CERCOM

Circular Economy in Road COnstruction and Maintenance

CERCOM case studies for validation of risk-based analysis framework

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Selected case studies

Case study	Type of application	Project	Country	Circularity level
Maintenance options for asphalt pavements	Asphalt	In-situ rejuvenation of ZOAB	Netherlands (NL)	Extend lifespan of pavements (R4)
		Refurbishing milled asphalt into new bound layers - BSM technology	Denmark (DK)	Reuse existing pavement to create new pavement with addition of limited materials (R5 or R6)
Recycling concrete technologies	Concrete	Processing technologies for aggregate recycling	Netherlands (NL)	Recycle (R8)

For resources, reports, and description of other case studies, link to CERCOM webpage: https://cercom.project.cedr.eu/

Selected case study

In-situ rejuvenation of porous asphalt (ZOAB)

- *Netherlands*
- *Circularity level – extend lifespan of pavement (R4)*

Spraying rejuvenating agents over existing ZOAB layer to extend its service life

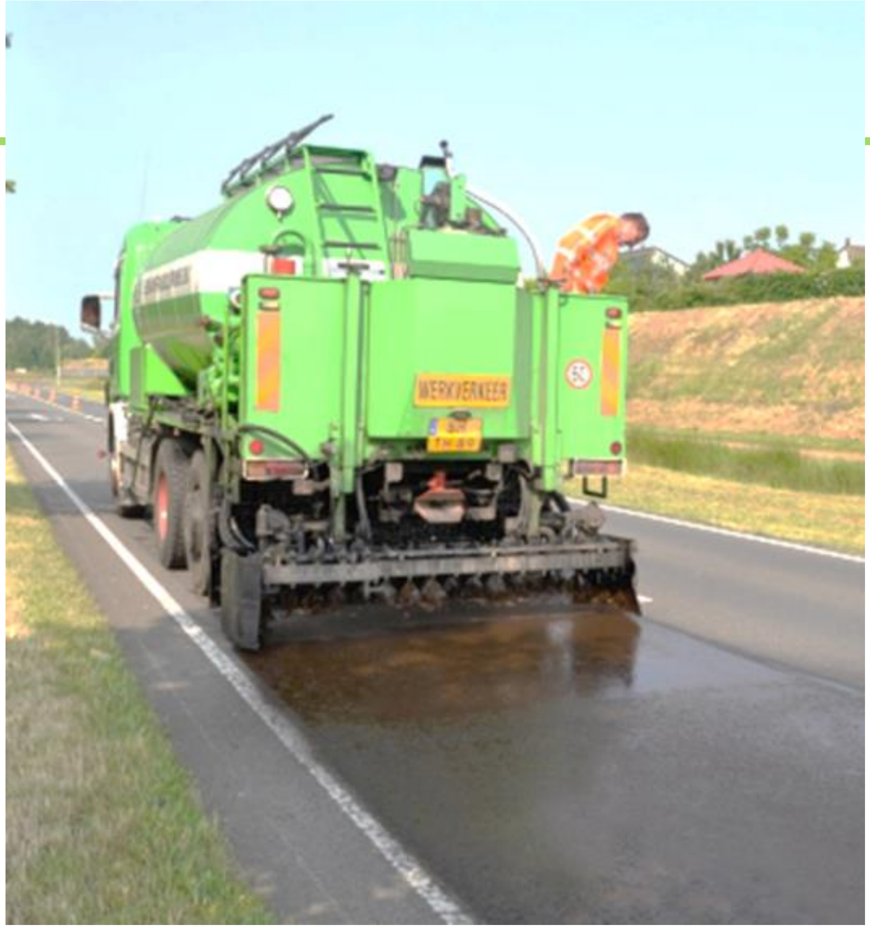

Image source: https://docplayer.nl/123192566-Factsheets-levensduurverlengende-technieken-voor-asfaltverhardingen.html

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Risk-based analysis framework

ASSESSMENT CATEGORIES

Construction or maintenance strategies

A

B

- Technical performance
- Economic - LCCA
- Resource efficiency and circular economy
- Environmental LCA
- Social LCA

Proposed set of assessment categories

Use of additional or fewer assessment categories feasible

Risk-based analysis framework

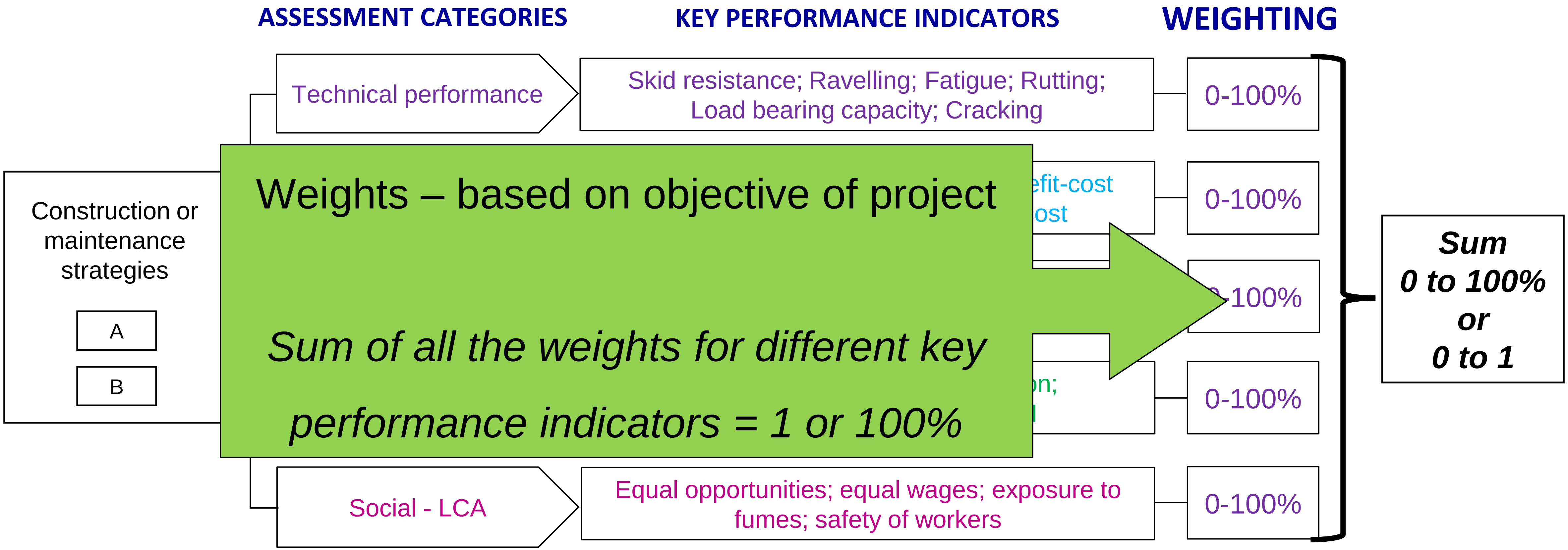
Typical examples of key performance indicators

Use of additional or fewer or different indicators feasible

ASSESSMENT CATEGORIES	KEY PERFORMANCE INDICATORS
Technical performance	Skid resistance; Ravelling; Fatigue; Rutting; Load bearing capacity; Cracking
Economic - LCCA	Net present value; Value added; Benefit-cost ratio; Equivalent uniform annual cost
Resource efficiency and circular economy	Circular economy index; Material circularity index; Circularity measurement toolkit; Platform CB'23
Environmental - LCA	Climate change-total; Acidification; Eutrophication-freshwater; MKI
Social - LCA	Equal opportunities; equal wages; exposure to fumes; safety of workers; technological advancements

For KPI computation methodology, refer to Deliverable 4.1 & 4.2 at CERCOM webpage: https://cercom.project.cedr.eu/

Risk-based analysis framework



For KPI computation methodology, refer to Deliverable 4.1 & 4.2 at CERCOM webpage: https://cercom.project.cedr.eu/

Risk-based analysis framework

Maintenance strategies

A

B

ASSESSMENT CATEGORIES	KEY PERFORMANCE INDICATORS	WEIGHTING
Technical performance	Skid resistance; Ravelling; Fatigue; Rutting; Load bearing capacity; Cracking	0-100%
Economic - LCCA	Net present value; Value added; Benefit-cost ratio; Equivalent uniform annual cost	0-100%
Resource efficiency and circular economy	Circular economy index; Material circularity index; Circularity measurement toolkit; Platform CB'23	0-100%
Environmental - LCA	Climate change-total; Acidification; Eutrophication-freshwater; MKI	0-100%
Social - LCA	Equal opportunities; equal wages; exposure to fumes; safety of workers	0-100%

