Smart Transportation Alliance

SUP&R ITN
Sustainable Pavement & Railway Initial Training Network

University of Nottingham
UK | CHINA | MALAYSIA

A Performance-based Sustainability Assessment tool for Road pavements and Railway tracks

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SUP&R ITN Research Project

SUPER ITN

Sustainable Pavement & Railway
Initial Training Network

How can we design Sustainable technologies for **Road Pavements** and **Railway Trackbeds ?**

Design:

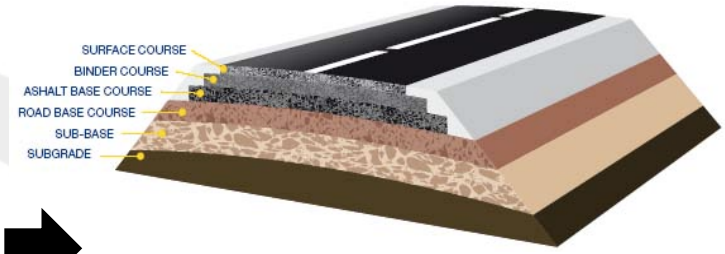
- Pavement/Railway structure
- Design Life/Mechanical performance prediction
- M & R strategies

Good? Bad?

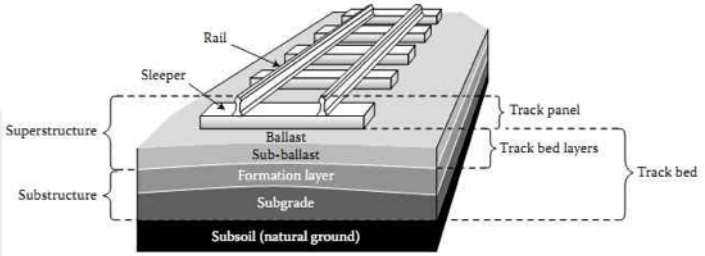
Sustainability Assessment

- Sustainability Performance prediction and rating

Good



Final Design



Sustainability Rating Systems (SRS) in Transp.Infr.Eng

Infrastructures

- CEEQUAL (UK)
- Envision (USA)
- BREEAM Infrastructures (NL)
- IS rating system (AUS)

Road Infrastructures (*in use*)

- GREENROADS (USA)
- FHWA INVEST (USA)
- GreenPave (CA)
- BE^{2}ST- In-Highway
- I-LAST (IL, USA)
- GreenLITES (NYS, USA)
- LCE4ROADS

SRS Conclusions and suggestions

- SRS are usually **qualitative based**, although few recent tools are defined for a quantitative assessment
- A third-party assessment system allows behaviour changing, however **self-assessment is a good first step for design workshops**
- **European, Flexible, User-friendly framework mainly based on quantitative measurements is needed!**

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SUP&R MCDA Tool

Performance-based
Sustainability assessment tool
Road Pavement and Railway trackbed technologies

The Team

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ER3 – IFSTTAR, FR

Methodology & Tool development

EU Stakeholders survey

Establish conceptual framework for comprehensive sustainability assessment

Define indicators to evaluate sustainability

Develop weighting methodology for assessment tool

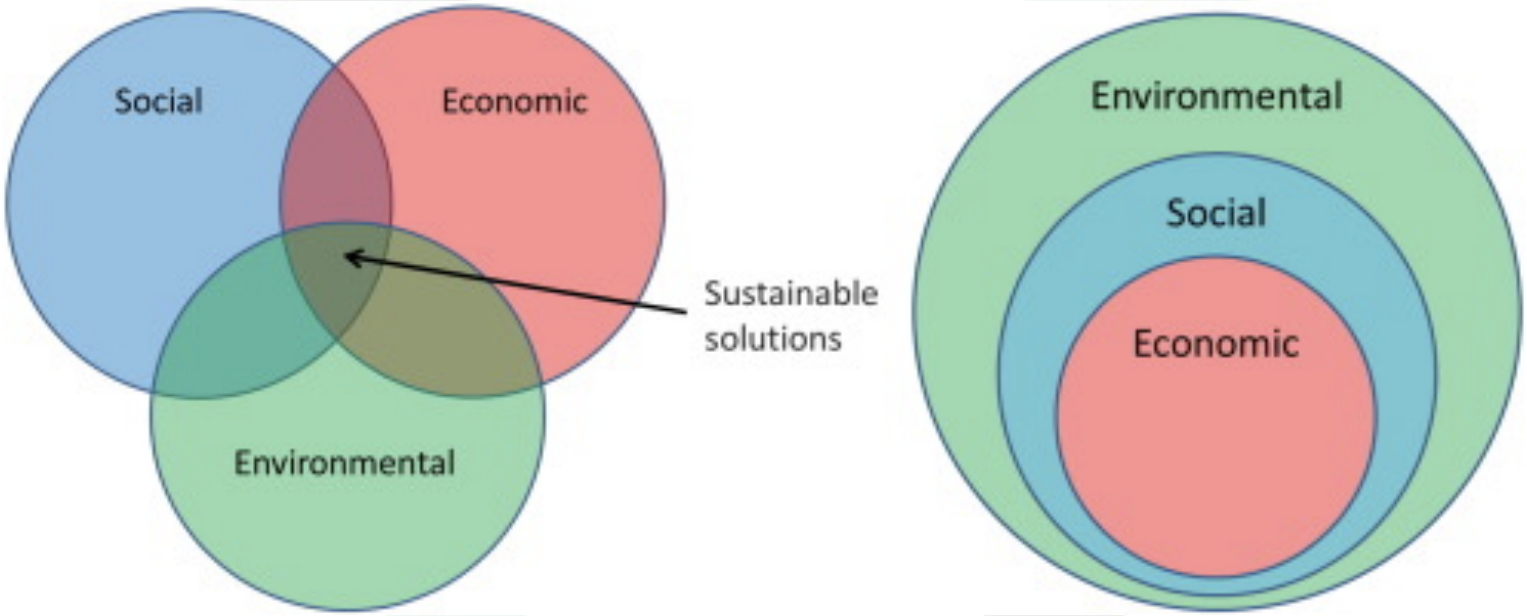
Validate and benchmark sustainability assessment tool

