



Circular Economy in Road COnstruction and Maintenance

Risk Based Analysis Framework

Dr. Emma Sheils, emma.sheils@researchdrivensolutions.ie

Research Driven Solutions

CEDR 2020 Resource Efficiency and Circular Economy - Final Conference

12th & 13th March 2024

Funded by

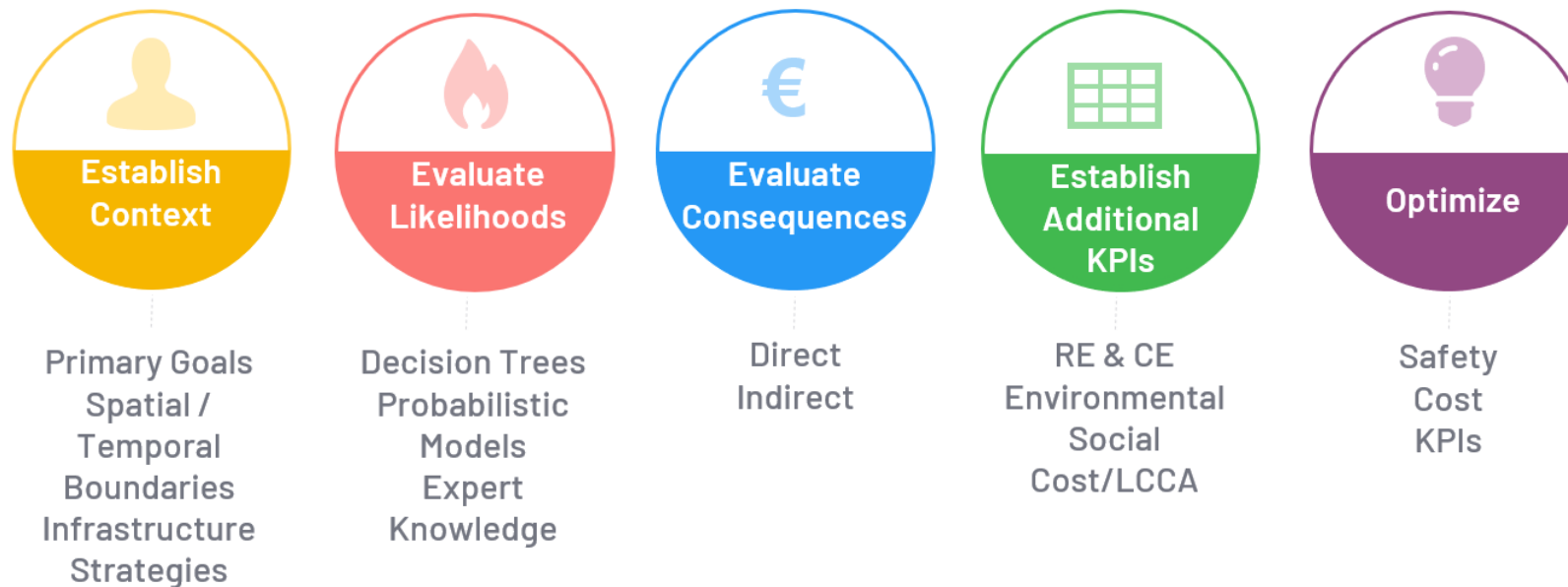


Collaborative Session 3 Outline

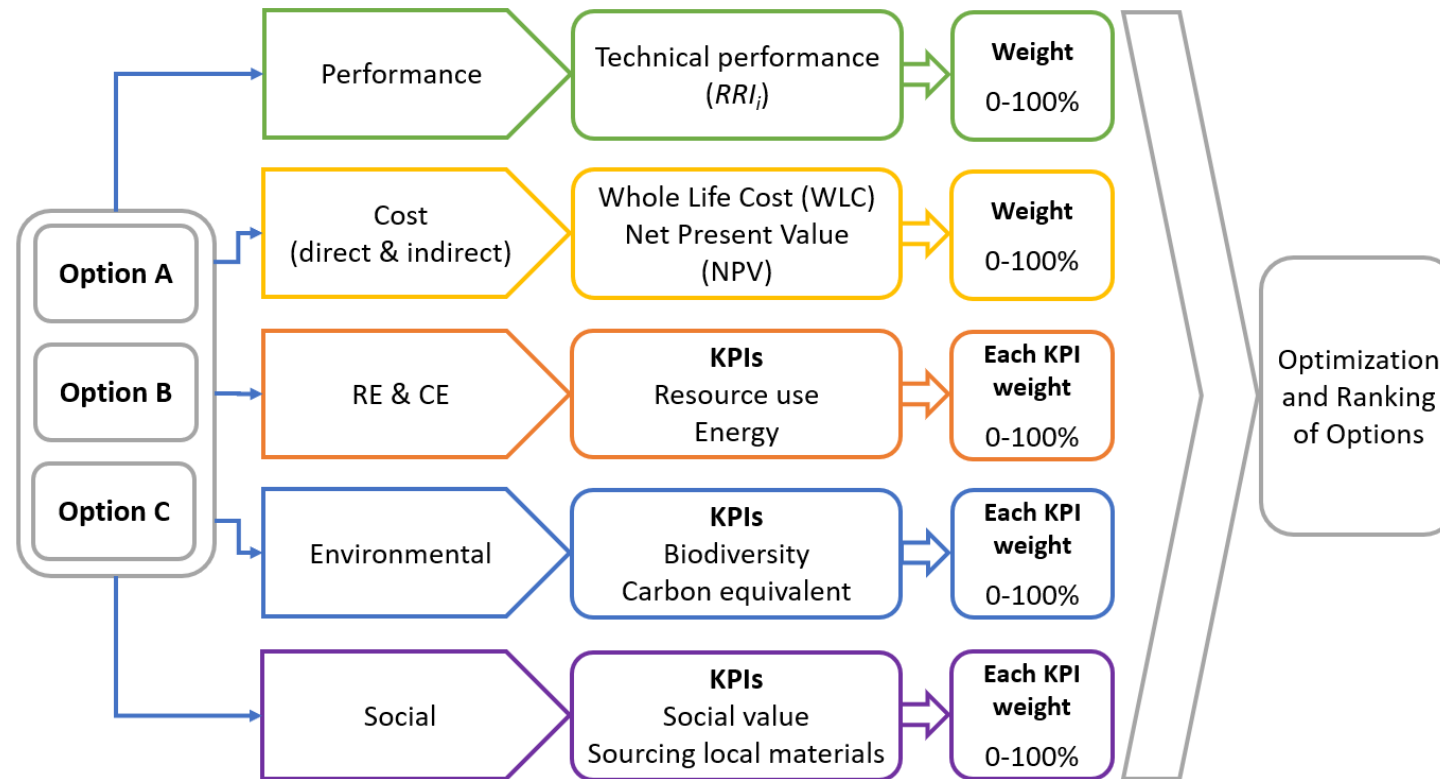
- RBAF and Software tool video demonstration 30 minutes
- CERCOM case study 15 minutes
- Discussion and feedback 30 minutes

