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Road Safety Performance Evaluation Based on a Multiple Layer Data Envelopment Analysis Model

Session 8---Safety Performance Indicator

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Road safety data: collection and analysis
for target setting and monitoring performances and progress

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Overview

- Introduction
- Road safety indicators (RSIs)
- Data
- Method--data envelopment analysis (DEA)
- Results
- Discussion
- Conclusion

Introduction

- The road safety issue
  - -- 1.3 mln fatalities/year in 2004 to 2.4 mln in 2030
  - -- 9th position in causes of death in '04 to 5th by '30
- Road safety indicators
  - -- Quantify the current safety situation
  - -- Gain insight into the crash process and
  - -- Monitor the effectiveness of safety actions
- A composite road safety index
  - -- Reduce the complexity of the problem
  - -- Represent a multi-dimensional concept and
  - -- Evaluate overall safety performance
  - ...

Framework

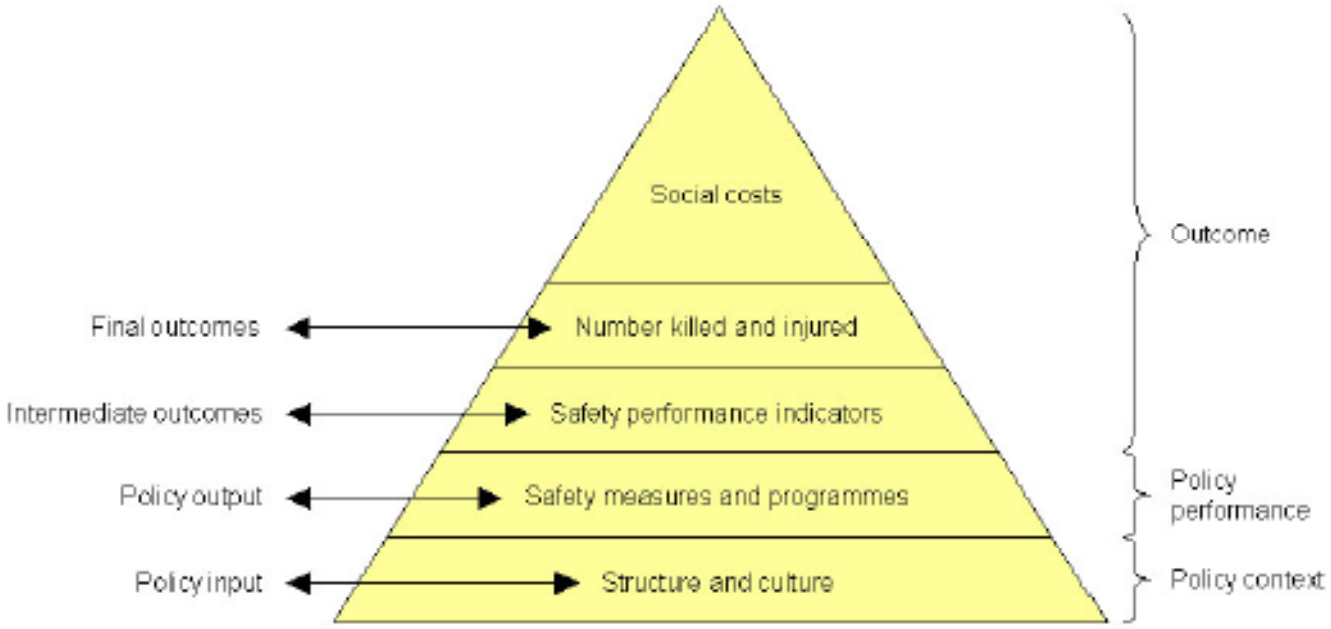

Figure 1. A target hierarchy for road safety, based on the New Zealand-hierarchy (LTSA, 2000) and SUNflower (Koornstra et al., 2002)

Hierarchical indicators

Table 1. Hierarchical structure of RSIs (SUNflowerNext 2008)