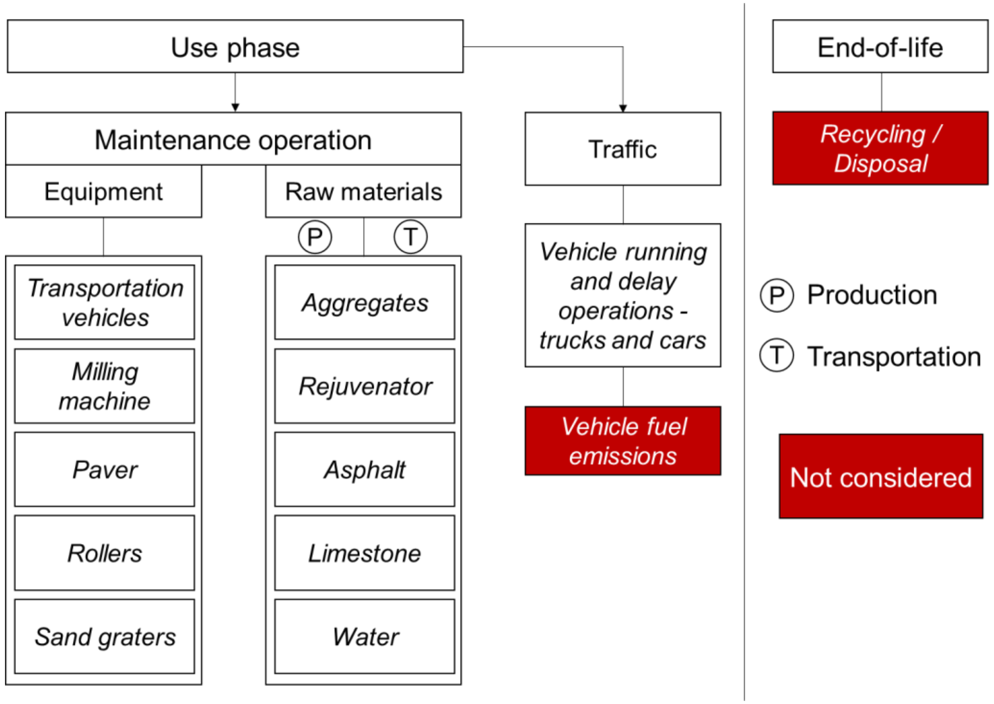
OPTIMIZATION & RANKING

Net risk reduction gain (NRRG)

$$NRRG_i = w_1 \times RRI_i + w_2 \times KPI_{1,i} + w_3 \times KPI_{2,i} + w_4 \times KPI_{3,i} + w_4 \times KPI_{3,i} + \cdots$$

Case studies

- Porous asphalt (ZOAB) in-situ rejuvenation
- ZOAB resurfacing using virgin materials



Case studies

- Porous asphalt (ZOAB) in-situ rejuvenation
- ZOAB resurfacing using virgin materials

Maintenance strategies

ZOAB rejuvenation

Resurfacing

ASSESSMENT CATEGORIES	KEY PERFORMANCE INDICATORS
Technical performance	Skid resistance and ravelling
Economic - LCCA	Net present value
Resource efficiency and circular economy	Circular economy index
Environmental - LCA	Climate change-total; Acidification Eutrophication-freshwater; Resource use
Social - LCA	Social impacts of pavement

Lifecycle assessment (LCA) – Environmental impacts

Category	Key performance indicators	Units	Rejuvenation	Resurfacing
LCA – environmental impacts	Climate change - total	kg CO_2 eq.	30938	50320
	Acidification	Mole of H^+ eq.	188.74	194.88
	Eutrophication, freshwater	kg P eq.	4.74	0.17
	Resource use, mineral and metals	kg Sb eq.	0.74	0.009

- In-situ rejuvenation → 39% lower kg CO_2 eq. than resurfacing
- kg CO_2 eq. contribution:
  - *Rejuvenation → production of rejuvenator (60%)*
  - *Resurfacing → material production (67%) - calcium hydroxide filler and bitumen*

Lifecycle cost assessment (LCCA) – economic impacts

- Deterministic lifecycle cost assessment (discount rate – 5%)

Maintenance alternative	Total (Million EUR)	Agency costs (Million EUR)	Vehicle operating costs (Million EUR)	Delay costs (Million EUR)	Salvage value (Million EUR)
Rejuvenation	**0.084**	0.072	0.007	0.005	0
Resurfacing	**0.177**	0.156	0.018	0.014	0.012

- Cost of rejuvenation → 7 times lower than for resurfacing
- User costs (vehicle operation and delay) for rejuvenation → 63% lower than the resurfacing

Lifecycle assessment (LCA) – social impacts

Stakeholders	Sub-categories
Worker	Working hours
	Health and safety
Local community	Local employment
	Access to material resources
	Secure living conditions
	Public commitment to sustainability issues
Society	Technological development
	Contribution to economic development
Consumer	Health and safety
	Feedback mechanism
	End-of-life responsibility

Larger value of SIP indicative of higher social benefits

Circular economy (CE) and resource efficiency (RE)

$$CEI_i = \sum_i \left[\frac{Material\ value\ added}{Material\ value\ for\ reproducing\ end-of-life\ product}\right]$$

Material value added → residual value – non-factor cost

Residual value → cost of material in given year – cumulative depreciation expense

Non-factor costs → expenditure incurred during maintenance

Material value for reproducing end-of-life product → expenditure for construction of new pavement

Circular economy (CE) and resource efficiency (RE)

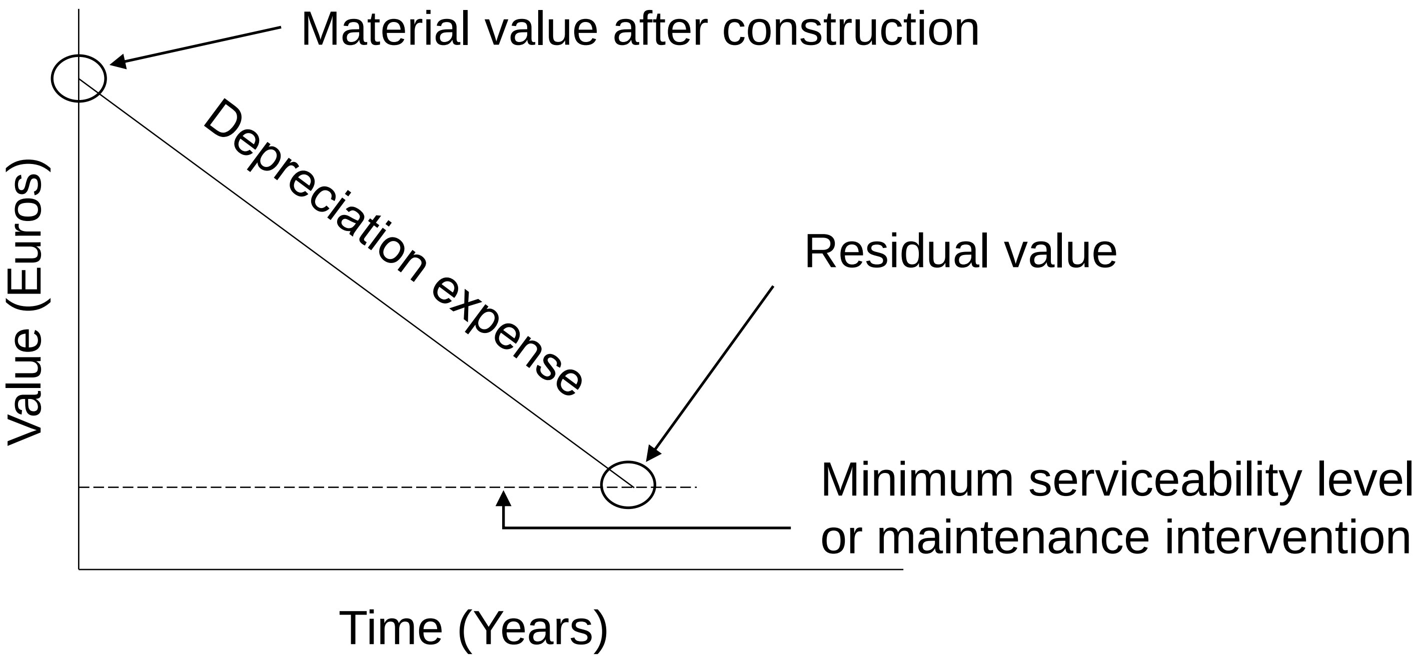
$$CEI_i = \sum_i \left[\frac{Material\ value\ added}{Material\ value\ for\ reproducing\ end-of-life\ product} \right]$$