Tailored methodology with literature review

MCDA TOOL

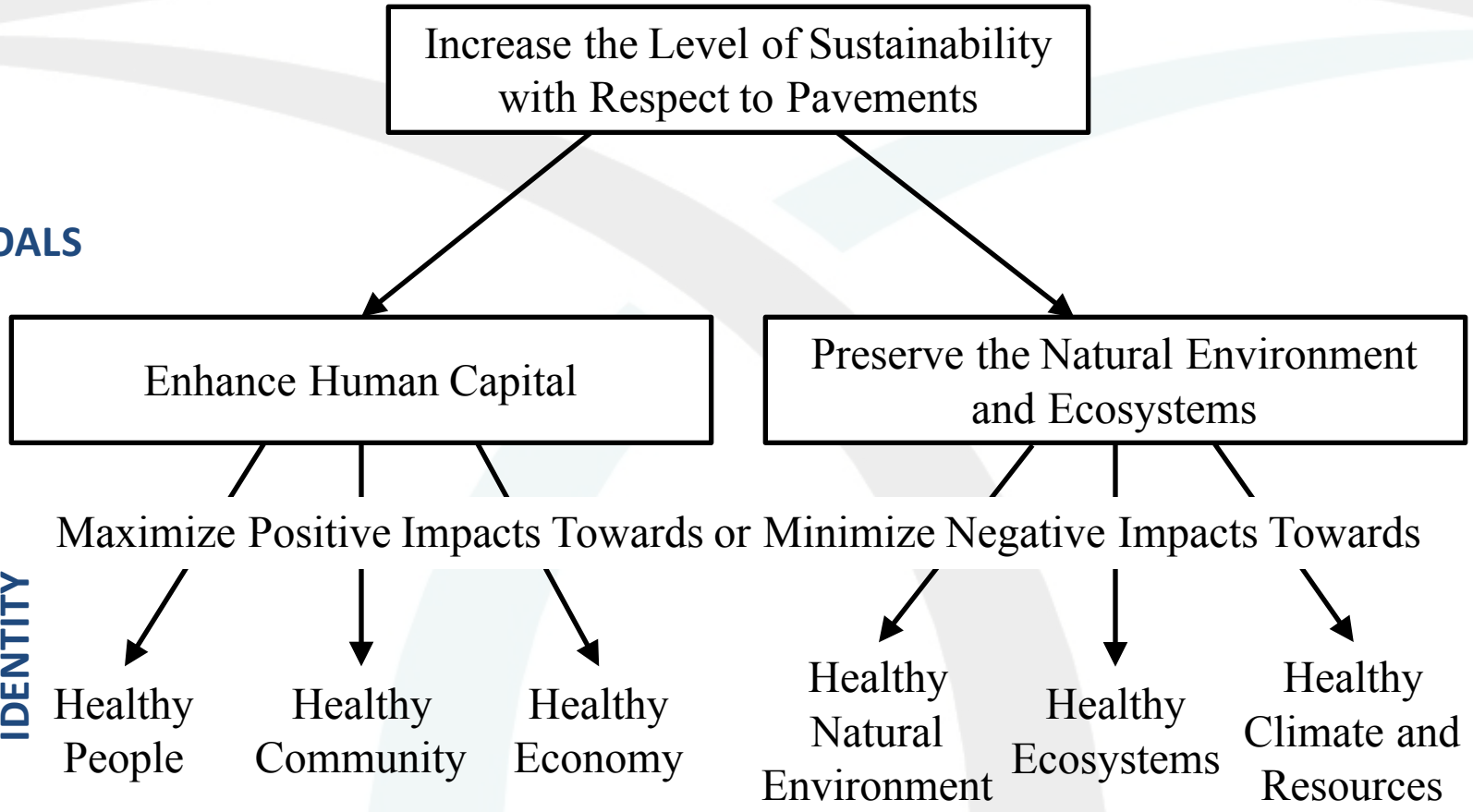
CASE STUDY

STEP1: Framework - Objective Hierarchy



James Bryce, Stefanie Brodie, Tony Parry, Davide Lo Presti, ***A systematic assessment of road pavement sustainability through a review of rating tools****, Resources, Conservation and Recycling, 2016*

STEP1: Framework - Objective Hierarchy

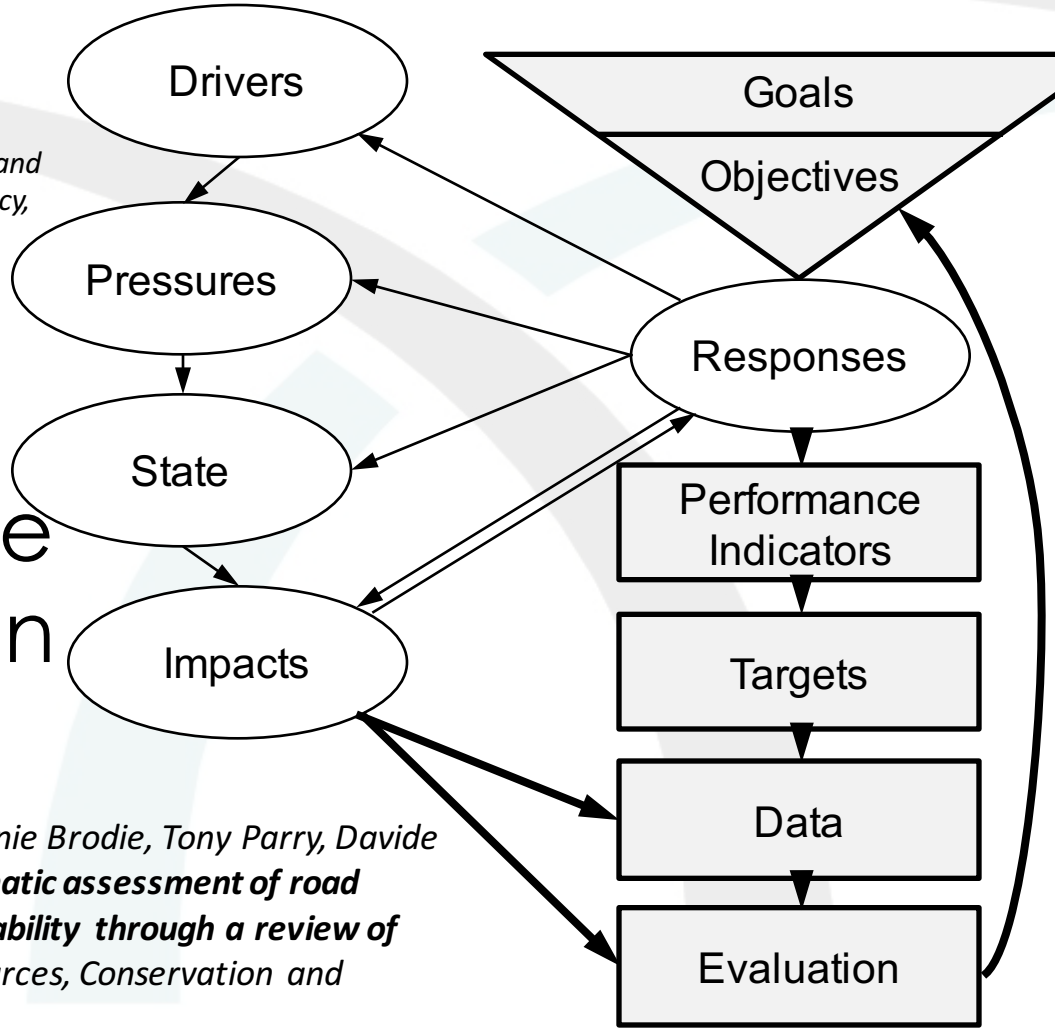


James Bryce, Stefanie Brodie, Tony Parry, Davide Lo Presti, ***A systematic assessment of road pavement sustainability through a review of rating tools****, Resources, Conservation and Recycling, 2016*

STEP1: Framework - Concept

Smeets, E., Weterings, R., 1999. Environmental Indicators: Typology and Review.European Environment Agency, Copenhagen.