Risk Based Analysis Framework (RBAF)

- Development of a framework to facilitate circular procurement with the ability to assess the technical risk of incorporating novel or innovative solutions into design, maintenance and construction of road infrastructure
- Assess current practice as well as more circular solutions



Development of Criteria/KPIs



Single Performance Metric

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

$KPI_{3,4,5\dots,i}$ = Values of each KPI (between 0 and 1) associated with maintenance / construction option i ;

$w_{1,2,3\dots}$ = Values of weights for each KPI.

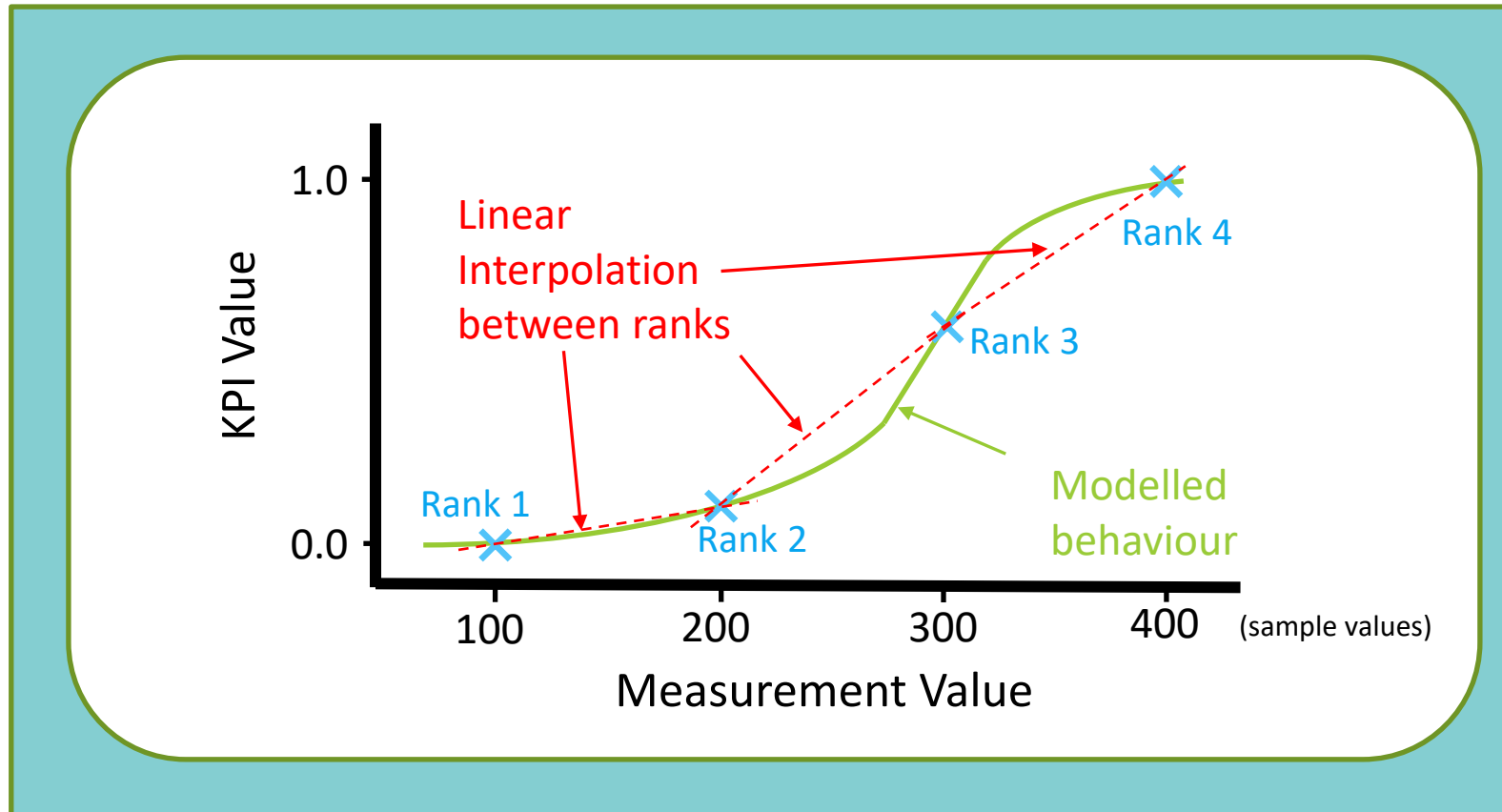
$$RRI_i = \frac{R - R_i}{R}$$

R = Risk associated with the “Do Nothing” option;
 R_i = Risk associated with maintenance / construction option i ;

$$CPI_i = \frac{B - C_i}{B}$$

B = Budget available for maintenance / construction activity;
 C_i = Cost associated with maintenance / construction option i ;

Additional KPIs: Ranked Interpolation



Rank 1 = minimum acceptable performance, KPI 0



Rank 2 = industry norm, established practice but not always applied, KPI 0.15



Rank 3 = industry leading performance, uncommon, KPI 0.6



Rank 4 = medium term goal, KPI 1.0.

