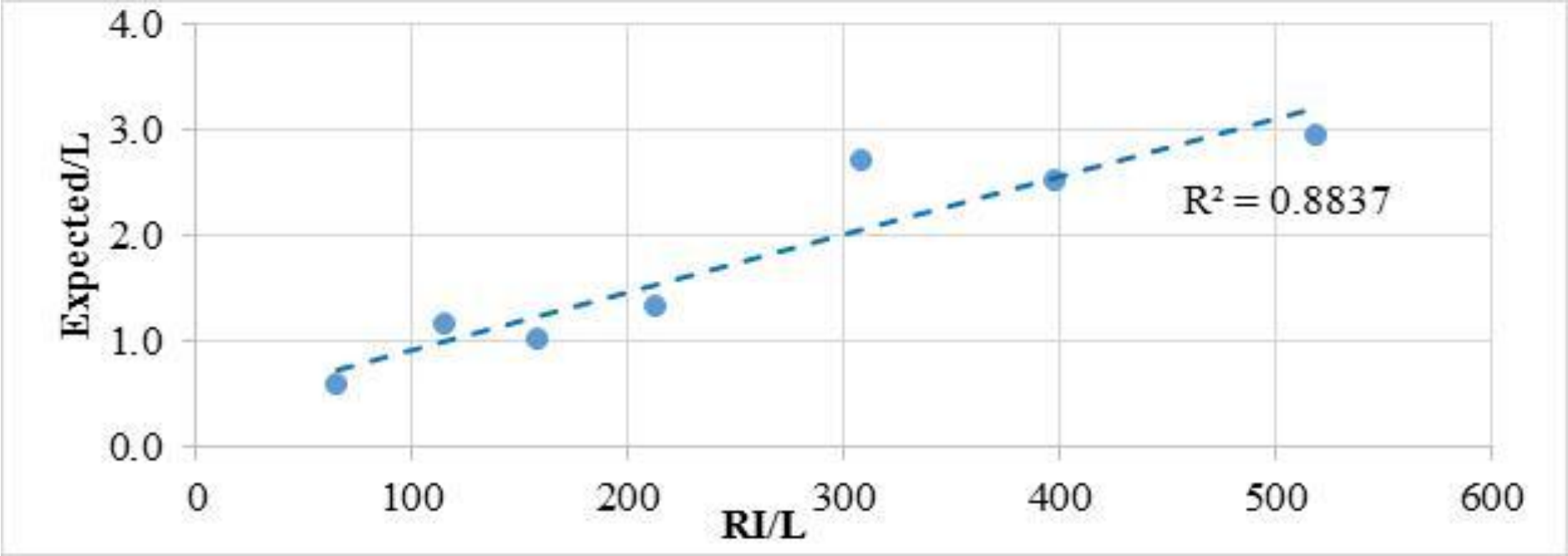
Crash Frequency Vs. RI



POLAND



73 homogeneous sections
CLUSTER ANALYSIS:



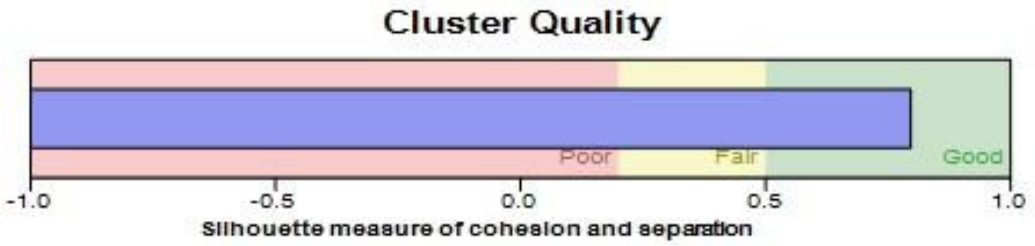
Risk index vs. crashes

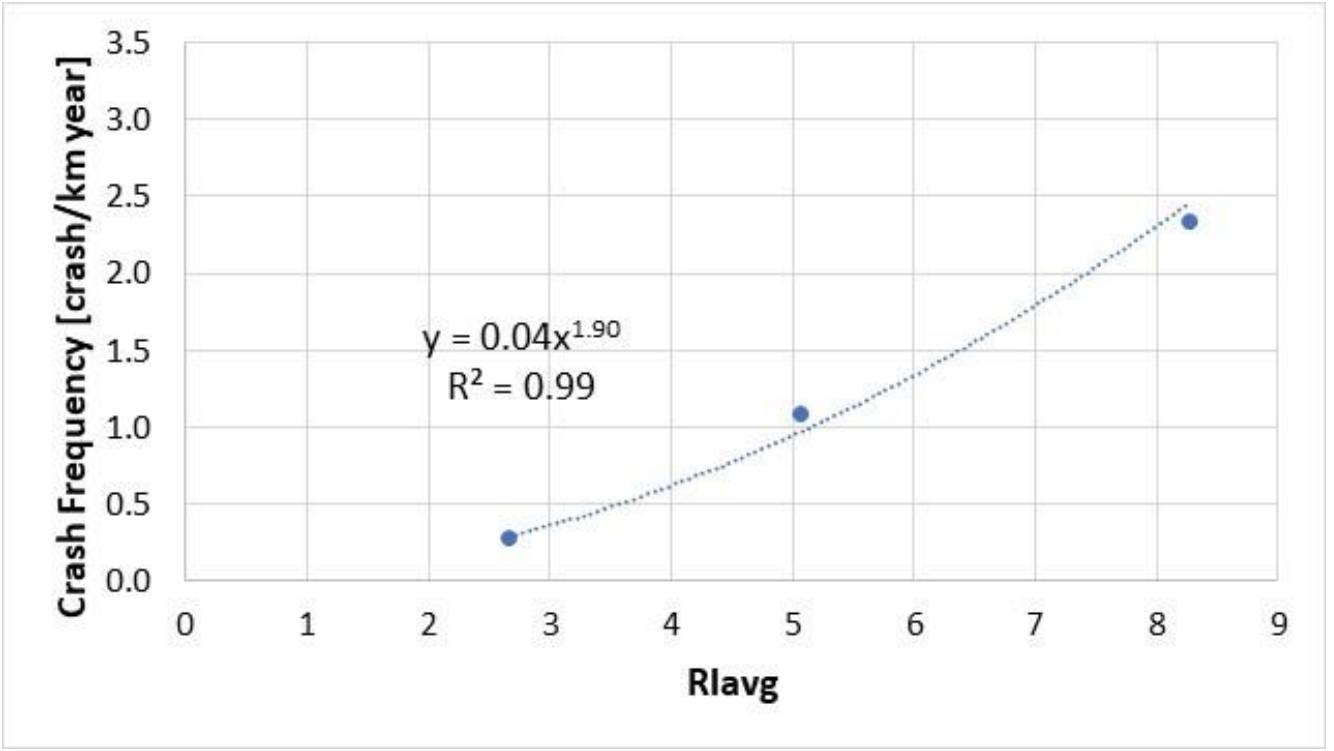
K-Means Cluster Analysis

HUNGARY



Number of Cases in each Cluster			RI Cluster Center	Crash Frequency [crash/km year]
Cluster	1	116	2.67	0.28
	2	29	5.08	1.08
	3	21	8.27	2.33
Total		166	3.80	0.67





Two Lane Rural Roads
EU countries







Example of application

Risk Index
case studies and Validation

Risk Index = RISK Management

The proposed methodological approach aims to define a Risk Index (RI) explaining the safety performance of rural road network, not based on accident history

Risk can be defined as the combination of the likelihood of an occurrence of a hazardous event and the severity of the consequences (human losses) that can be caused by the event (road crash)

Risk Assessment:

RI is a proactive approach, so that identification and ranking of high-risk segments may be implemented before accidents happen.

Risk Mitigation:

specific safety issues, that give more contribution to unsafe, are pointed out by RI in order to give indications regarding more appropriate mass-action programs

Case study in Argentina

Case study 1 -Before





	MODULE FOR BACK-SEAT INSPECTOR								
	Markings		Cross sections		Pavement		Signs	Delineation	
	Edge lines	Center lines	Line width	Shoulder width	Friction	Unevenness	Worning signs, regulation signs	Chevrons	Guide posts and barrier reflectors
Before	0	0	0	0	0	0	0	0	0
After	0	0	1	1	0	0	2	2	0
Base	0	0	1	1	0	0	0	0	0
	0	0	1	1	0	0	0	0	0