DPSIR & Performance Management



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STEP1: Framework - Concept

Goal — Preserve the Natural Environment & Ecosystems

Objective — Maximize healthy resources

Response

Increase the use of recycled material in the production of pavements

- **Driver** – Traffic growth leading to pavement construction and maintenance
- **Pressure** – Resource use
- **State** – Resources available, Biodiversity, GHG concentration, etc.
- **Impacts** – For example: Resource depletion, biodiversity loss, global warming potential, resource costs, etc.

Performance Indicators — For example: GHG emissions (production, transport), Virgin material use, Waste diverted from landfills, Energy consumption (production), etc.

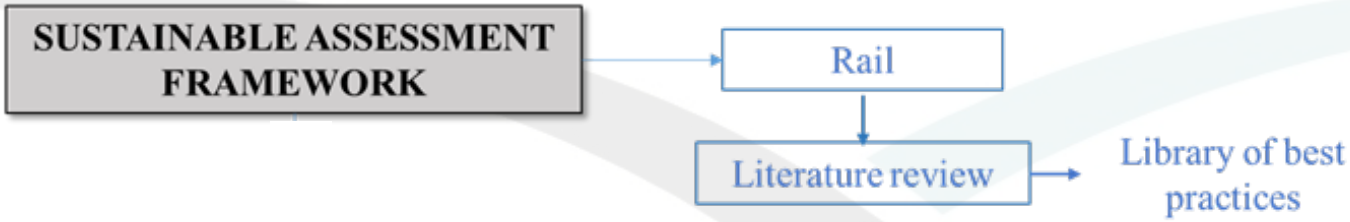
Target — Developed based on models and data

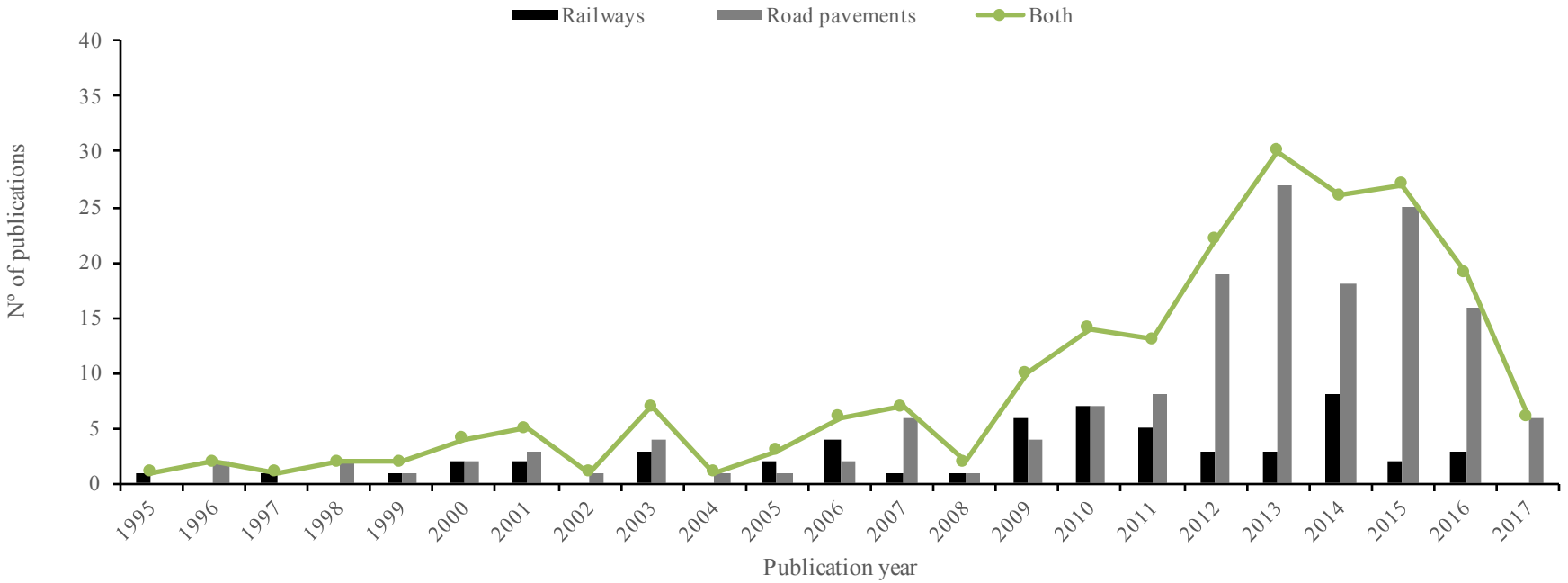
Data — Results from evidence based assessment (e.g., LCA) conducted to determine impacts

Evaluation — Is response adequate to meet the objective and targets?

- Comparative analysis
- Design workshops

STEP 2: Definition of indicators (short list)