Risk Based Software Tool

Risk Base Analysis Framework
(Version V6.0)

This software tool can be used to quantify and assess the risks and other economic, social, environmental factors associated with moving from a linear to a circular economy. Using the tool, it is possible to assess the "Do minimum" option as well as 3 possible alternative schemes. For users with low maturity and a limited amount of data, it is possible to use pre-set scales to input information based on empirical evidence. Higher maturity can choose to input more specific and accurate information for the scheme and maintenance options in question and use the inputs from LCA/ALCA to assess multi-life cycle factors.

Instructions

1. Enable Macros
2. User input - Insert data into 'WHITE BOXES' with black border in "Input Data" worksheet. All white boxes require an input. Grey boxes indicate that user input is optional.
3. The number of scheme options being considered is selected. This can be between 1 and 3. Note: The "Do Minimum" option is a requirement of the analysis for reference purposes.
4. Some input boxes require numerical input, data or text and others require user to select from a drop down menu.
5. For each construction/maintenance option - the sum of the weights selected for KPIs must equal to 1.0. If the sum of weights is not equal to 1, an error message will be displayed and values should be reviewed.
6. Pre-set PF values for the calculation of risk are based on two inputs selected by the user from a drop down menu, one related to the performance characteristics of the construction/ maintenance option and the other related to the level of uncertainty the user has in relation to the performance characteristics. This references a matrix of values for the determination of PF value.
7. KPI calculation using Ranked Interpolation - The user can choose to input data to calculate KPIs or select pre-set values from a drop down menu. When the user chooses Numerical Input, the number of ranks, the unit of measurement for the data considered, the least favourable and most favourable threshold values must be entered, as well as a data value for each proposed construction/maintenance scheme option. When 2 ranks are chosen, a KPI value of 0 is assigned to the least favourable rank and a KPI value of 1.0 is assigned to the most favourable rank. A value for each scheme option is entered between these thresholds and linear interpolation is carried out to determine the KPI value. It is possible to select up to 4 ranks and use multi-linear interpolation, with a different slope between each rank. In this case, numerical values must be entered to quantify each rank using a data input value and a corresponding KPI value between 0 and 1. **Note: least favourable and most favourable threshold values must be entered before**

8. When the user chooses to select KPIs using a pre-set scale, the following options are available:
 0.00 - No commitment to KPI ambition
 0.10 - Below minimum industry practice
 0.25 - Minimum industry practice
 0.50 - Exceed industry practice
 0.75 - Far exceeds industry practice

Project Name: _____ Date: _____

Project Number: _____ User Initials: _____

Number of Scheme Options to be considered:

Description	Value	Unit
Length of road		km
Type of Road		-
Budget available		Euro
Duration of assessment period		years
Name of Scheme	Option 1	-
	Option 2	-
	Option 3	-

Click to Clear User Inputs for Worksheet

General Scheme Information

Input Criteria name or KPI name as text in "name" column and select input type in drop down menu for the number of options

Category	Name	Do	Option 1	Option 2	Option 3
Performance					
Cost					
CE					
Environment					
Social					

Option A

Option B

Option C

Performance

Technical performance (RR)

Weight 0.100%

Cost (direct & indirect)

Whole Life Cost (WLC)

Net Present Value (NPV)

Weight 0.100%

RE & CE

KPIs

Resource use

Energy

Each KPI weight 0.100%

Environmental

KPIs

Biodiversity

Carbon equivalent

Each KPI weight 0.100%

Social

KPIs

Social value

Sourcing local materials

Each KPI weight 0.100%

Optimization and Ranking of Options

Input Values for Performance and Risk
(Risk = Probability of Failure x Consequences)

Risk	Probability of Failure	Consequences (unit of currency)			
Name	Input	Do	Option 1	Option 2	Option 3
Performance	Uncertainty				
	User - Numerical Input (Between 0 and 1)				
Performance	Uncertainty				
	User - Numerical Input (Between 0 and 1)				
Performance	Uncertainty				
	User - Numerical Input (Between 0 and 1)				
Performance	Uncertainty				
	User - Numerical Input (Between 0 and 1)				
Performance	Uncertainty				
	User - Numerical Input (Between 0 and 1)				
Performance	Uncertainty				
	User - Numerical Input (Between 0 and 1)				
Performance	Uncertainty				
	User - Numerical Input (Between 0 and 1)				

Results

Press Button for Updated Results

Product of Criteria/KPI and Weight				
Category	Name	Option A	Option B	Option C
Performance	Technical Performance RRI x Weight	0.20	0.23	0.18
Cost	CPI x Weight	0.18	0.16	0.24
CE	Example CE 1 x Weight	0.04	0.04	0.08
	Example CE 2 x Weight	0.06	0.03	0.05
Environment	Example Environment x Weight	0.03	0.05	0.03
Social	Example Social x Weight	0.06	0.01	0.04
Net Risk Reduction Gain (NRRG)		0.56	0.50	0.60

Technical Performance RRI x Weight
CPI x Weight
Example CE 1 x Weight
Example CE 2 x Weight
Example Environment x Weight
Example Social x Weight