An overall road safety index	Final outcome indicators	Personal safety		Fatalities per million inhabitants (F1)
		Traffic safety		Fatalities per million passenger cars (F2)
				Fatalities per 10 billion passenger-km travelled (F3)
		Traffic injury		Injury accidents per fatality (F4)
		Vulnerable road users		Share of pedestrian fatalities out of the total fatalities (F5)
				Share of bicyclist fatalities out of the total fatalities (F6)
				Share of motorcyclist fatalities out of the total fatalities (F7)
	Safety performance indicators	Alcohol		Share of the total fatalities in drink-driving accidents (S1)
		Protective systems		Daytime wearing rates of seat belts in the front seats (S2)
				Daytime wearing rates of seat belts in the rear seats (S3)
		Vehicles	Crashworthiness of the passenger car fleet	Average EuroNCAP score of the passenger car fleet (S4)
				Median age of the passenger car fleet (S5)
			Vehicle fleet composition	Share of motorcycles in the vehicle fleet (S6)
				Share of heavy goods vehicles in the vehicle fleet (S7)
	Policy performance indicators			The availability and ambition of national safety targets (P1)
				Selection of interventions (P2)
				Economic evaluation (P3)
				Monitoring the programme's performance (P4)
				Programme's stakeholders (P5)
	Structure and culture indicators			Number of passenger cars per 1000 inhabitants (C1)
				Population per 1 km^2 of country's territory (C2)