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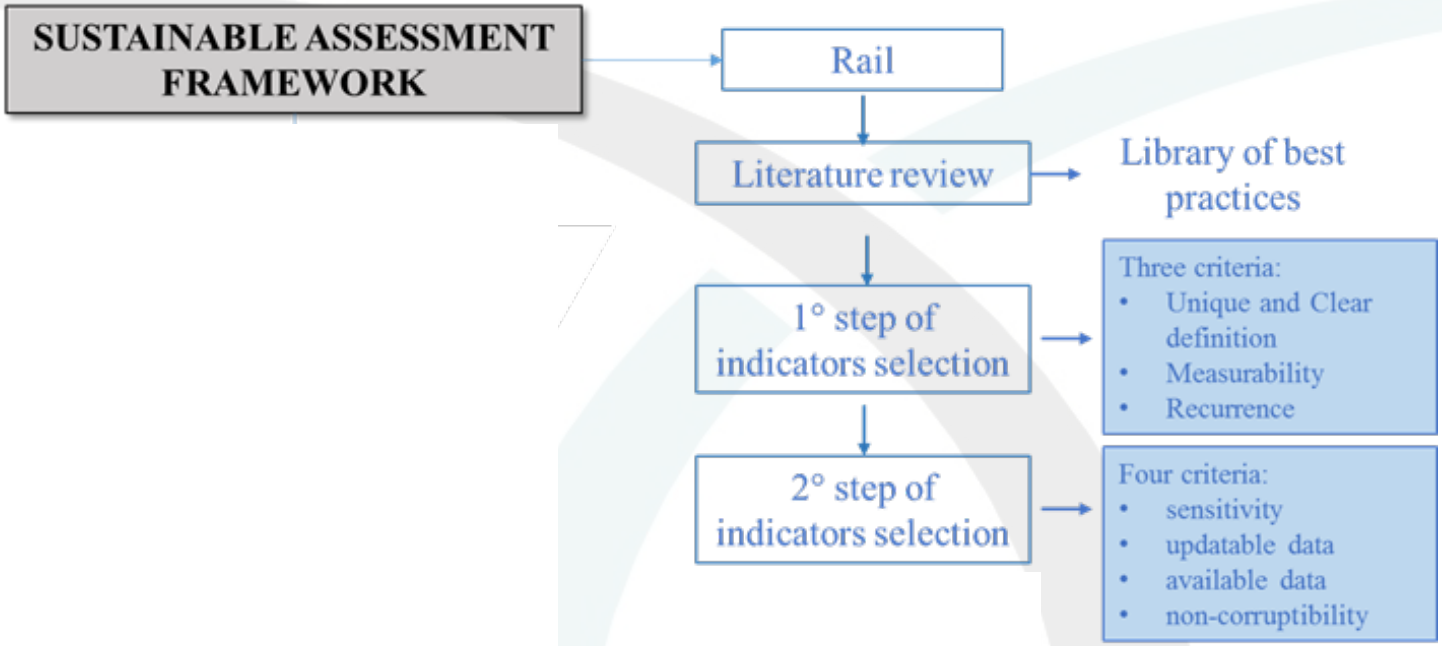
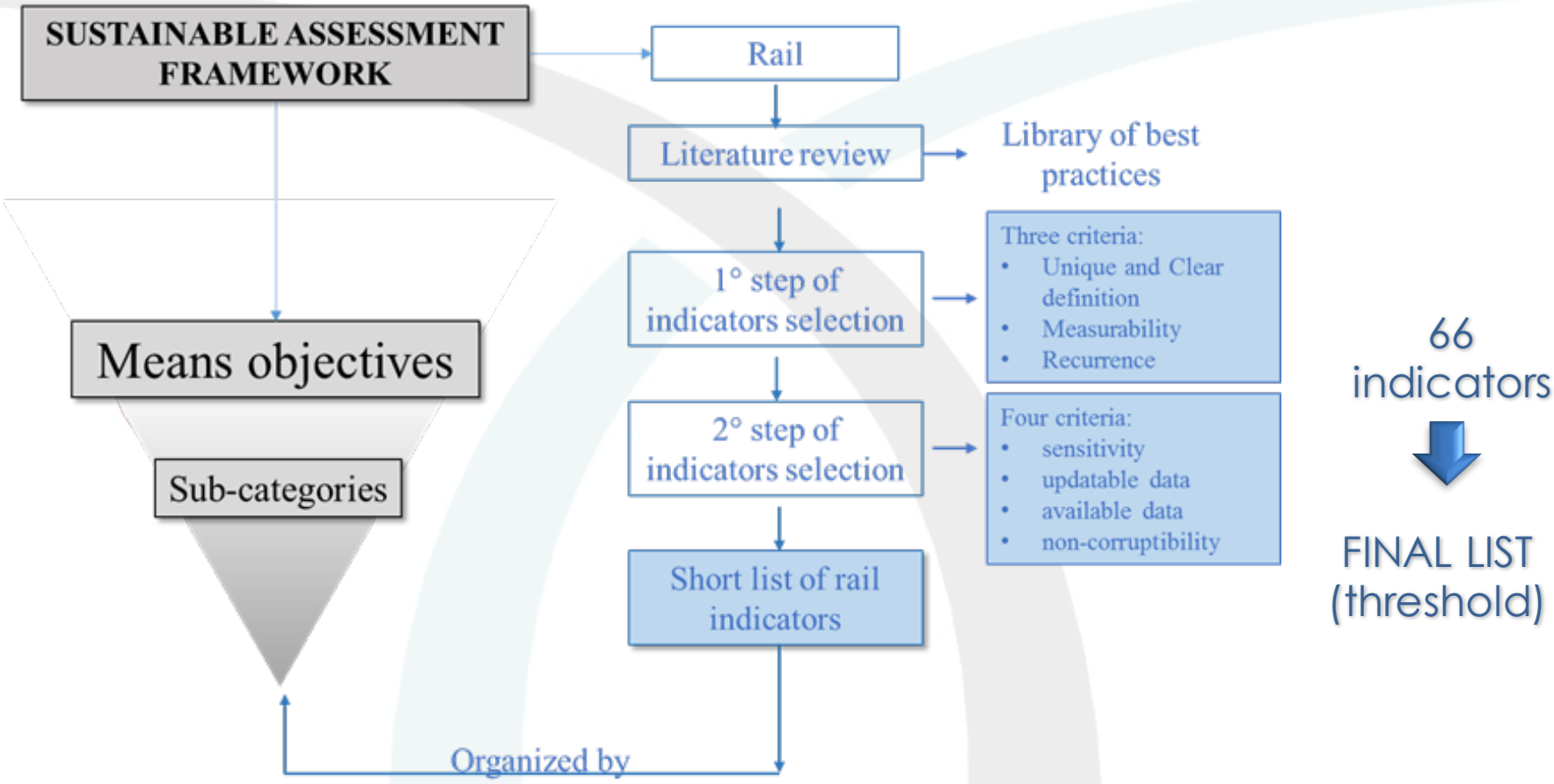


66 indicators

STEP 2: Definition of indicators (short list)



STEP 2: Definition of indicators (railways)

Indicator	*Means objectives*	*Description*
Greenhouse GHG (primarly CO_2 emission)	Healthy Climate and Resources	Various gaseous compounds (principally carbon dioxide) that absorb infrared radiation and trap heat in the atmosphere.
Energy consumption	Healthy Climate and Resources	Amount of energy consumed in the process of construction or maintenance.
Recycled content (Slag and ashes, RAP)	Healthy Natural Environment	Recycled content recovered from existing structure of total discarded/waste material.
Water depletion	Healthy Natural Environment	Amount of water used for the required operations of construction or maintenance.
Acidification potential	Healthy Natural Environment	Increase in the concentration of the hydrogen ions (H+) in water and soil. This alters the pH of that medium which may cause damage to the organic and inorganic materials.
Eutrophication potential (EP)	Healthy Ecosystems	Potential presence of nutrients that can cause over-fertilisation of water and soil which in turn can result in increased growth of biomass.
Ozone depletion potential (ODP)	Healthy Ecosystems	Indicates the potential for emissions of chlorofluorocarbon (CFC) compounds and other halogenated hydrocarbons to deplete the ozone layer.
Safety impact	Healthy People	Accidents in property damage, medical, and legal costs.
User comfort	Healthy People	Factor that evaluates passenger's feeling about vibration environment.
Noise or vibration reduction	Healthy Community	Reduction of noise/vibration level in order to reduce the acoustic impact on the users and population.
Life cycle cost	Healthy Economy	The total cost of the purchase and installation, and the use and the maintenance during the life cycle.

STEP 3: EU survey with Stakeholders (weights)

Approximately **fifty** stakeholders have been interviewed. It was asked them to judge the relative importance of the means objectives and sub-categories.