Input Format

Category	Name	Input Format			
		Do Minimum	Option A	Option B	Option C
Performance	Technical Performance	Preset scale	Numerical Input	Preset scale	Numerical Input
Cost	Cost (CPI)		Numerical Input	Numerical Input	Numerical Input
	Example Cost 2		Preset scale	Preset scale	Numerical Input
CE	Example CE 1		Numerical Input	Numerical Input	Preset scale
	Example CE 2		Numerical Input	Preset scale	Preset scale
Environment	Example Environment		Preset scale	Preset scale	Preset scale
Social	Example Social		Numerical Input	Preset scale	Numerical Input

Option B	Option C
Preset scale	Numerical Input
Preset scale	Numerical Input

For each white cell, user selects input format from drop down menu

Risk Assessment Input

Input Values for Performance and Risk (Risk = Probability of Failure x Consequences)					
Risk	Probability of Failure				
Name	Input	Do Minimum	Option A	Option B	Option C
Technical Performance	Performance	Above Average		Below Average	
	Uncertainty	Low		High	
	User - Numerical Input (between 0 and 1)				

Pre-set scale input

Numerical input

User provides estimate of performance and uncertainty for required options using drop down

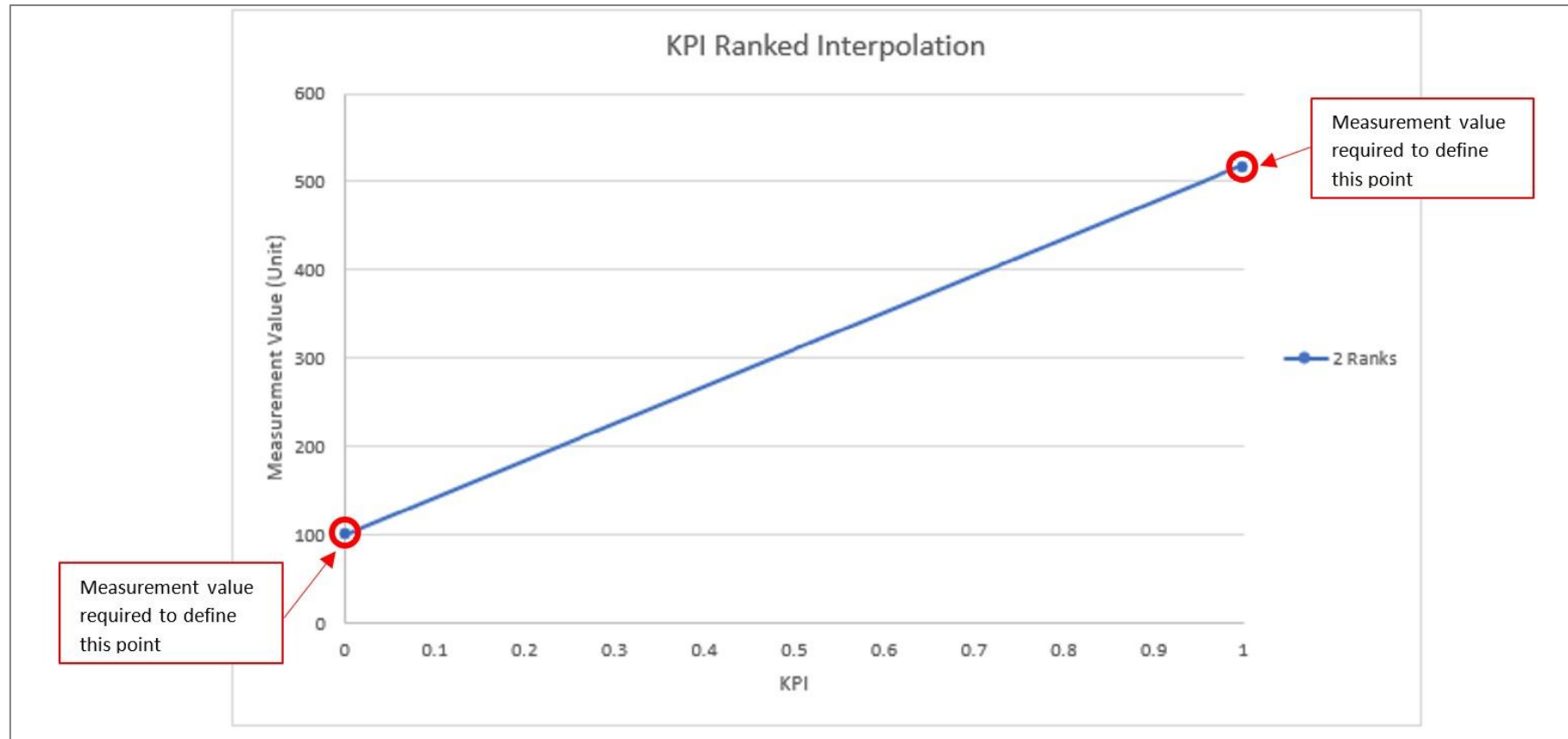
Risk	Probability of Failure				
Name	Input	Do Minimum	Option A	Option B	Option C
Technical Performance	Performance	Above Average		Below Average	
	Uncertainty	Low		High	
	User - Numerical Input (between 0 and 1)		0.2		0.15