Data description

Table 2. Ordinal and normalized numerical data

Country	F1	F2	F3	F4	F5	F6	F7	S1	S2	S3	S4	S5	S6	S7	P1	P2	P3	P4	P5	C1	C2
AT	0.76	0.81	0.75	0.18	0.80	0.69	0.39	0.82	0.62	0.51	0.17	0.69	0.42	0.89	1	3	2	2	1	0.37	0.78
BE	0.69	0.72	0.76	0.47	0.93	0.57	0.48	0.87	0.30	0.14	0.47	0.77	0.76	0.64	2	2	2	2	2	0.46	0.12
CY	0.63	0.67	0.45	0.60	0.55	0.94	0.03	0.34	0.54	0.30	0.23	0.51	0.68	0.00	1	2	2	2	1	0.44	0.82
CZ	0.67	0.60	0.55	0.79	0.66	0.47	0.64	0.84	0.32	0.00	0.24	0.35	0.28	0.77	2	3	2	2	2	0.63	0.69
DK	0.94	0.86	0.94	0.84	0.64	0.48	0.51	0.32	0.68	0.66	0.22	0.71	0.72	0.18	1	2	2	2	2	0.70	0.71
EE	0.40	0.31	0.42	0.93	0.38	0.84	0.86	0.16	0.38	0.22	0.62	0.18	0.97	0.46	2	3	2	2	1	0.60	0.96
FI	0.89	0.90	0.95	0.80	0.91	0.41	0.68	0.31	0.76	0.86	0.14	0.53	0.52	0.61	1	2	2	2	2	0.45	1.00
FR	0.82	0.86	0.90	0.85	0.93	0.85	0.22	0.15	1.00	0.75	0.25	0.61	0.74	0.48	1	1	2	1	1	0.38	0.74
DE	0.91	0.96	0.93	0.00	0.84	0.52	0.41	0.85	0.97	1.00	0.00	0.84	0.52	1.00	1	2	2	1	2	0.23	0.43
EL	0.42	0.34	0.42	0.98	0.76	1.00	0.00	0.69	0.51	0.20	0.24	0.64	0.17	0.26	1	2	2	2	2	0.61	0.82
HU	0.53	0.17	0.00	0.87	0.53	0.39	0.66	0.74	0.19	0.28	0.20	0.64	0.88	0.55	1	3	2	2	2	0.89	0.75
IE	0.77	0.73	0.62	0.83	0.66	0.90	0.46	0.56	0.70	0.43	0.21	0.93	0.99	0.42	2	2	2	1	2	0.59	0.88
IT	0.72	0.84	0.86	0.40	0.89	0.79	0.21	0.93	0.30	0.11	0.34	0.65	0.00	0.78	3	4	3	3	4	0.15	0.52
LV	0.26	0.00	0.07	0.97	0.00	0.72	0.87	0.36	0.46	0.13	0.47	0.45	0.88	0.57	2	3	2	2	2	0.73	0.94
LT	0.00	0.05	0.35	1.00	0.14	0.78	0.61	0.65	0.00	0.00	1.00	0.00	1.00	0.84	2	3	2	2	2	0.46	0.90
LU	0.83	0.95	0.95	0.78	0.99	0.98	1.00	1.00	0.54	0.62	0.27	1.00	0.55	0.83	1	4	2	2	2	0.00	0.56
NL	1.00	0.98	0.97	0.55	1.00	0.00	0.39	0.55	0.81	0.67	0.04	0.84	0.73	0.63	1	1	2	1	1	0.53	0.00
NO	0.96	0.95	0.91	0.57	0.82	0.88	0.49	0.09	0.84	0.92	0.36	0.64	0.58	0.28	2	1	1	2	2	0.52	1.00
PL	0.49	0.26	0.16	1.00	0.20	0.42	0.87	0.71	0.49	0.13	0.18	0.27	0.83	0.44	2	3	2	2	2	0.75	0.72
PT	0.74	0.69	0.61	0.50	0.77	0.84	0.20	0.66	0.70	0.42	0.25	0.48	0.60	0.02	2	3	2	2	2	0.62	0.73
SK	0.65	0.19	0.24	0.91	1.00	0.75	0.75	0.65	0.43	0.14	0.34	0.74	0.88	0.59	2	3	2	2	2	1.00	0.75
SI	0.52	0.59	0.69	0.36	0.85	0.76	0.32	0.05	0.73	0.22	0.41	0.94	0.82	0.93	2	3	2	2	2	0.42	0.78
ES	0.73	0.75	0.67	0.72	0.79	0.97	0.41	0.64	0.38	0.50	0.21	0.68	0.31	0.30	1	3	2	2	2	0.48	0.81
SE	0.98	0.97	0.99	0.43	0.89	0.74	0.48	0.00	0.86	0.79	0.99	0.74	0.57	0.75	1	1	1	1	1	0.48	0.98
CH	0.97	1.00	1.00	0.11	0.61	0.52	0.28	0.43	0.59	0.53	0.18	0.71	0.42	0.92	1	1	1	2	1	0.34	0.56
UK	0.95	0.95	0.97	0.10	0.59	0.81	0.42	0.49	0.81	0.93	0.20	0.94	0.88	0.66	1	2	2	1	1	0.46	0.38

DEA model

- What is DEA:

  -- a mathematical programming methodology to measure the relative efficiency of a set of decision making units

- Why DEA:

  --Make use of country-specific characteristics

  --Provide information on priorities for policy action

- DEA model based composite index (CI):

$$CI_c = \max \sum_{i=1}^{m} v_i x_{ic}$$

$$s.t. \quad \sum_{i=1}^{m} v_i x_{ij} \le 1, \quad j = 1, \cdots, n$$

$$v_i \ge \varepsilon, \quad i = 1, \cdots, m$$

n countries, *m* indicators, *x:* indicator value, *v:* indicator weight

Multiple layer DEA

- The proposed MLDEA is an extension of the basic DEA model:

  -- Taking the hierarchical structure of the indicators into account

  Weighted sum approach within the same category

  -- Incorporating the value judgment from decision makers or experts

  Similar importance of the indicators within the same category;
  $Share_F > 2Share_S > 3Share_P > 4Share_C$