Material value added

residual value – non-factor cost

Residual value

initial cost of material in given year – cumulative depreciation expense

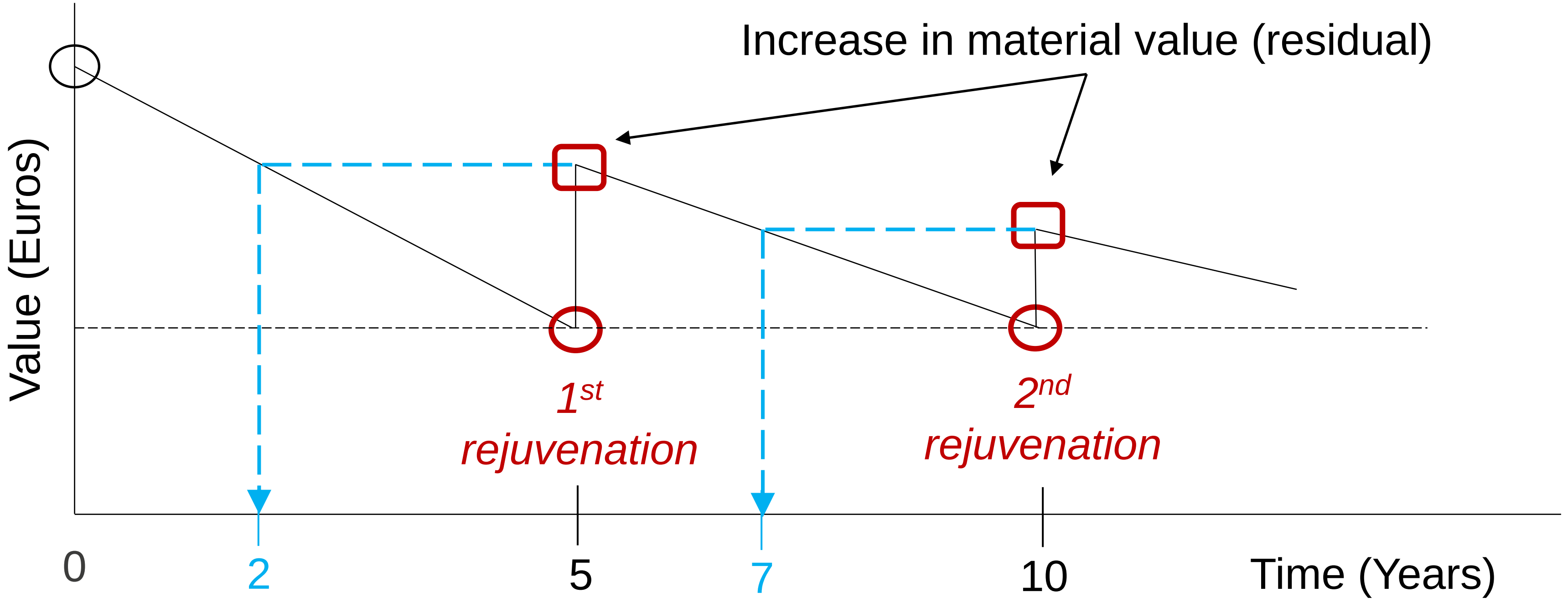


Circular economy (CE) and resource efficiency (RE)

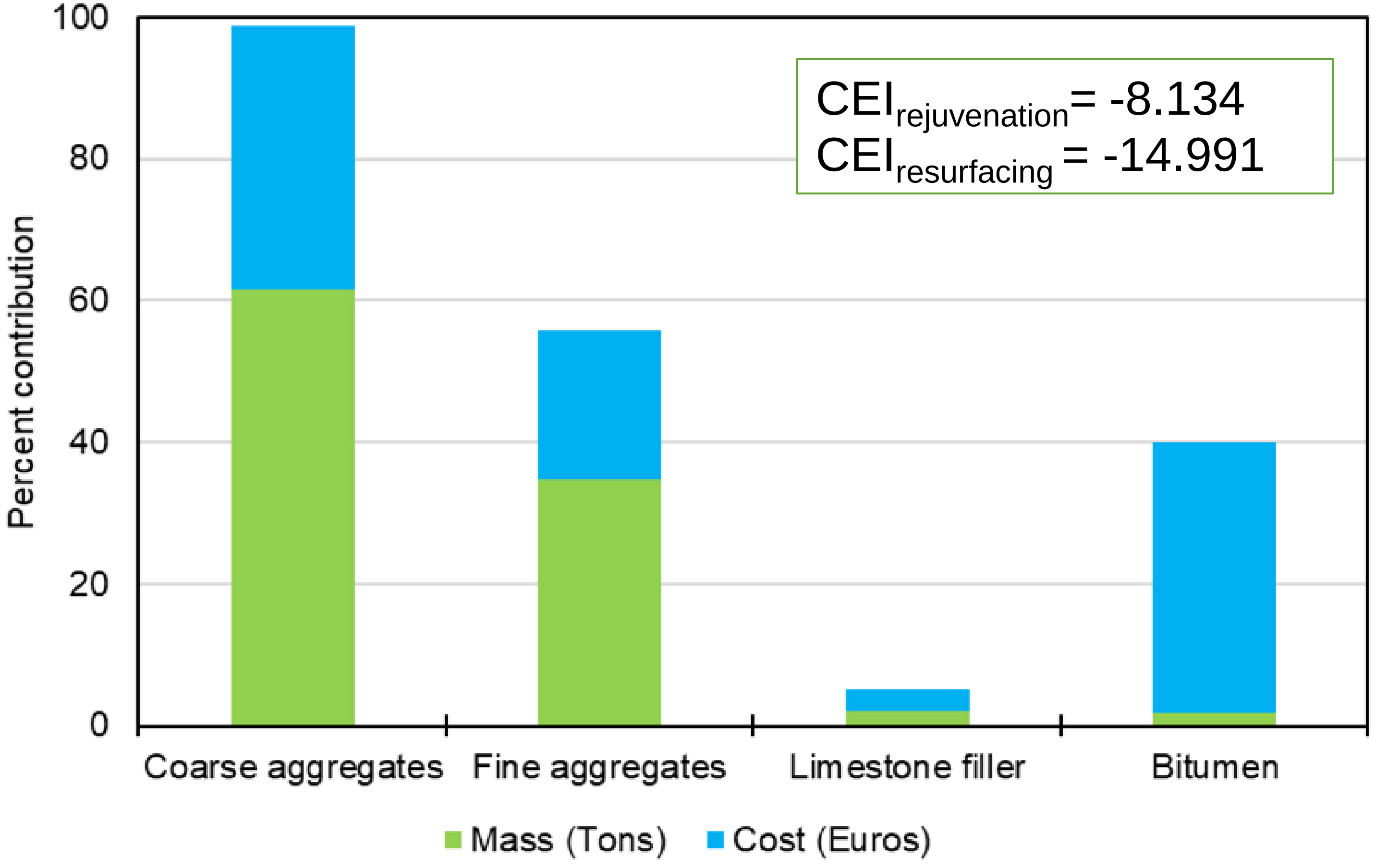
Assumptions

- Design life of ZOAB → 15 years
- Material depreciation rate (reciprocal of design life) → 6.67%
- Each rejuvenation **increases service life by 3 years**

$$CEI_i = \sum_i \left[\frac{Material\ value\ added}{Material\ value\ for\ reproducing\ end-of-life\ product}\right]$$



Circular economy (CE) and resource efficiency (RE)



Material / activity	Quantity / dosage (tonnes)	Base year price (EUR)
Coarse aggregates	279.99	4611.48
Fine aggregates	158.15	2604.75
Limestone	9.10	397.49
Bitumen	7.77	4741.49
Rejuvenation (m^2)	0.00088	2.31
Resurfacing (m^2)	-	16