	MODULE FOR FRONT-SEAT INSPECTOR								
	Roadside					Accesses		Alignment	
	Embankments	Bridges	Dangerous terminal and transitions	Trees,utility poles and rigid obstacles	Ditches	Dangerous accesses	Presence of accesses	Inadequate sight distance on horizontal curve	Inadequate sight distance on vertical curve
Before	0	0	0	0	0	0	0	0	0
After	0	0	2	0	0	2	0	0	0
Base	0	0	0	0	0	1	0	0	0
	0	0	0	0	0	0	0	0	0

<u>Design Consistency</u>
Before: 0.75
After: 0.5
Base: 0.0

Case study 1 -Before

AADT=5000 vehicle/day

L=200 m

Risk Index$_{before}$= 388/km

Risk Index$_{Base\ condition}$= 19/km

CMF$_{before}$=Risk$_{before}$/Risk$_{base}$ = 20







Crash estimation

Crash$_{before}$=Crash Rate$_{base}$ · CMF$_{before}$

<u>10 years estimation</u>

Crash rate$_{base}$=0.1 inc/km year

Expected crash$_{after}$ = 0.8

Case study 1 - After



Case study 1 - After

$$CMF_{after} = Risk_{after} / Risk_{base} = 5$$



AADT=5000 vehicle/day

L=200 m

Risk Index$_{after}$= 93/km

<u>10 years estimation</u>

Expected crash = 0.20

Expected crash reduction = 0.6

Case Study 2 - Before





AADT=5000 vehicle/day

L=200 m

Risk Index$_{before}$= 206/km

Risk Index$_{Base\ condition}$= 19/km

CMF$_{before}$=Risk$_{before}$/Risk$_{base}$ = 10.8

Crash estimation

Crash$_{before}$=Crash Rate$_{base}$ · CMF$_{before}$

<u>10 years estimation</u>

Crash rate$_{base}$=0.1 inc/km year

Expected crash$_{after}$ = 0.43

Case Study 2 - After



Case Study 2- After

$$\mathbf{CMF_{after}} = Risk_{after}/Risk_{base} = 2.9$$