  -- Treating the numerical and ordinal data differently

  $V(4) \neq 2V(2)$

  $V(1) > V(2) > V(3) > V(4) > \cdots$

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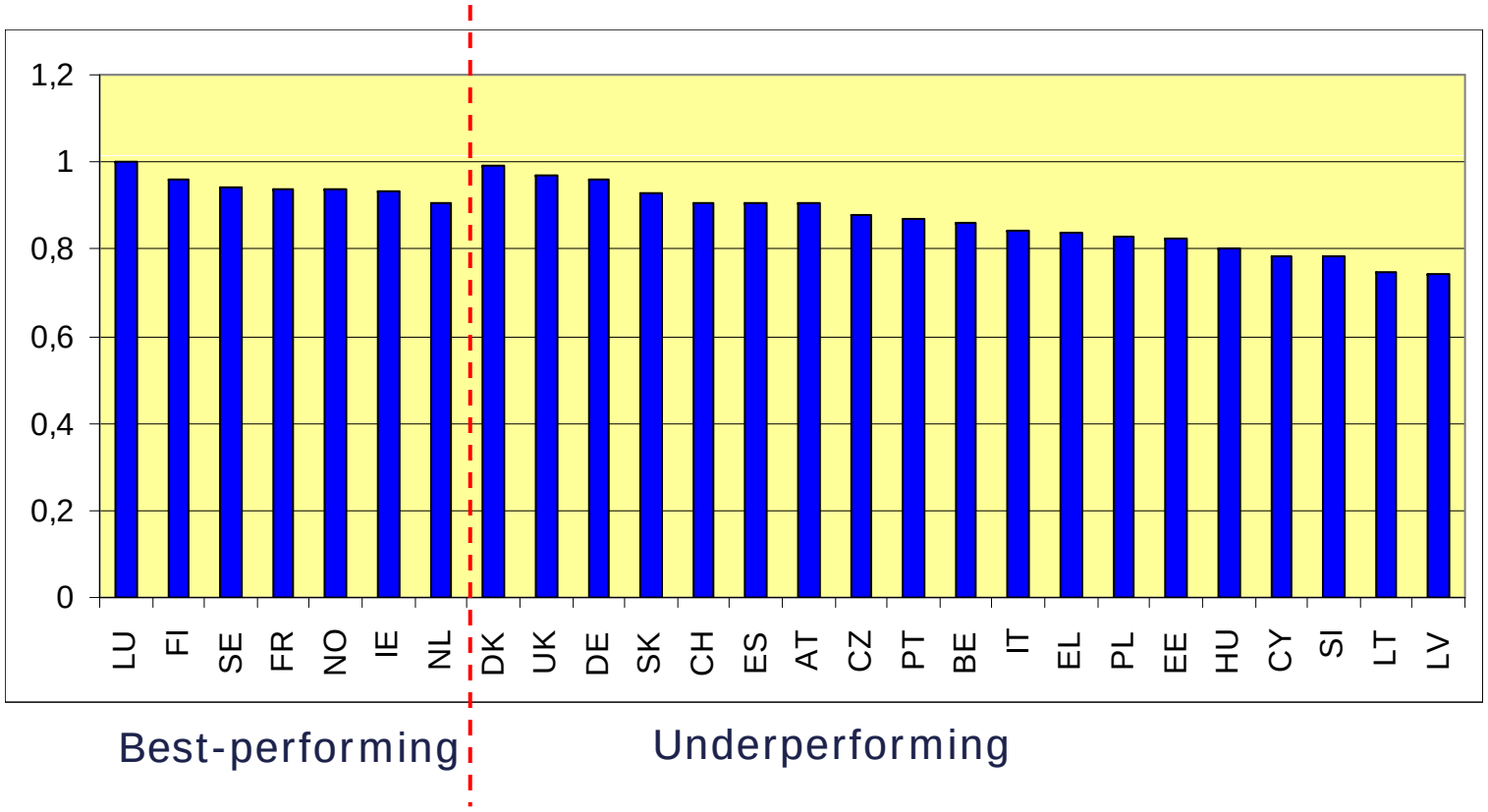
Results