Larger value of CEI indicative of higher circularity

Risk assessment using cost of consequences

Cost of consequences → crash costs

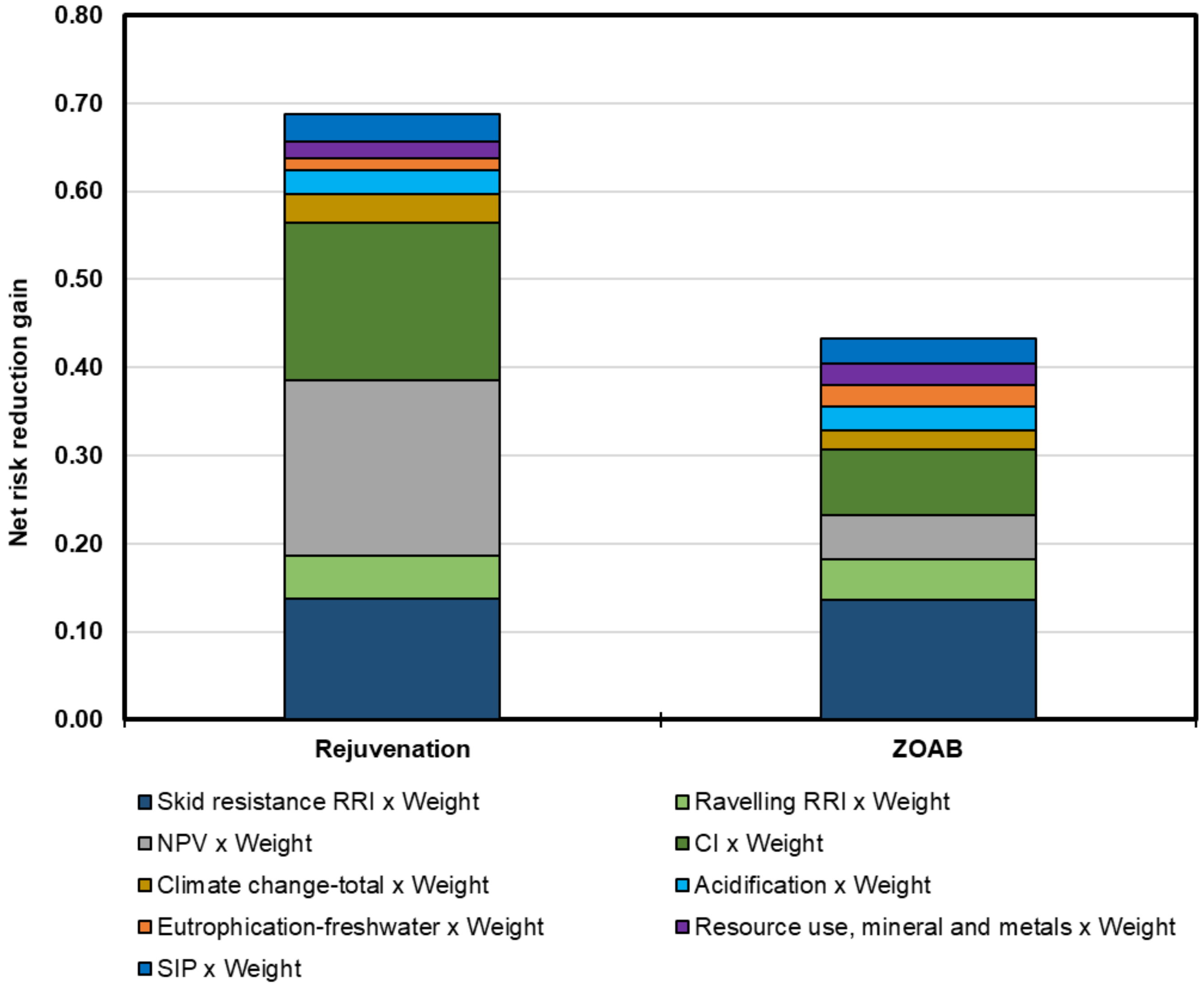
- Average annual crash costs → SWOV 2020
- Netherlands → road fatalities (15%); severe injuries (55%); minor damage (17%)
- Data: initial skid resistance, reduction in skid resistance with time, crash rate per 100 million vehicle km

Cost of consequences (Million EUR)	Technical KPIs					
	Skid resistance			Ravelling		
	Do-minimum	Rejuvenation	Resurfacing	Do-minimum	Rejuvenation	Resurfacing
Fatality	1650.95	134.60	160.53	1.60	0.06	0.11
Serious injury	6053.48	493.53	588.61	5.86	0.23	0.40
Minor damage	1871.07	152.55	181.93	1.81	0.07	0.12
Total	**9575.50**	**780.68**	**931.07**	**9.27**	**0.37**	**0.63**

Do-minimum → no maintenance activity is performed

Net risk reduction gain (NRRG)

KPIs	Weight	KPI value	
		Rejuvenation	Resurfacing
Skid resistance	0.15	-	-
Ravelling	0.05	-	-
Climate change	0.05	0.66	0.44
Acidification	0.05	0.56	0.53
Eutrophication-freshwater	0.05	0.26	0.49
Resource use	0.05	0.38	0.50
Net present value	0.25	0.80	0.20
Circular economy index	0.3	0.59	0.25
Social impact	0.05	0.64	0.55



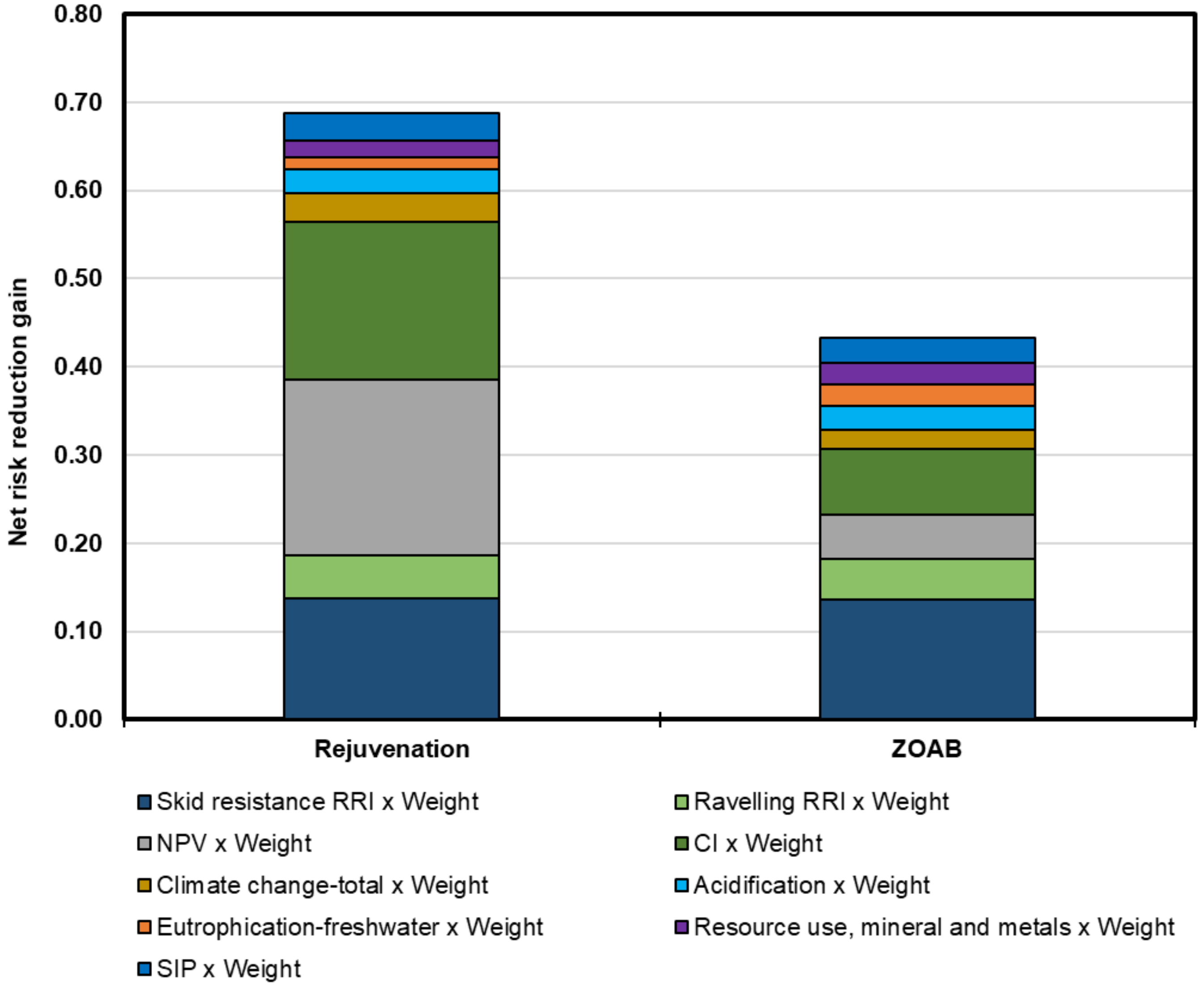
Net risk reduction gain (NRRG)

- $NRRG_{rejuvenation}$ → 1.60 times higher than resurfacing
- Similar technical risks for two maintenance options
- Economic and circularity benefits for rejuvenation