- **public/institutional representative**
- **public administration,**
- **self-employed professional,**
- **universities,**
- **Enterprises**
- **other social agents**

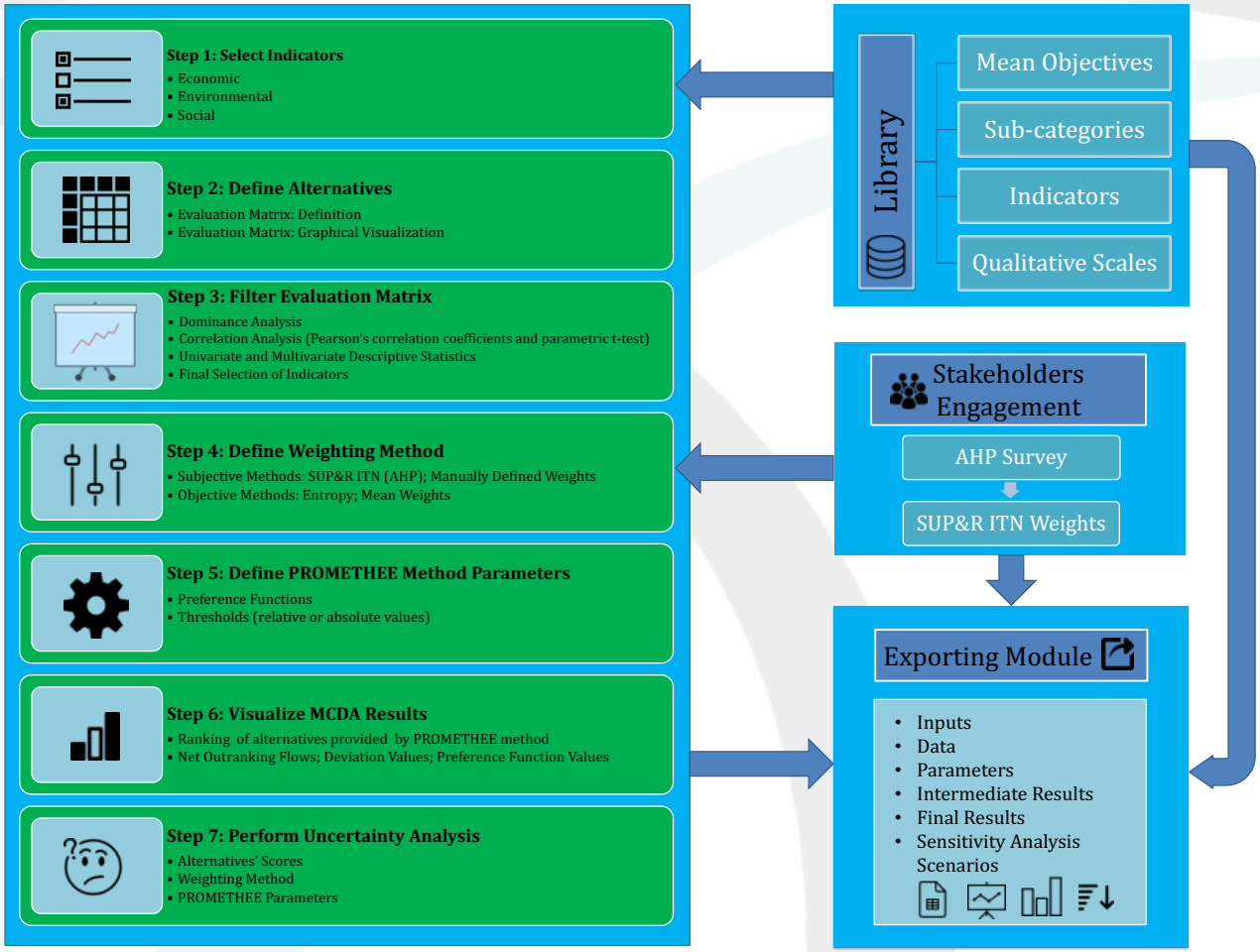
AHP method

Means objectives	Weights of the means objectives	Sub-category	Weights of the sub-categories
Healthy Climate and Resources	11,25	Recycling and Materials Conservation	15,63
		Long-life Pavements	11,97
		GHG Emissions and Non-renewable Resources	11,87
		Land Resources	11,06
		Energy	10,83
		Local Materials	10,56
		Climate Change	10,42
		Renewable resources	10,25
		Albedo	7,46

Step 4 – SUSTAINABILITY ASSESSMENT TOOL (MCDA)