AADT=5000 vehicle/day

L=200 m

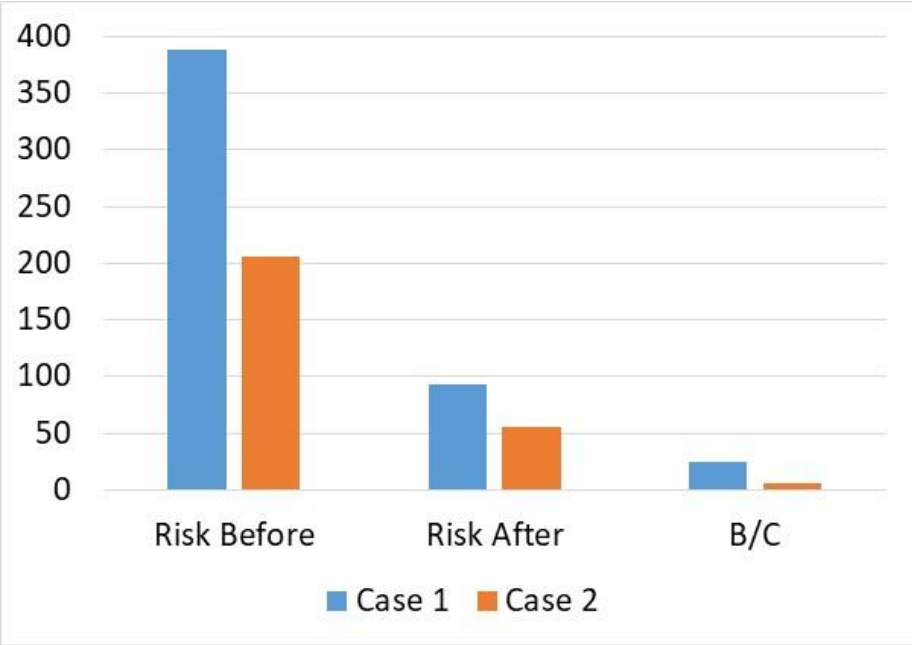
Risk Index$_{after}$= 55/km

<u>10 years estimation</u>

Expected crash = 0.12

Expected crash reduction = 0.3

Case studies - Results

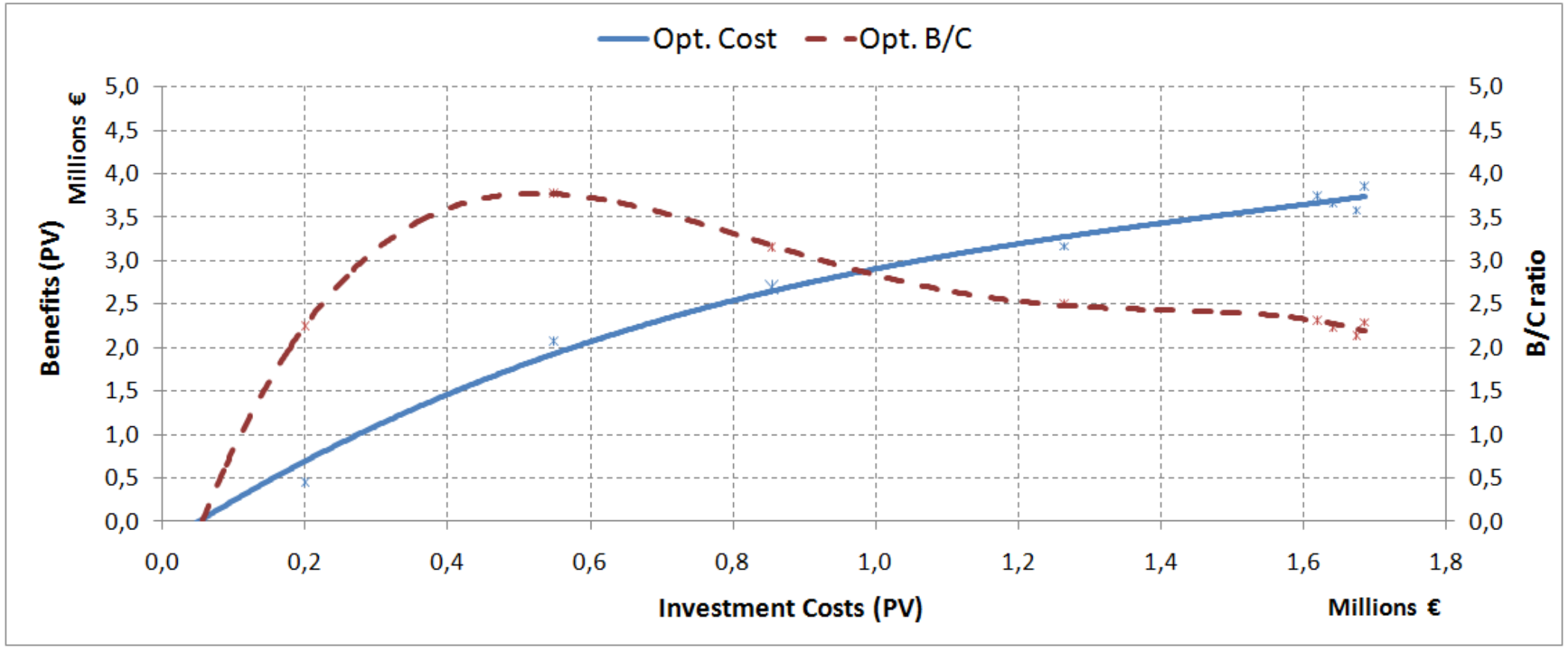


	Risk Before	Risk After	B/C	Benifit [crash]	Cost [pesos]	Rank
Case 1	388	93	25	0.62	$ 300,000	1
Case 2	206	55	5	0.32	$ 700,000	2

PROGRAM LEVEL

Optimum budget allocation

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



Remarks & Recommendations

EU Directive and International practice require the establishment and implementation of procedures relating to the Safety Management of Road Network and Safety Inspections by the Road Agencies
SIs for their qualitative nature are not able to define a priority ranking for maximizing the benefit/cost ratio of treatments at network level
Risk Index makes it possible to identify the countermeasures that produce the greatest benefits in terms of safety
Using the optimization method the best intervention strategy under budget constrains can be carried out
Model structure based on the state of the art and open source references facilitate the international transferability of the procedure

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NETWORK WIDE ROAD SAFETY ASSESSMENT



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EUROPEAN ROAD SAFETY PARTNERSHIP

NETWORK WIDE ROAD SAFETY ASSESSMENT

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