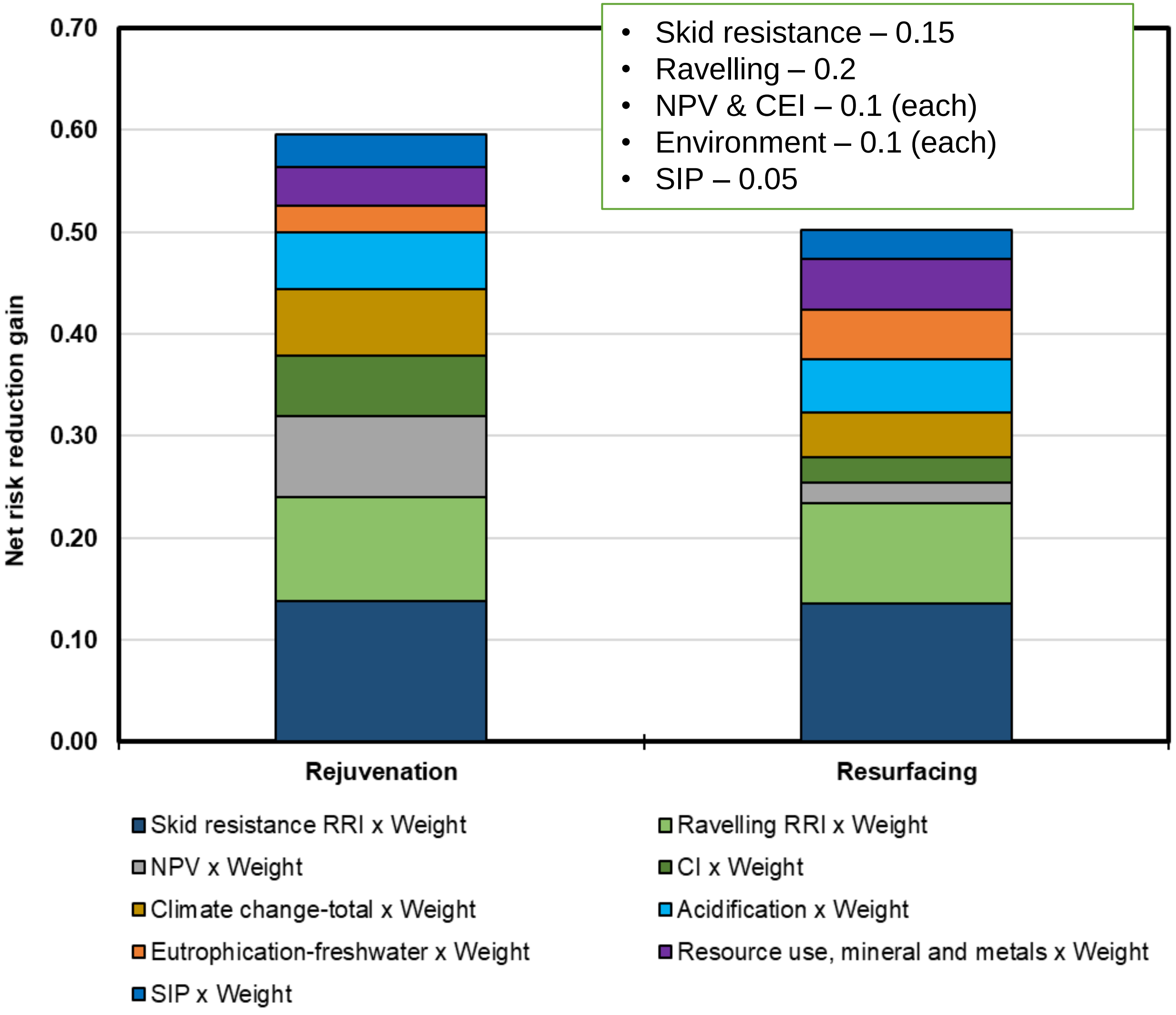
Preventative maintenance (rejuvenation) has higher net risk reduction gain over corrective maintenance (resurfacing)

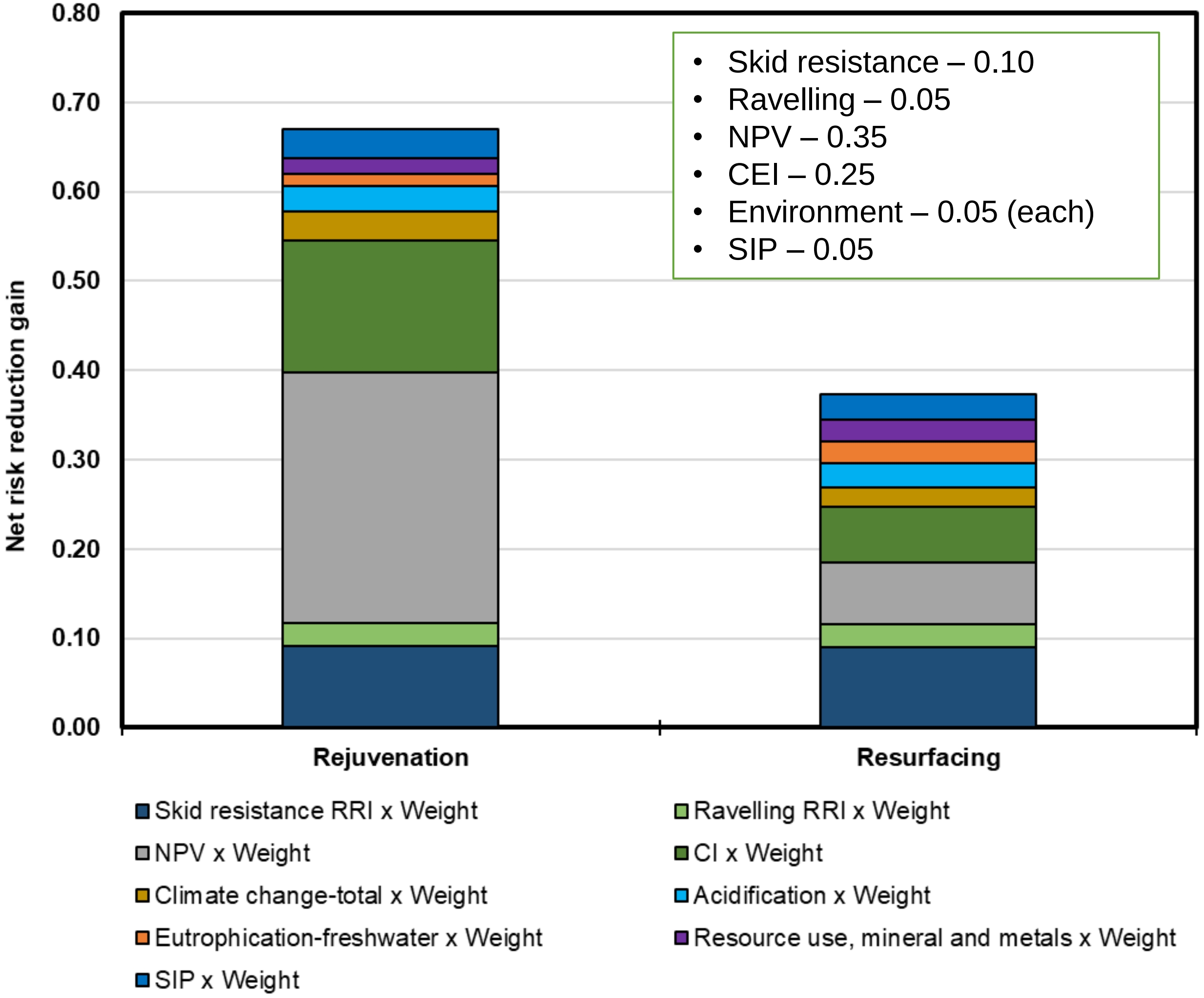
Higher NRRG – circular and sustainable option

Note: these results were generated based on the data collected from different pavement stakeholders and are applicable to the current case studies only



Influence of weights on net risk reduction gain (NRRG)