Pre-set scale input

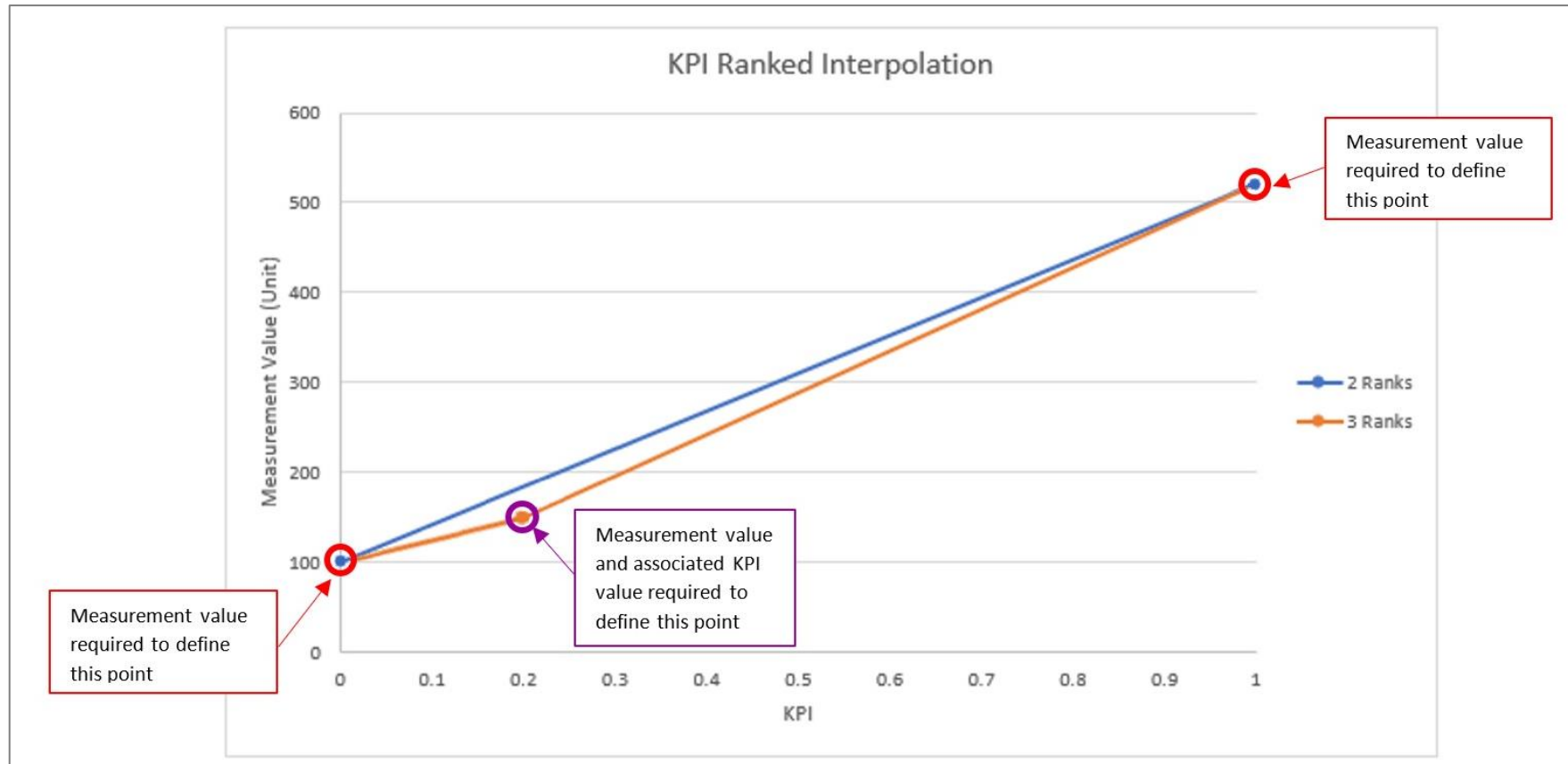
Numerical input

User numerical value for Pf (value between 0 and 1.0)