Table 3. The overall results from the MLDEA model

	AT	BE	CY	CZ	DK	EE	FI	FR	DE	EL	HU	IE	IT	LV	LT	LU	NL	NO	PL	PT	SK	SI	ES	SE	CH	UK
AT	**0.91**	0.83	0.84	0.82	0.81	0.83	0.80	0.81	0.80	0.78	0.79	0.77	0.88	0.77	0.77	0.77	0.83	0.79	0.80	0.85	0.79	0.83	0.83	0.85	0.88	0.82
BE	0.82	**0.86**	0.80	0.84	0.81	0.81	0.80	0.76	0.80	0.79	0.80	0.83	0.84	0.80	0.81	0.78	0.75	0.77	0.83	0.83	0.84	0.83	0.80	0.78	0.79	0.79
CY	0.79	0.75	**0.78**	0.72	0.76	0.74	0.74	0.73	0.73	0.72	0.71	0.73	0.77	0.70	0.71	0.63	0.70	0.67	0.73	0.74	0.71	0.73	0.75	0.72	0.73	0.75
CZ	0.85	0.85	0.79	**0.88**	0.80	0.82	0.79	0.76	0.76	0.79	0.83	0.82	0.90	0.81	0.84	0.77	0.71	0.76	0.85	0.83	0.84	0.82	0.83	0.77	0.82	0.72
DK	0.98	0.99	0.97	0.94	**0.99**	0.92	0.97	0.90	0.97	0.92	0.95	0.94	0.99	0.92	0.93	0.85	0.90	0.90	0.96	0.97	0.92	0.95	0.98	0.91	0.92	0.96
EE	0.75	0.73	0.76	0.75	0.72	**0.82**	0.73	0.75	0.64	0.70	0.74	0.74	0.79	0.79	0.79	0.63	0.64	0.69	0.78	0.72	0.77	0.75	0.74	0.73	0.70	0.67
FI	1.00	1.00	0.99	0.96	1.00	0.94	**1.00**	0.93	1.00	0.93	0.96	0.96	1.00	0.94	0.94	0.88	0.92	0.93	0.96	0.99	0.94	0.97	0.99	0.94	0.94	0.98
FR	0.98	0.93	1.00	0.90	0.97	0.95	0.95	**1.00**	0.99	0.90	0.91	0.94	0.93	0.91	0.90	0.80	0.98	0.91	0.92	0.94	0.90	0.94	0.94	0.94	0.94	0.99
DE	0.92	0.92	0.90	0.88	0.92	0.86	0.90	0.86	**0.96**	0.85	0.84	0.88	0.90	0.82	0.80	0.86	0.92	0.89	0.85	0.94	0.84	0.90	0.91	0.89	0.91	0.94
EL	0.80	0.83	0.82	0.82	0.85	0.78	0.84	0.78	0.76	**0.84**	0.78	0.84	0.85	0.78	0.81	0.71	0.68	0.73	0.80	0.79	0.82	0.79	0.84	0.74	0.77	0.74
HU	0.78	0.77	0.78	0.83	0.79	0.80	0.79	0.74	0.68	0.77	**0.80**	0.80	0.84	0.78	0.79	0.72	0.65	0.73	0.82	0.75	0.80	0.75	0.83	0.78	0.76	0.66
IE	0.94	0.97	0.96	0.95	0.97	0.95	0.94	0.91	0.95	0.91	0.92	**1.00**	0.98	0.93	0.94	0.83	0.86	0.90	0.96	0.95	0.94	0.95	0.95	0.90	0.91	0.91