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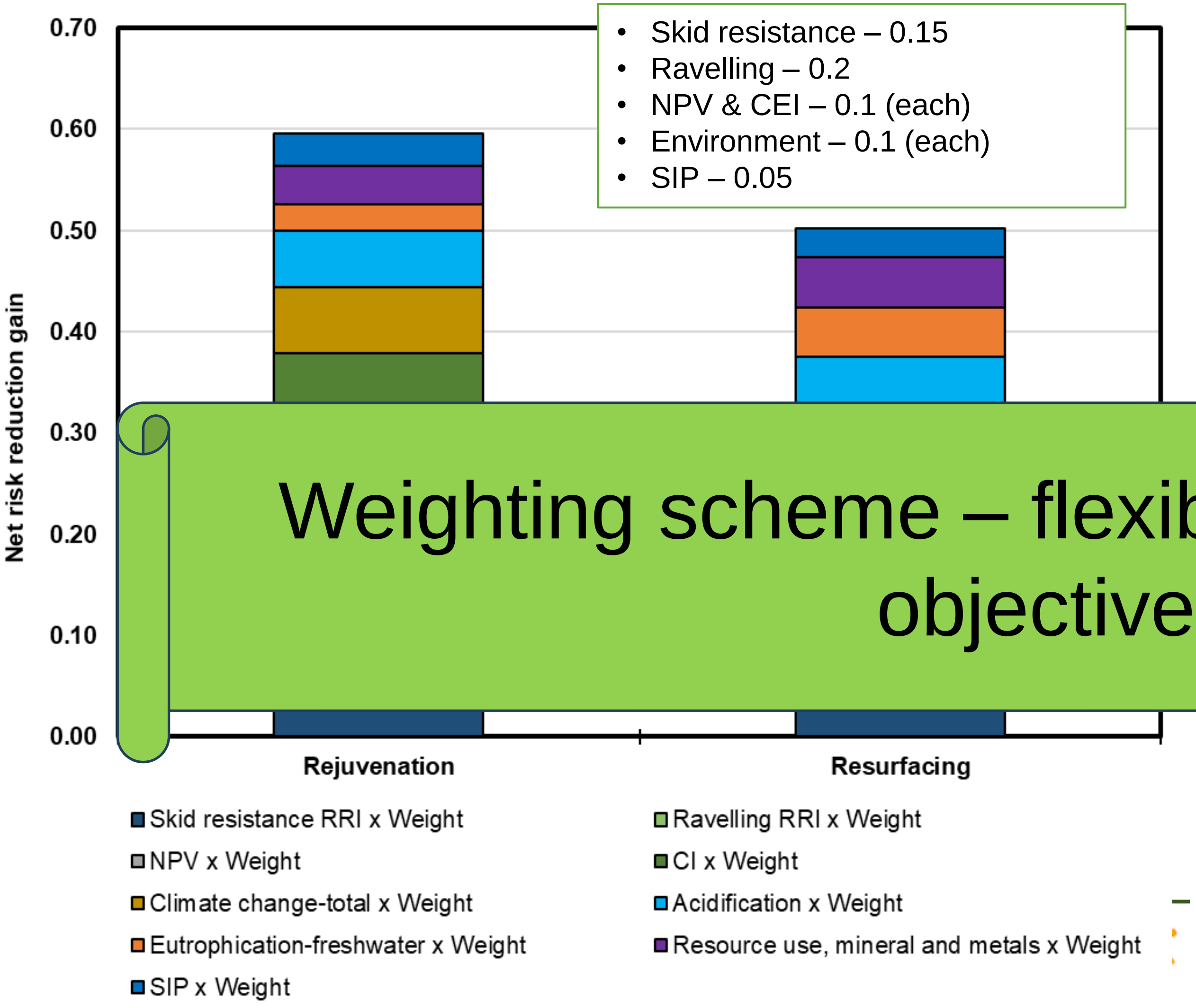
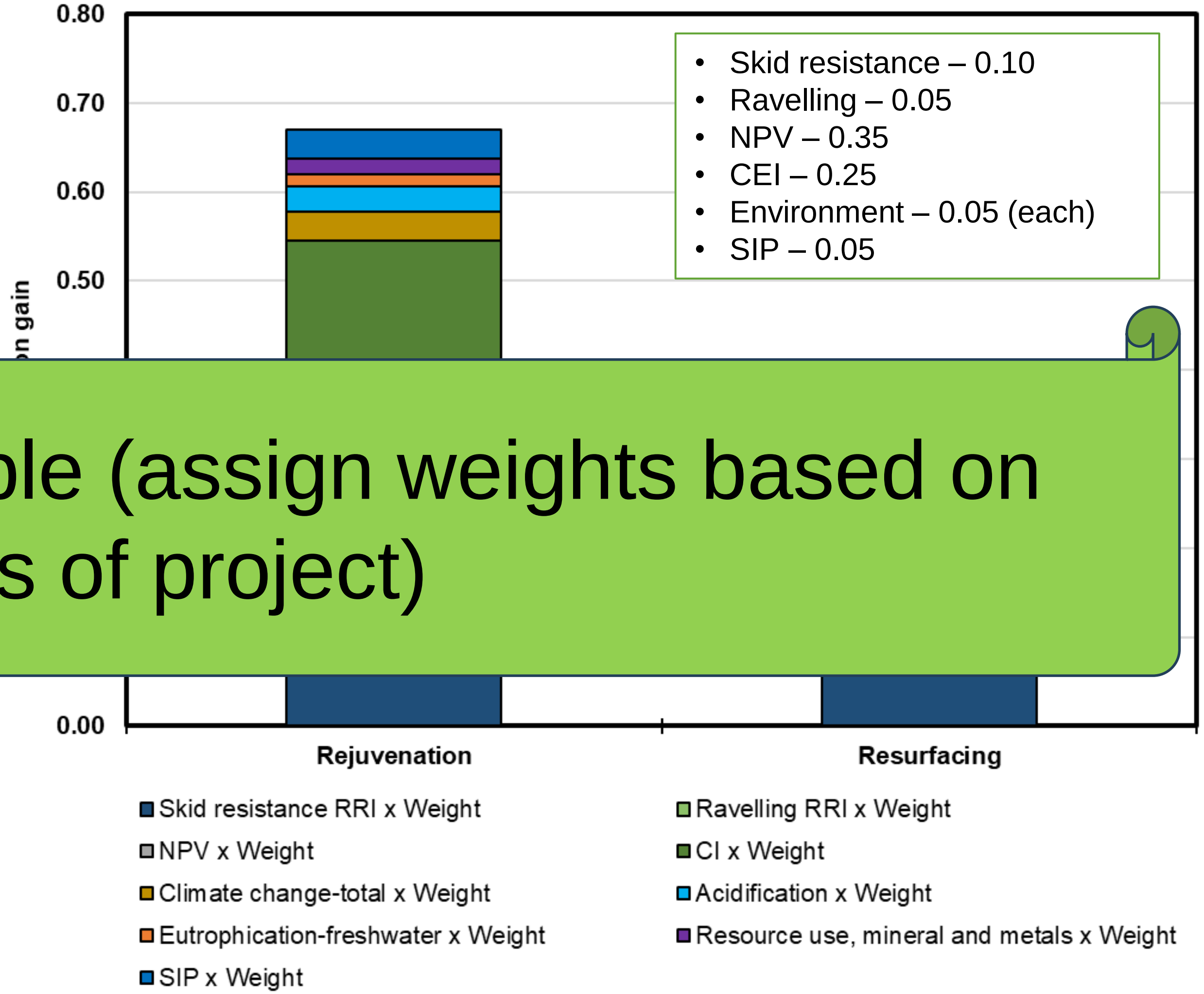




Weighting scheme – flexible (assign weights based on objectives of project)

Data requirements

Surveying, inspections, and site clearance/preparation

Raw material production (asphalt, aggregates, filler, additives, etc.)

Loading-unloading vehicles, other equipment, and transportation

Mixture production and transportation

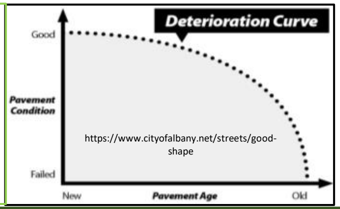
Pavement construction and maintenance – materials, equipment, and transportation distance

Traffic characteristics – flow, density, vehicle distribution, running cost, delay cost (at scheduled construction/maintenance and biannual/annual)

Waste strategies – demolition, transportation, processing, recycling, reusing, etc.

Social impact data
decision-makers, roadway agencies, national statistics board, Eurostat, & other sources

Pavement condition roughness, skid resistance, other distress (annual/biannual)



Lessons learnt

- Need for spatially and temporally **harmonized data**
- Develop systematic **approach** for quantification of risk
- **Performance prediction models** based on literature and secondary data
- Record the **variation** in performance characteristics **with time**
- **Engage** in knowledge sharing activities with **stakeholders**

- Risk-based analysis framework → **Excel® based tool** to select optimum maintenance strategy
- For **circularity** assessment, a **value-based indicator** was proposed
- Choice to **assign different weights** to various KPIs based on their level of importance

Risk-based framework → promising tool to assist in selection of sustainable and circular pavement construction and maintenance options

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Thank you!

Question, comments, and suggestions?