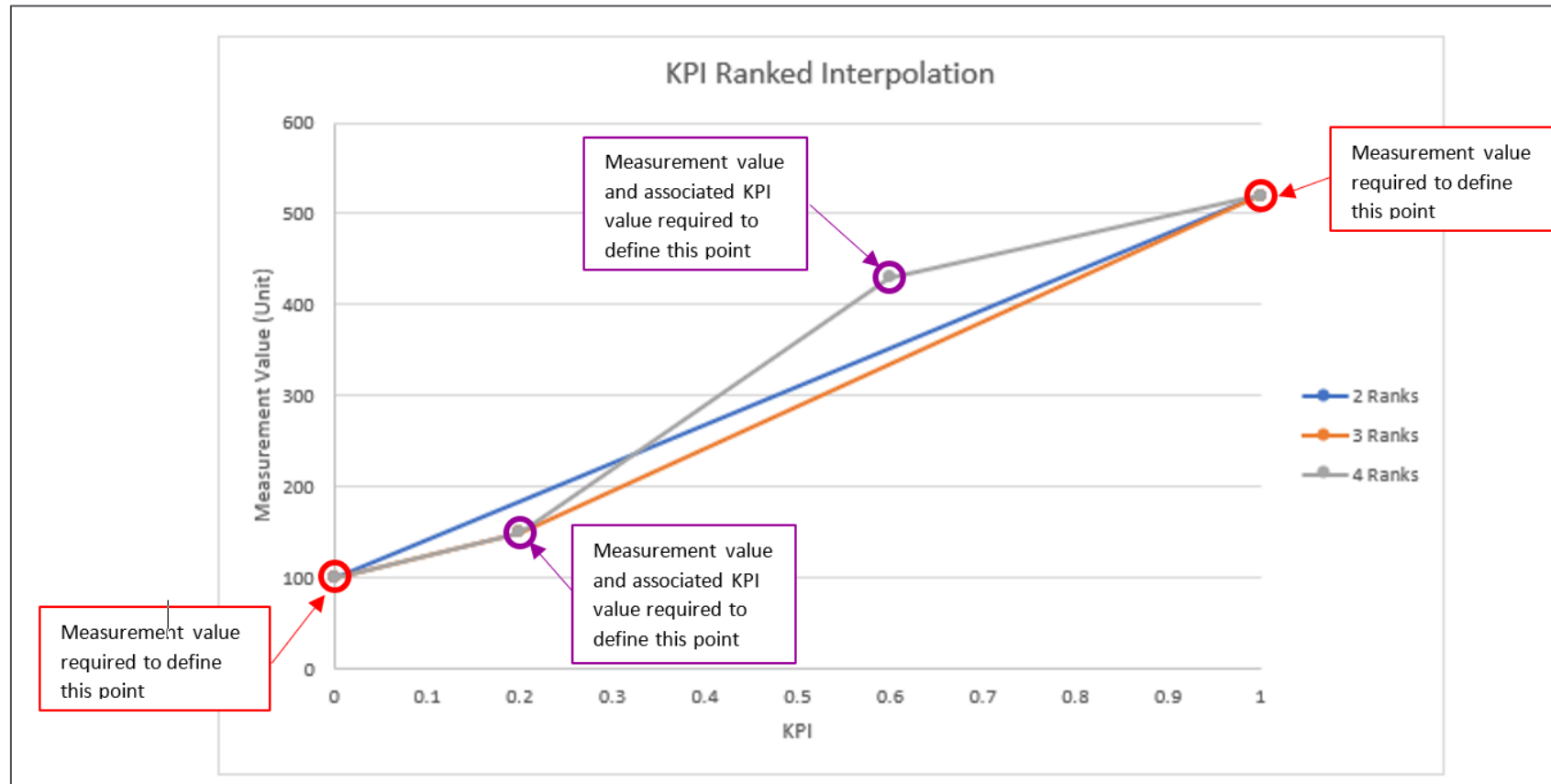
Ranked Interpolation



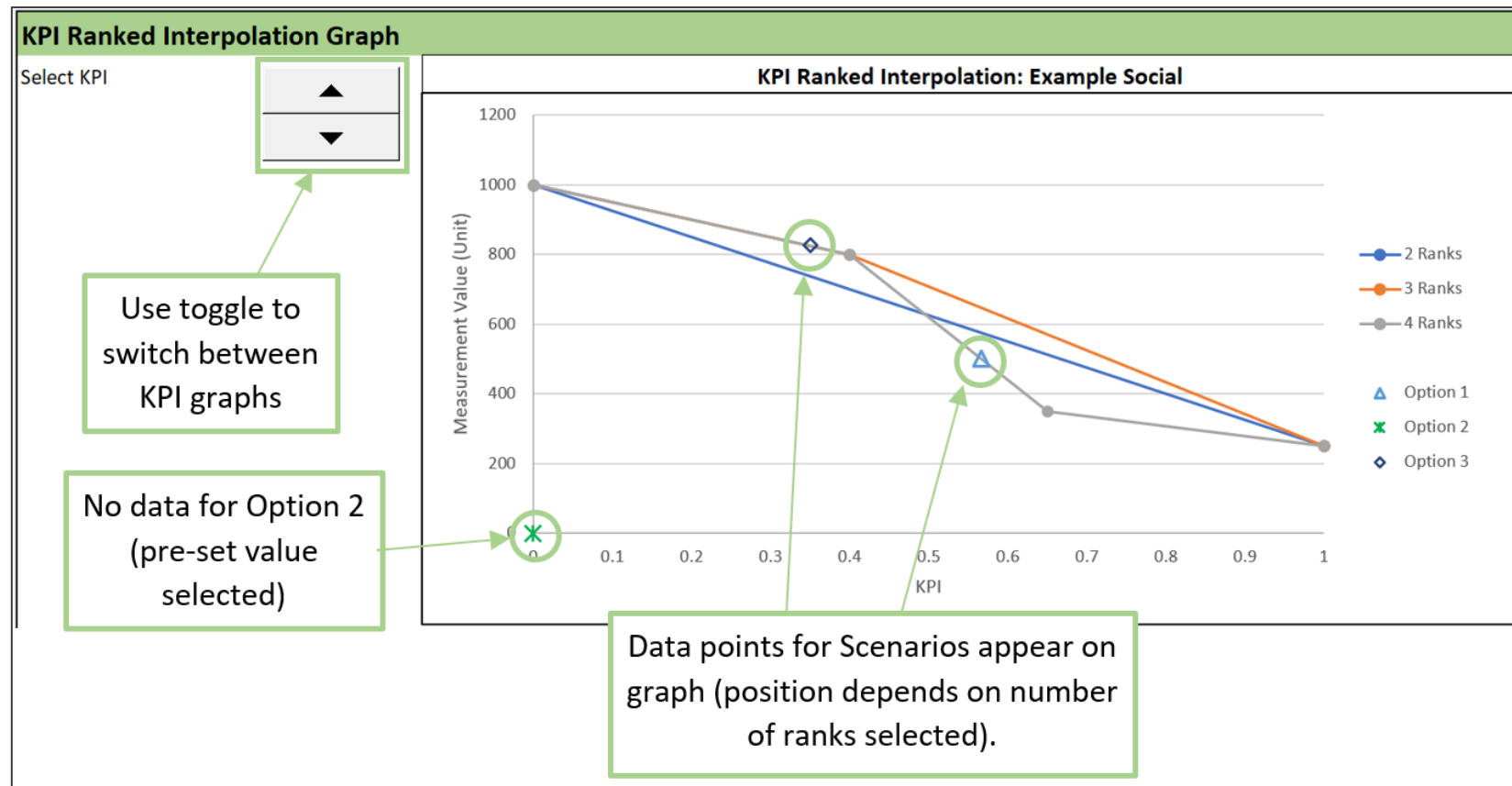
Ranked Interpolation



Ranked Interpolation



Ranked Interpolation



Additional KPIs: Pre-set Scale

KPI Value	Description
0	No commitment to KPI ambition
0.1	Below minimum industry practice
0.25	Minimum industry practice
0.5	Exceed industry practice
0.75	Far-exceeds industry practice
1	KPI ambition achieved