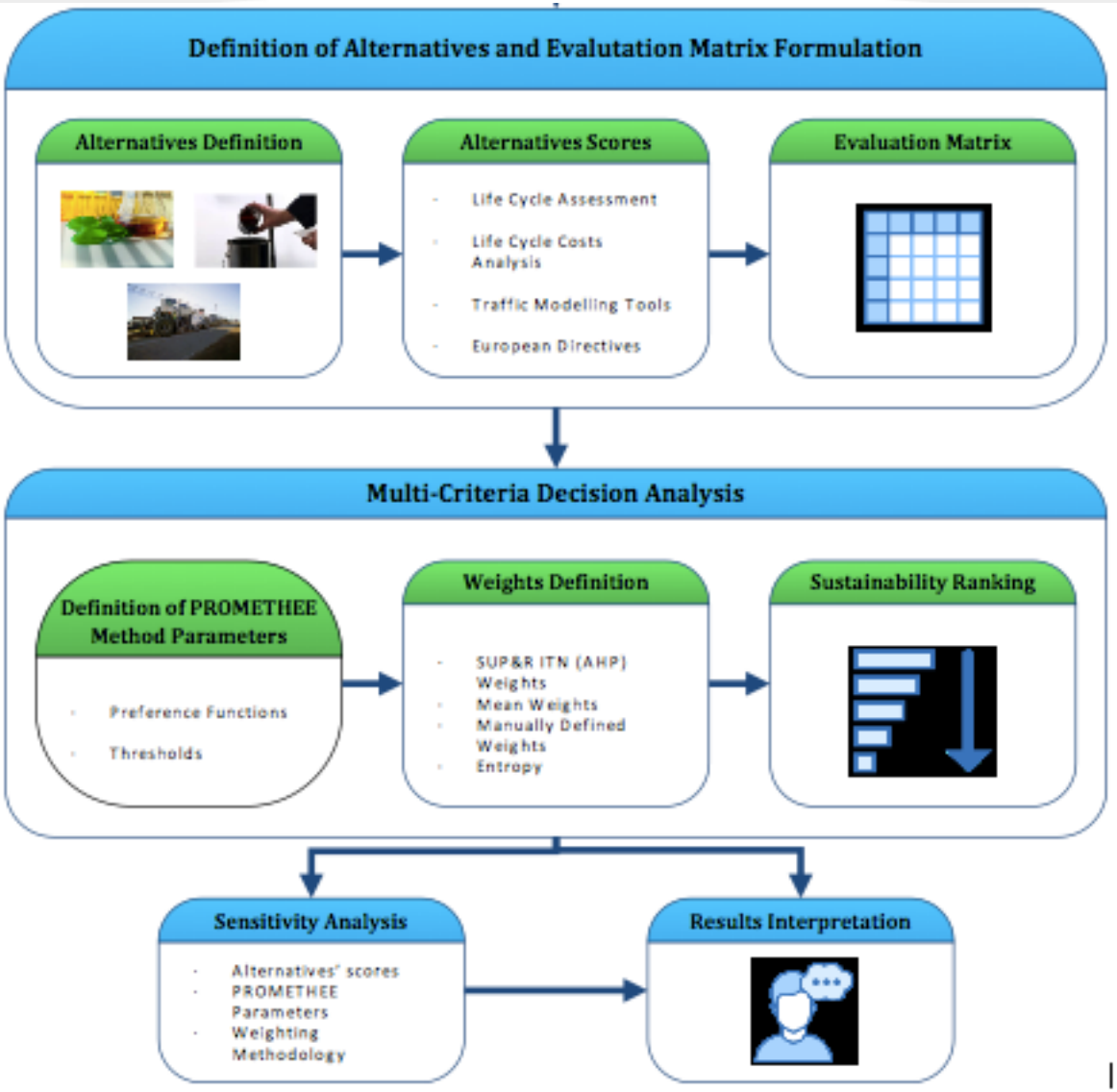
PROMETHEE METHODS

DEFINITION OF ALTERNATIVES, MCDA and SA



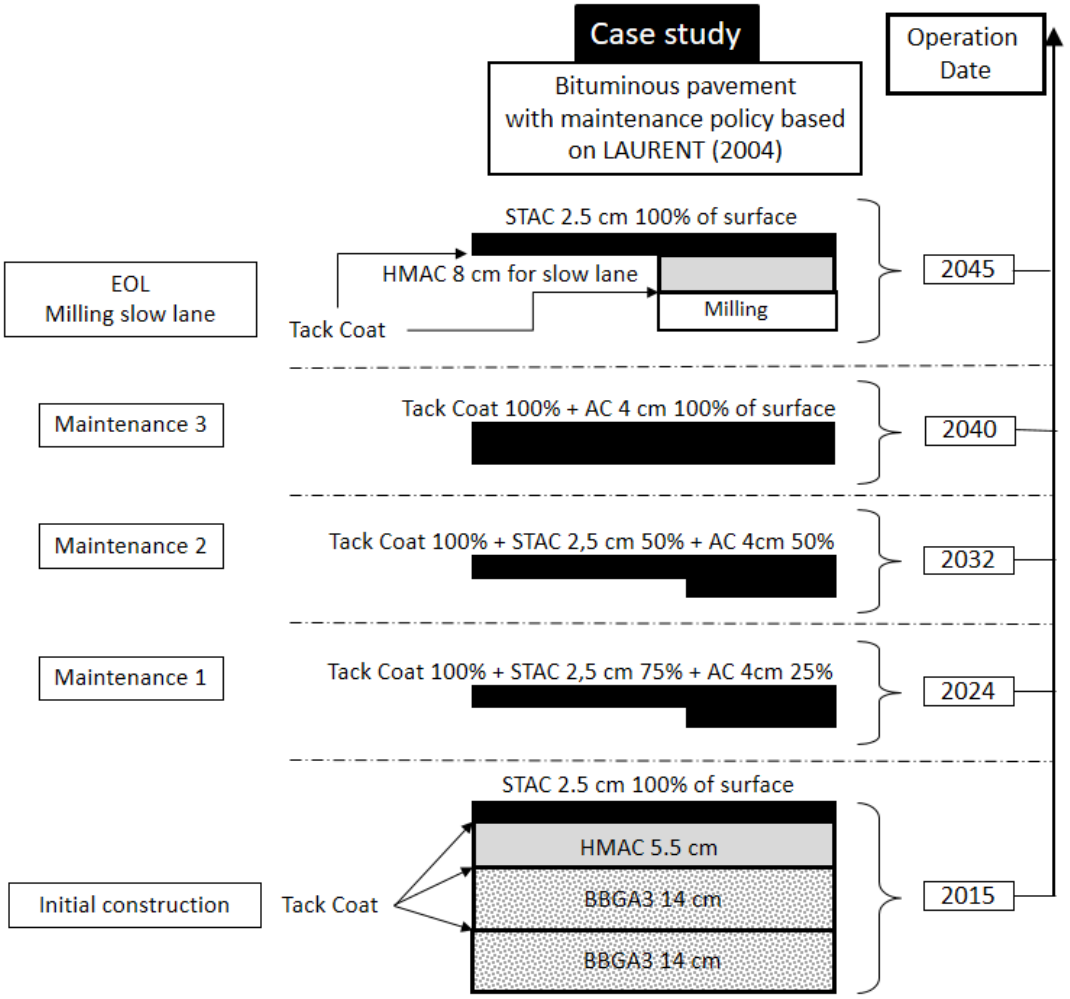
✓ European ✓ Multi-sector ✓ Flexible ✓ User-friendly ✓ Quantitative

Step 4 – SUSTAINABILITY ASSESSMENT TOOL (MCDA)



Case Study: Road Pavement

Initial pavement structure and M&R plan



Case Study: Road Pavement

Definition of the alternative (asphalt mixtures for road surface)

Item	Type of mixture					
	HMA, 0% RAP	WMA-CECABASE®, 0% RAP	Foamed WMA, 0% RAP	HMA, 50% RAP	WMA-CECABASE®, 50% RAP	Foamed WMA, 50% RAP
Virgin aggregate						
Quantity (%/m)	94.4	94.4	94.4	48.4	48.37	48.36
Water content (%/a)	3	3	3	3	3	3
RAP						
Quantity (%/m)	-	-	-	48.4	48.37	48.36
Water content (%/RAP)	-	-	-	3	3	3
Bitumen						
Penetration grade	35/50	35/50	35/50	35/50	35/50	35/50
Quantity (%/m)	5.4	5.4	5.4	3.2	3.2	3.2
WMA agent						
Type	-	surfactant	water	-	surfactant	water
Quantity (%/m)	-	0.054	0.077	-	0.054	0.077
Mixture density (kg/m^3)	2360	2340	2260	2370	2360	2360

Case Study: Road Pavement

Evaluation matrix

Table 1. Evaluation matrix.