IT	0.77	0.73	0.72	0.70	0.67	0.69	0.67	0.69	0.72	0.69	0.68	0.69	**0.84**	0.66	0.68	0.66	0.71	0.68	0.68	0.71	0.67	0.70	0.68	0.72	0.79	0.72
LV	0.65	0.68	0.70	0.73	0.71	0.76	0.70	0.67	0.56	0.68	0.70	0.72	0.75	**0.74**	0.75	0.61	0.53	0.66	0.74	0.67	0.74	0.69	0.72	0.65	0.63	0.55
LT	0.61	0.66	0.64	0.71	0.64	0.74	0.68	0.65	0.52	0.67	0.68	0.70	0.72	0.73	**0.75**	0.61	0.50	0.61	0.72	0.62	0.75	0.67	0.68	0.62	0.60	0.53
LU	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
NL	0.97	0.92	0.95	0.89	0.92	0.90	0.89	0.94	0.97	0.84	0.89	0.89	0.89	0.85	0.82	0.82	**1.00**	0.87	0.89	0.92	0.85	0.90	0.90	0.93	0.95	0.98
NO	0.96	0.99	0.96	0.91	0.96	0.91	0.96	0.92	0.96	0.88	0.91	0.93	0.99	0.91	0.91	0.82	0.91	**1.00**	0.93	0.98	0.90	0.96	0.96	0.95	0.96	0.94
PL	0.76	0.77	0.77	0.83	0.77	0.81	0.76	0.74	0.67	0.75	0.79	0.79	0.82	0.80	0.81	0.70	0.64	0.72	**0.83**	0.76	0.81	0.75	0.80	0.73	0.74	0.64
PT	0.85	0.86	0.82	0.84	0.83	0.81	0.81	0.78	0.78	0.79	0.80	0.81	0.90	0.80	0.81	0.74	0.74	0.80	0.83	**0.87**	0.83	0.84	0.85	0.79	0.81	0.76
SK	0.87	0.90	0.88	0.93	0.89	0.91	0.88	0.85	0.78	0.86	0.88	0.92	0.95	0.90	0.92	0.80	0.73	0.84	0.92	0.86	**0.93**	0.89	0.90	0.87	0.85	0.75
SI	0.73	0.74	0.71	0.72	0.73	0.74	0.71	0.70	0.69	0.66	0.69	0.73	0.78	0.73	0.73	0.66	0.66	0.70	0.73	0.74	0.75	**0.78**	0.71	0.70	0.69	0.67
ES	0.90	0.89	0.86	0.88	0.87	0.84	0.87	0.83	0.85	0.85	0.87	0.86	0.92	0.85	0.87	0.81	0.80	0.84	0.87	0.89	0.87	0.87	**0.91**	0.84	0.86	0.83
SE	1.00	0.97	0.99	0.89	0.96	0.94	0.96	0.97	1.00	0.87	0.90	0.92	0.98	0.89	0.88	0.81	0.98	0.98	0.91	0.96	0.88	0.95	0.93	**1.00**	1.00	1.00
CH	0.89	0.84	0.83	0.78	0.81	0.78	0.79	0.80	0.85	0.74	0.77	0.74	0.85	0.74	0.73	0.74	0.87	0.82	0.78	0.84	0.74	0.81	0.79	0.87	**0.91**	0.88
UK	0.94	0.90	0.92	0.83	0.90	0.88	0.88	0.87	0.93	0.82	0.83	0.85	0.90	0.82	0.80	0.79	0.93	0.86	0.84	0.91	0.81	0.89	0.88	0.90	0.90	**0.97**