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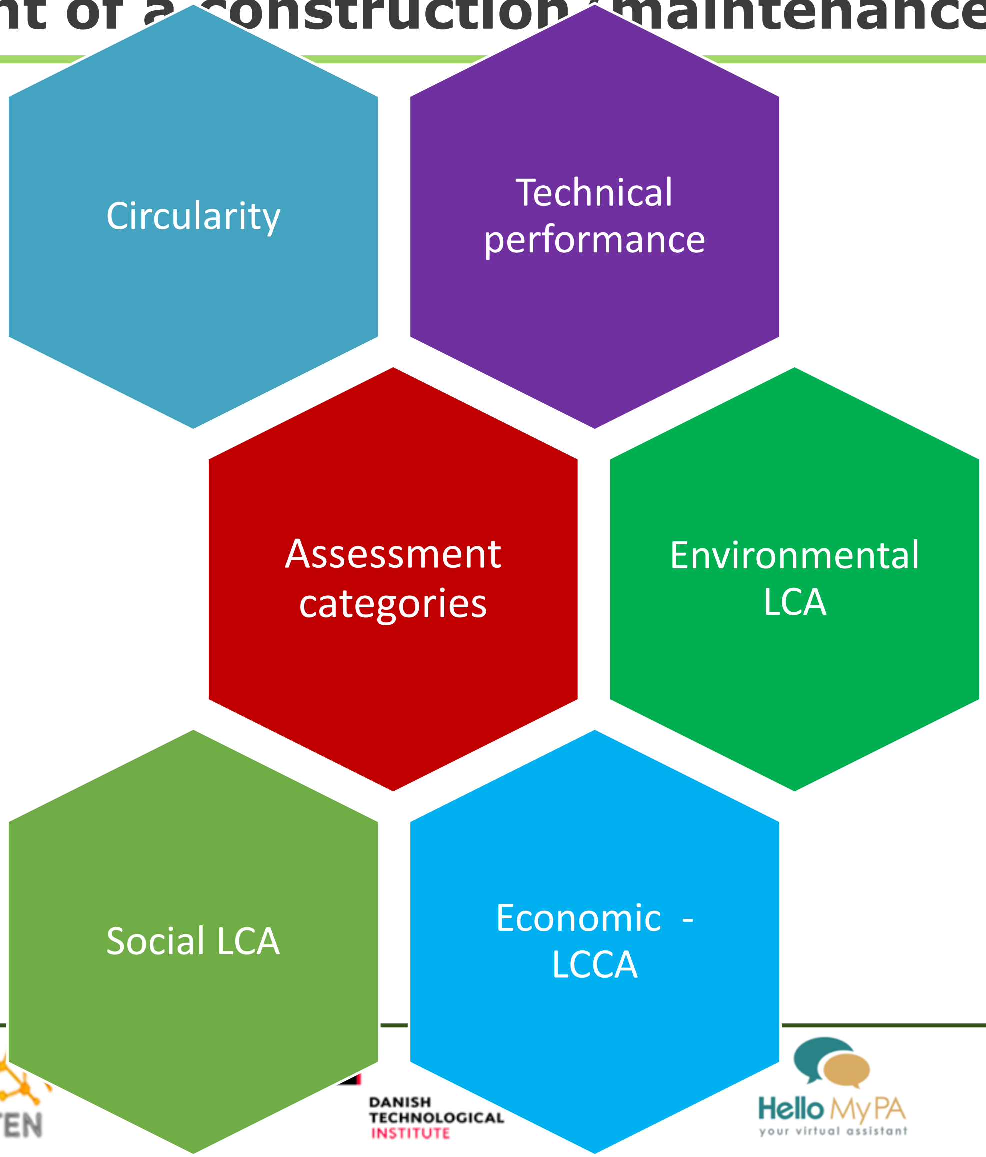
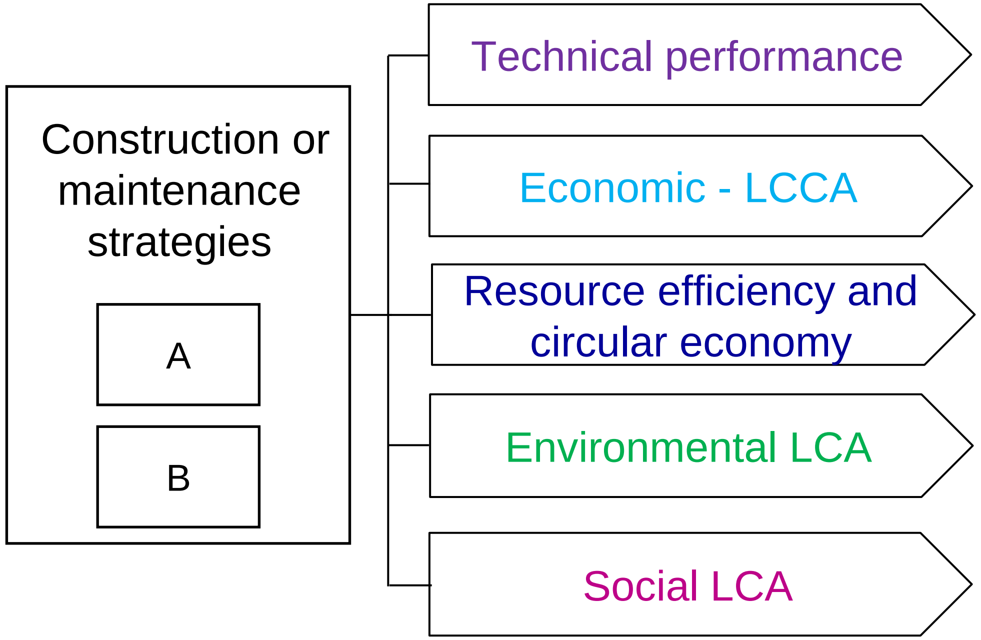
Think of a case study in your organization and suggest how to utilize the CERCOM framework for procurement of a construction/maintenance option.

a) What assessment categories does your organization consider to evaluate pavement construction or maintenance options?



Think of a case study in your organization and suggest how to utilize the CERCOM framework for procurement of a construction/maintenance option.

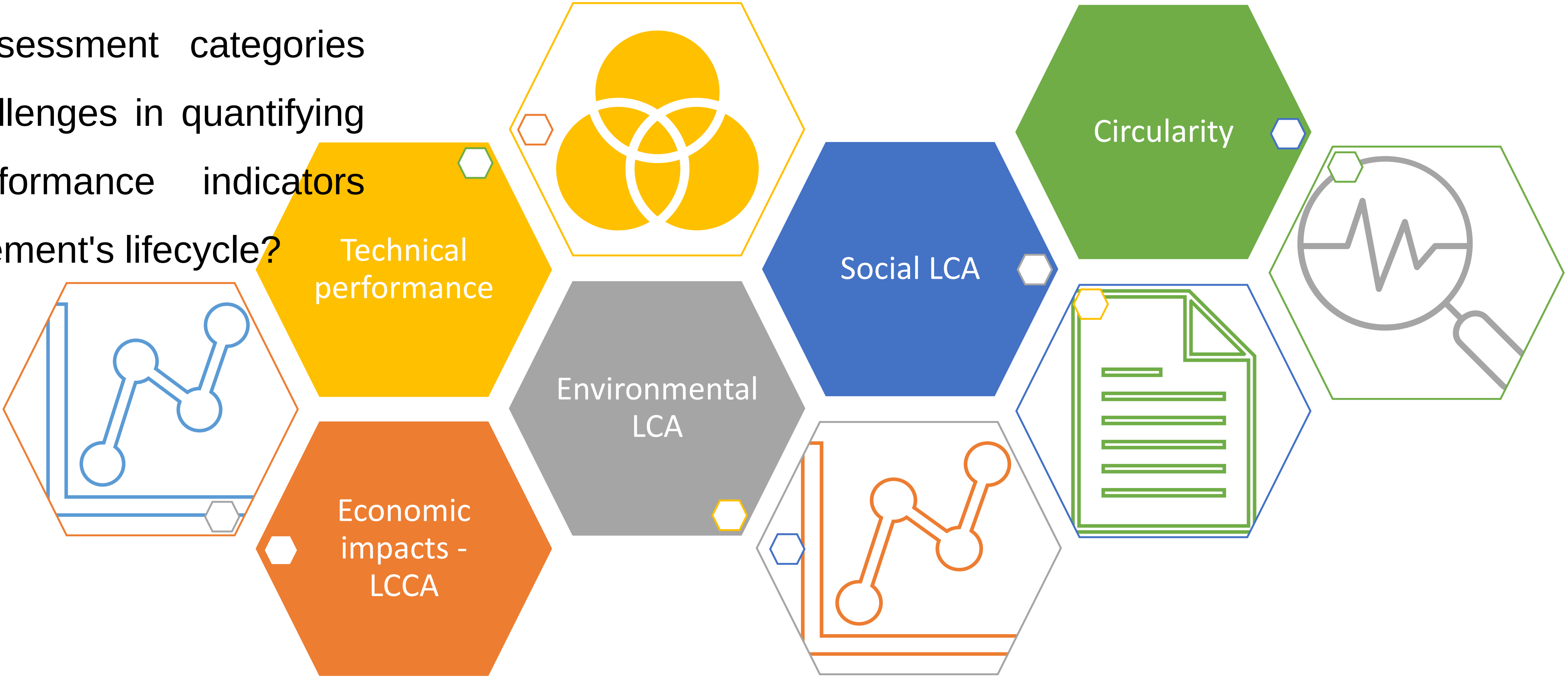
b) What key performance indicators does your organization undertake to evaluate pavement construction and maintenance options?