Alternative scenario		Sustainability indicators										
ID	Name	GW (Kg CO_2-eq)	ED (MJ)	SMC (%)	WC (m^3)	AC (kg SO_2-eq)	EU (kg PO_4-eq)	SOD (kg CHC_{11}-eq)	PM (kg PM_{10}-eq)	TC (Hr)	LCHAC (€)	LCRUC (€)
1	HMA, 0%RAP	1257898	69679068	0	2424	10376	4513	0.823	2871	46.142	1266306	2145
2	WMA-CECABASE®, 0%RAP	1236348	69442583	0	4123	10221	4495	0.818	2847	40.921	1270296	2042
3	Foamed WMA, 0%RAP	1223723	68680490	0	2399	10117	4431	0.811	2809	40.921	1259028	2042
4	HMA, 50%RAP	1202024	63620766	11	2234	9788	4273	0.750	2713	46.142	1204773	2145
5	WMA-CECABASE®, 50%RAP	1181481	63536209	11	3936	9645	4259	0.748	2691	40.921	1209036	2042
6	Foamed WMA, 50%RAP	1178377	63380866	11	2232	9630	4248	0.748	2679	40.921	1203225	2042

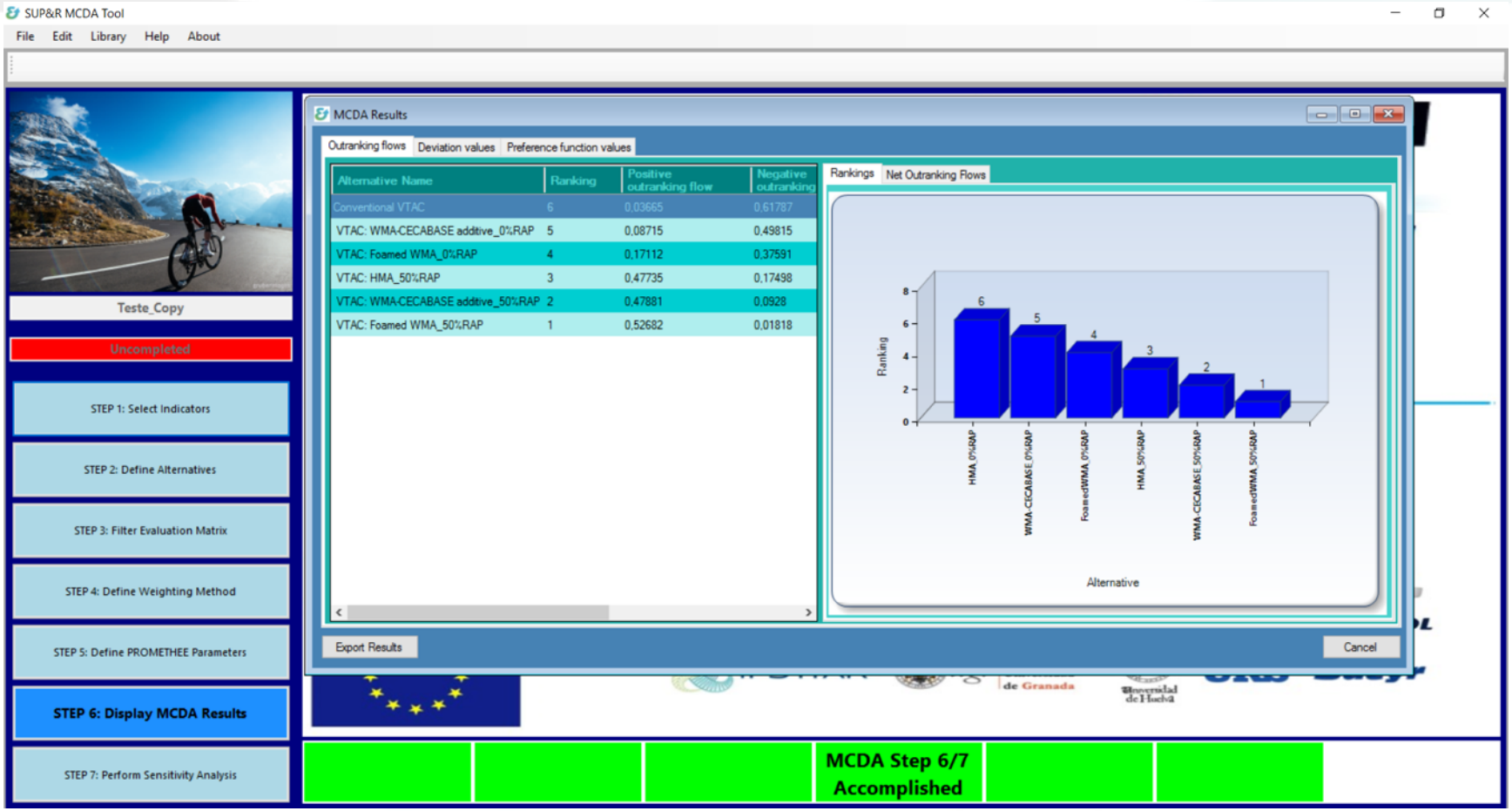
Key: HMA- hot mix asphalt; WMA- warm mix asphalt; RAP- reclaimed asphalt pavement; GW- global warming; ED- Energy demand; SMC- Secondary materials consumption; WC- Water consumption; AC- acidification; EU- Eutrophication; SOD- Stratospheric ozone depletion; PM- Particulate matter, TC- Traffic congestion; LCHAC- Life cycle highway agency costs; LCRUC- Life cycle road user costs.