Weighting

Select Weights				
(Input weight in white boxes between 0 and 1.0 - Note: Sum of weights for each option must equal 1.0)				
Category	Name	Option A	Option B	Option C
Performance	Technical Performance	0.3	0.3	0.3
Cost	Cost (CPI)	0.2	0.2	0.2
	Example Cost 2	0.1	0.1	0.1
CE	Example CE 1	0.1	0.1	0.1
	Example CE 2	0.1	0.1	0.1
Environment	Example Environment	0.1	0.1	0.1
Social	Example Social	0.1	0.1	0.1

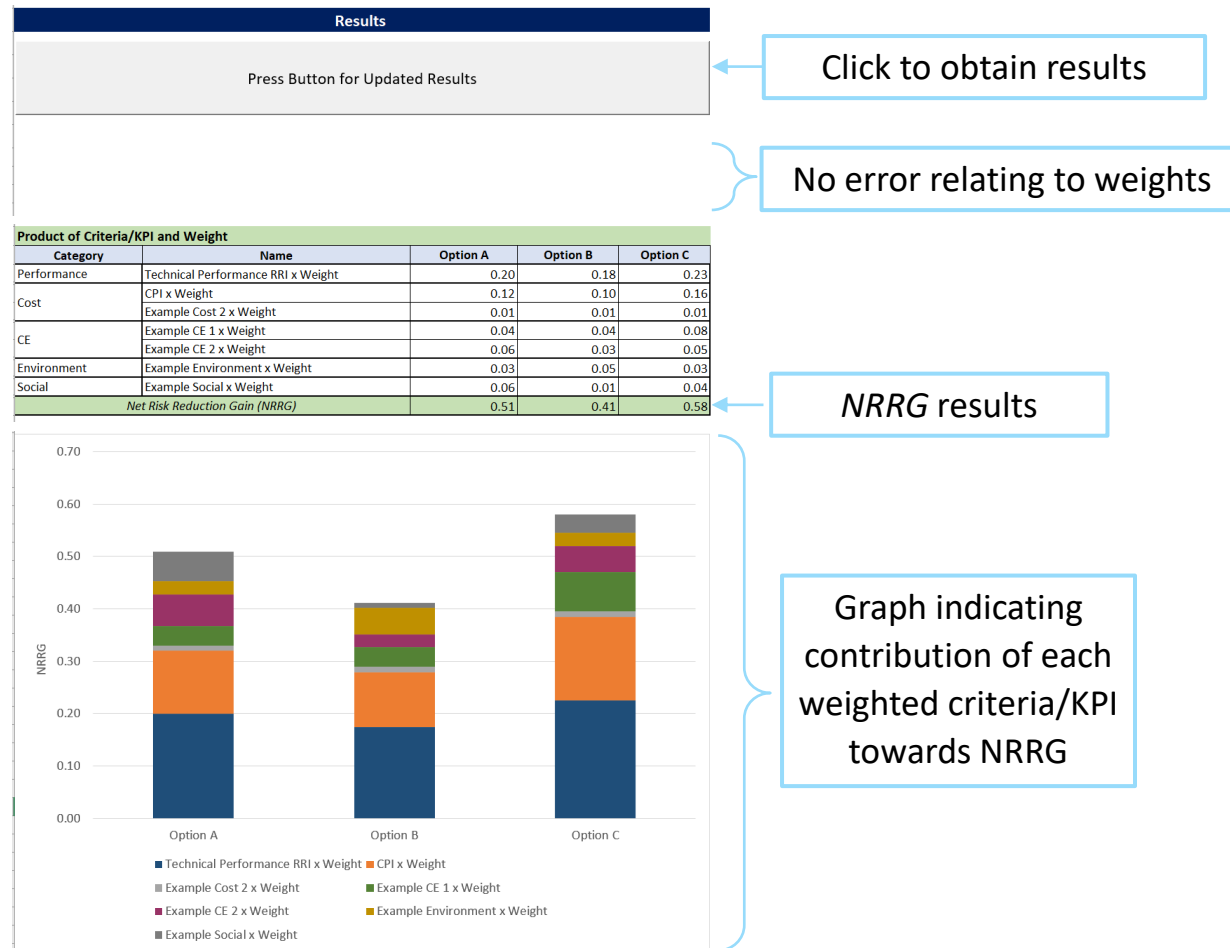
Input values for weights as indicated by white boxes