KEY PERFORMANCE INDICATORS????

Think of a case study in your organization and suggest how to utilize the CERCOM framework for procurement of a construction/maintenance option.

c) What assessment categories pose challenges in quantifying key performance indicators over pavement's lifecycle?



Think of a case study in your organization and suggest how to utilize the CERCOM framework for procurement of a construction/maintenance option.

d) What data does your organization possess for evaluating assessment categories in CERCOM framework?

Think of a case study in your organization and suggest how to utilize the CERCOM framework for procurement of a construction/maintenance option.

d) What data does your organization possess for evaluating assessment categories in CERCOM framework?

e) Which tools does your organization use to evaluate pavement circularity?

Think of a case study in your organization and suggest how to utilize the CERCOM framework for procurement of a construction/maintenance option.

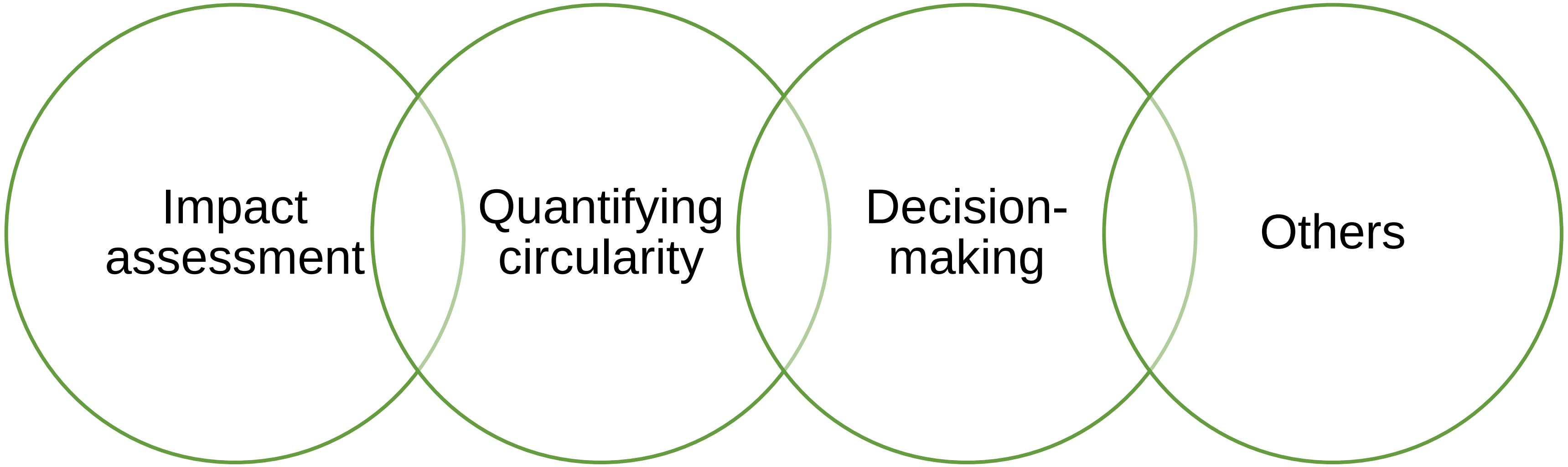
d) What data does your organization possess for evaluating assessment categories in CERCOM framework?

e) Which tools does your organization use to evaluate pavement circularity?

f) Which framework, if any, does your organization employ either with a smaller or broader scope, to facilitate decision-making?

Do you think CERCOM tool can be used within your organization to facilitate procurement of circular solutions?

a) What are the potential benefits of using the CERCOM framework in your organization?



Do you think CERCOM tool can be used within your organization to facilitate procurement of circular solutions?

a) What are the potential benefits of using the CERCOM framework in your organization?

b) How do you think the implementation of CERCOM framework would impact collaboration and communication among stakeholders within our organization?

Do you think CERCOM tool can be used within your organization to facilitate procurement of circular solutions?

a) What are the potential benefits of using the CERCOM framework in your organization?

b) How do you think the implementation of CERCOM framework would impact collaboration and communication among stakeholders within our organization?

c) Do you have suggestions to make any changes to the current CERCOM framework to facilitate its adoption in your organization?

Do you think CERCOM tool can be used within your organization to facilitate procurement of circular solutions?

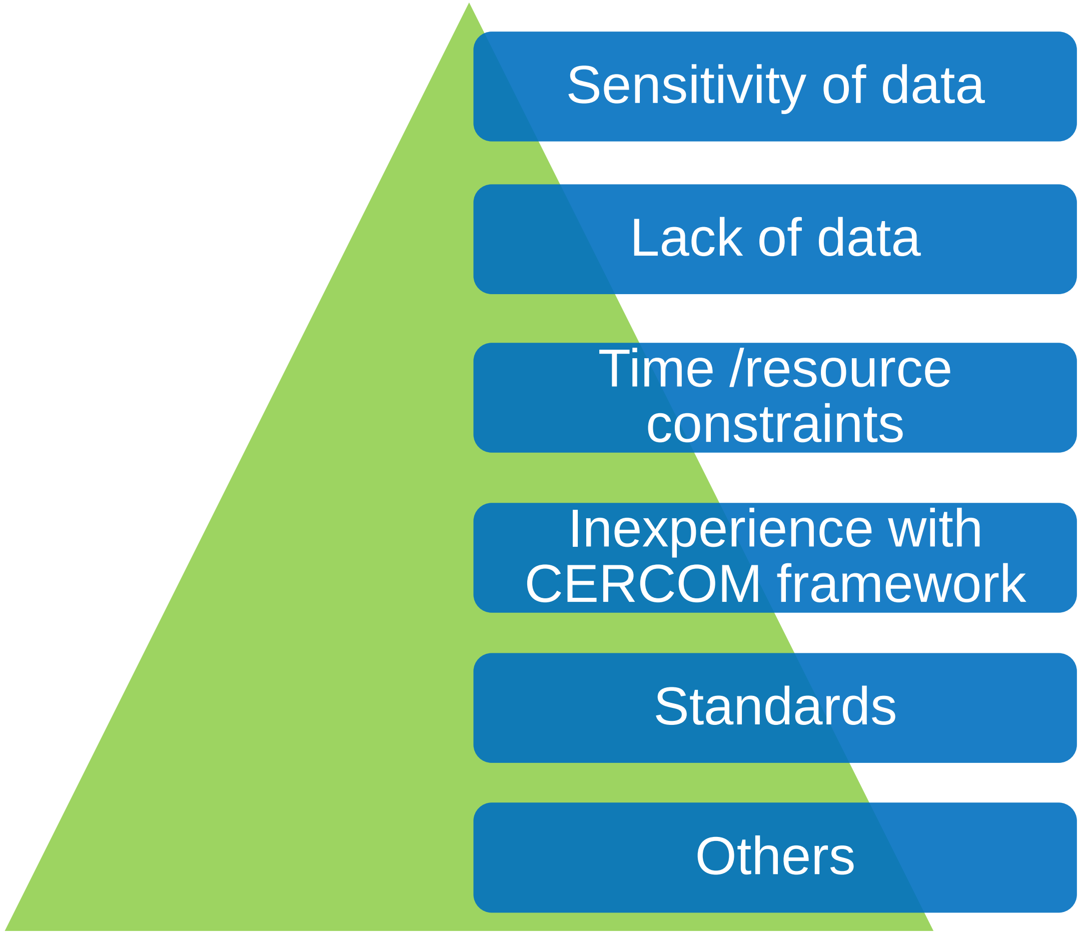
a) What are the potential benefits of using the CERCOM framework in your organization?

b) How do you think the implementation of CERCOM framework would impact collaboration and communication among stakeholders within our organization?

c) Do you have suggestions to make any changes to the current CERCOM framework to facilitate its adoption in your organization?

d) From your perspective, what additional resources or support would be necessary to effectively implement the CERCOM framework in our organization?

What are the potential barriers for implementation of CERCOM risk-based analysis framework within procurement practices?



Which factors would provide increased motivation to consider circularity during tendering process?

- Net zero targets (within organization)
- Economic consideration
- Requirement in standards
- Specified in tender award criteria
- Availability of materials and resources
- Others

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