Case Study: Road Pavement

Define Weighting Method

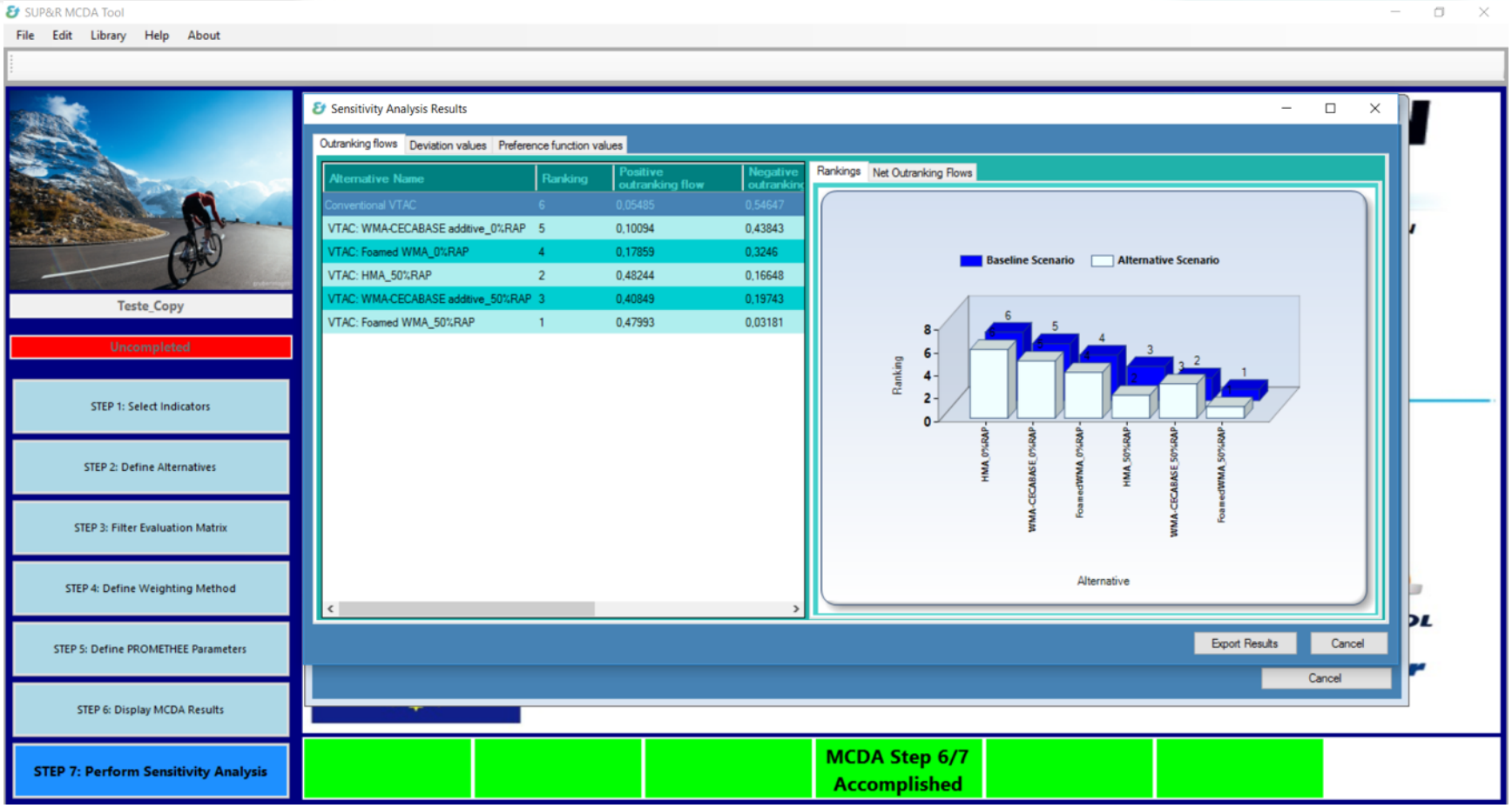
Case Study: Road Pavement

Visualize MCDA results



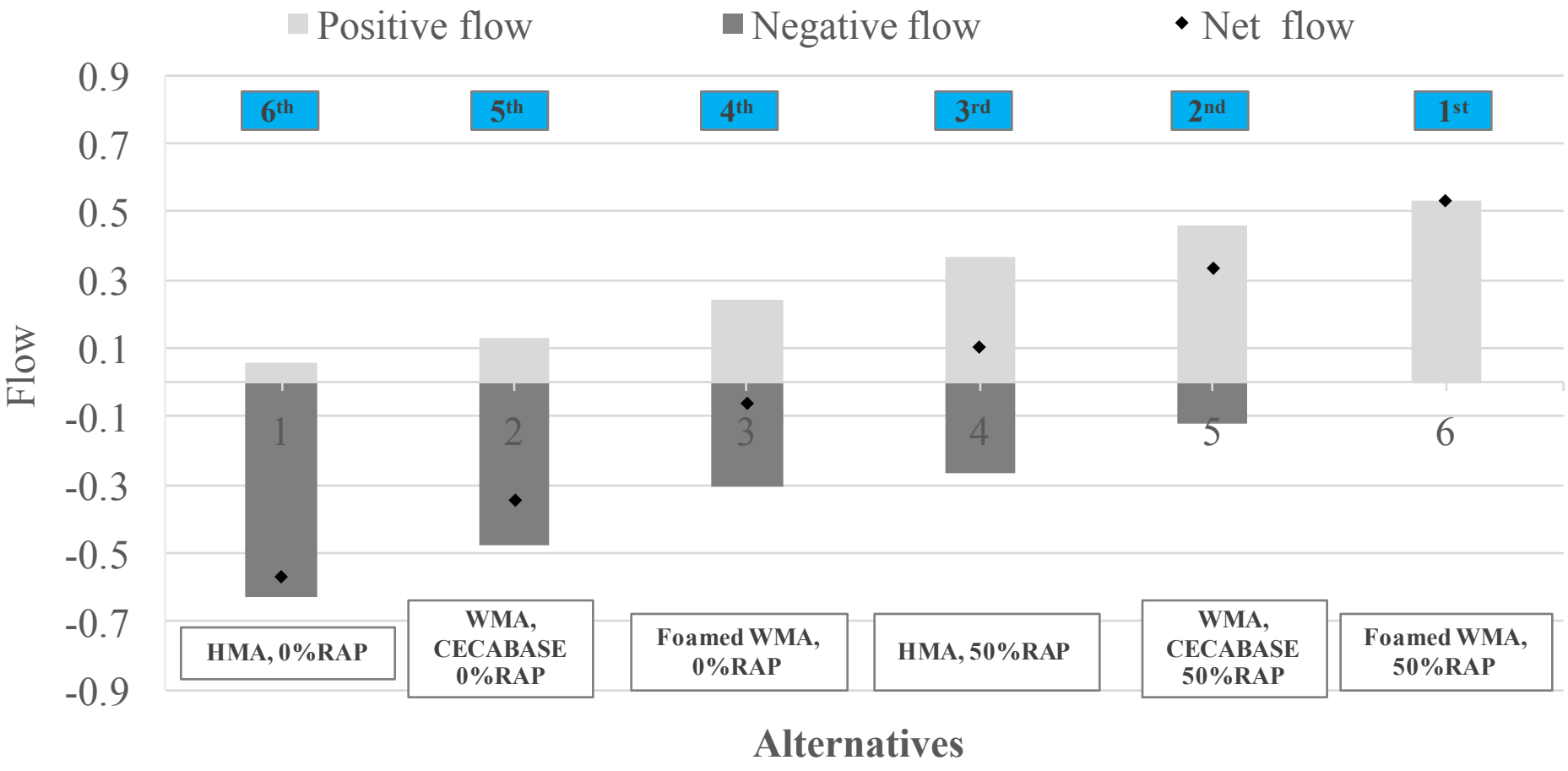
Case Study: Road Pavement

Sensitivity analysis (weights)



Case Study: Road Pavement

Sustainability Ranking



Conclusions

Flexible Performance-based Sustainability Assessment

General SA Framework

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Sustainable Pavement & Railway Internal Training Network

ER1, ER1bis - Sustainability Assessment framework:

- Objectives
- Categories
- Indicators identity

ER2,

- Selection methodology

ER3

- Multi-Criteria Decision Analysis (Rating tool)

Conclusions

SUP&R MCDA tool

General SA Framework

SUP&R ITN
Sustainable Pavement & Railway Internal Training Network

ER1, ER1bis - Sustainability Assessment framework:

- Objectives
- Categories
- Indicators identity
- Stakeholders engagement (Weighting set)

ER2,

- Review of system specific scientific papers, reports, etc
- Selection methodology (ER2)
- Railway indicator selection
- Sust Assess SUP&R railway technologies

System specific tasks:

- Road Pavements

- Railway trackbeds

ER3

- Multi-Criteria Decision Analysis (Rating tool)
- Review of papers, reports, SRS
- Pavement indicator selection
- Sust Assess SUP&R railway technologies

ACKNOWLEDGMENTS

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement number 607524.

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SUPeRITN
#sustainablepavement(s)
#sustainablerailway(s)

The next one…

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2017/2021

SMARTI

European Training Network

Sustainable Multi-functional Automated Resilient Transport Infrastructures

15 Marie Curie researchers in place

http://smartietn.eu

GRAZIE!

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PROJECTS:

- **Sustainable Pavements**
- **Sustainable Railways**
- **Sustainability Assessment of Transport Infrastructures**