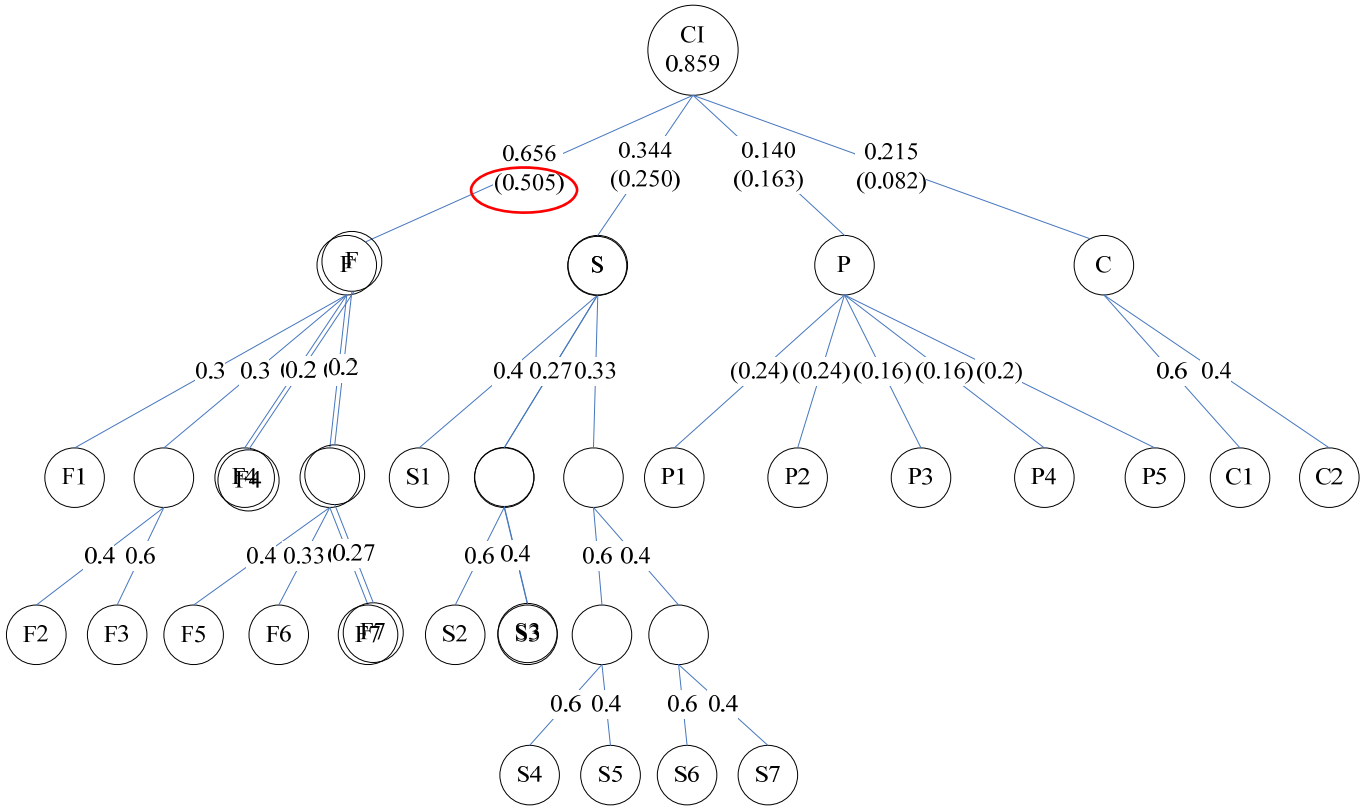
Results 2

Figure 2. Ranking of the 26 European countries



Results 3

Figure 3. Assigned weights (and shares) in each layer of the hierarchy for Belgium



Discussion

- Valuable results:

  -- Based on the country-specific models, the most optimal road safety index score is calculated, and countries ranked.

  -- The weights allocated in each layer of the hierarchy can be deduced for each country, which lead up to priorities for policy action.

- Limitations:

  -- Sensitive to sample size, indicator specification, and chosen weight restrictions.

- Solutions:

  -- As many countries as possible should be considered, appropriate indicators selected, and accepted views from experts adopted.

Conclusion

- There is a growing need for a country to evaluate its road safety performance and compare it with that of other countries.
- Data envelopment analysis has proven valuable in creating a composite road safety index.
- A multiple layer DEA model is proposed to reflect the hierarchical structure of the indicators and meanwhile deal with both quantitative and qualitative data.
- A countries' ranking is set up representing the overall optimal road safety performance, and the assessment of the weights on the various layers of the hierarchy helps in guiding policymakers to take appropriate action for each country.

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