Sum of values in each column equals 1.0

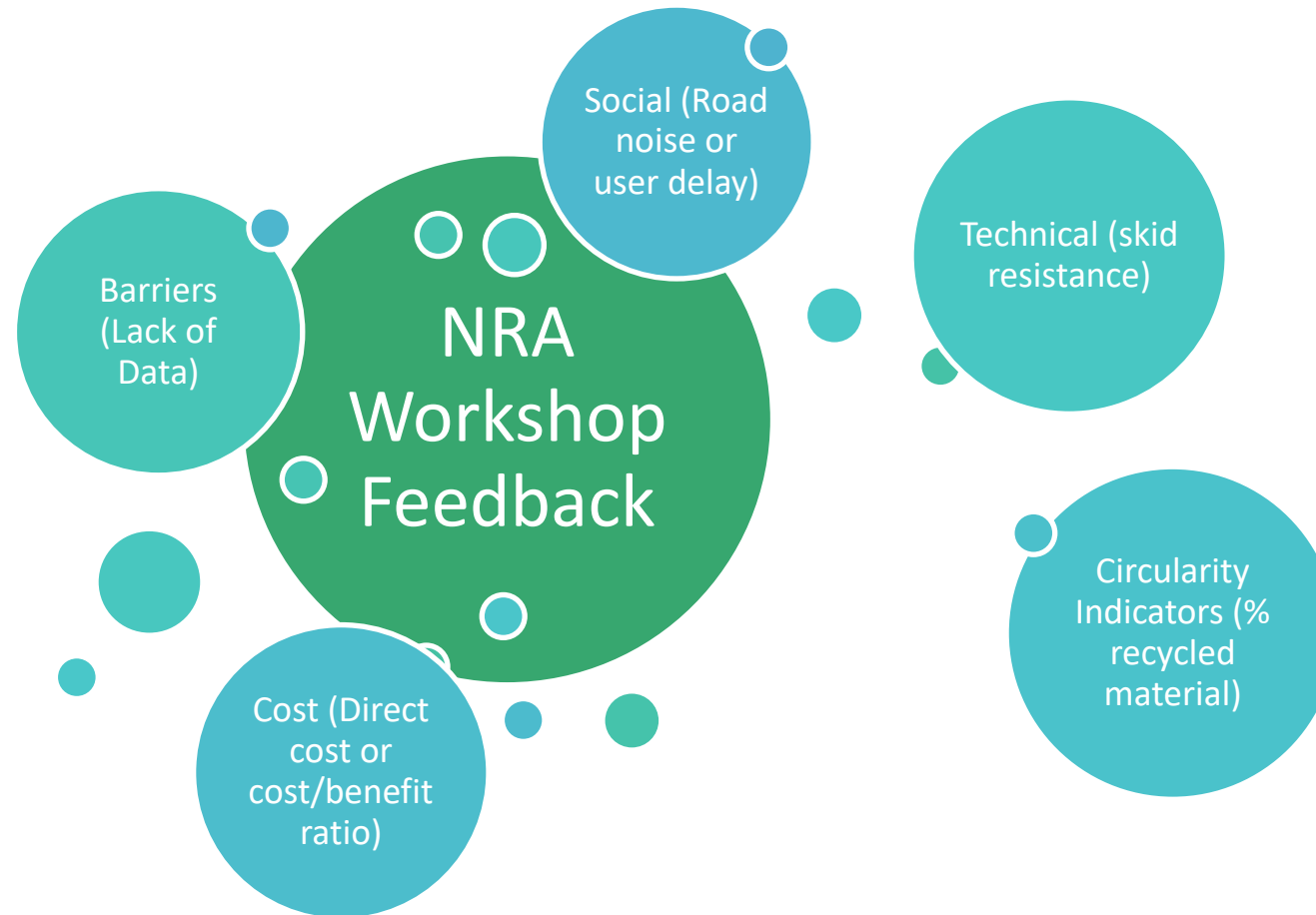
➔

No Error

Software tool results format



Software Demonstration - Overview



Software Demonstration – Input data

Category	Indicator		Input	Do Nothing	No RA	20% RA	50% RA	Least favourable	Most favourable
Risk	Skid resistance	Pf - performance	P	Average	Average	Average	Average		
		uncertainty		Medium	Low	Medium	High		
		Consequences (€)	N	150,000	150,000	150,000	150,000		
Cost	Capital Cost (€)		N		300,000	250,000	270,000		
CE	Proportion of recycled material (%)		N		0	20	50	0	100
Environmental	Carbon emissions (kg CO2/m2)		N		16	12	9	18	5
Social	Ride quality		P		0.25 - Minimum industry practice	0.25 - Minimum industry practice	0.25 - Minimum industry practice		

INTEGRATE VIDEO

C12 X ✓ fx N

A	B	C	D	E	F	G
Project Name	CERCOM Final Conference			Date	13/03/2024	
Project Number	24.101			User Initials	ES	
Number of Scheme Options to be considered		3				
Description	Value	Unit				
Length of road	1	km				
Type of Road	Single Carriageway	-				
Budget available	500,000	Euro				
Duration of assessment period	50	years				
Name of Scheme Option	Option 1	-				
	Option 2	-				
	Option 3	-				

Click to Clear User Inputs for Worksheet

(Input Criteria name or KPI name as text in "name")

Category	Name	Input Format			
		Do Minimum	Option 1	Option 2	Option 3
Performance					
Cost					
CE					

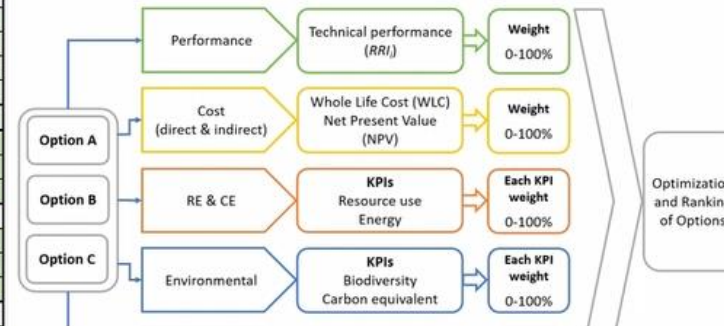
Option A

Option B

Option C

INTEGRATE VIDEO

Input Categories and KPIs					
(Input Criteria name or KPI name as text in "name" column and select input type in drop down menu for the number of options considered)					
Category	Name	Input Format			
		Do Minimum	No RA	20% RA	50% RA
Performance	Skid Resistance	Preset scale	Preset scale	Preset scale	Preset scale
Cost	Cost (CPI)		Numerical Input	Numerical Input	Numerical Input
CE	Proportion of Recycled content		Numerical Input	Numerical Input	Numerical Input
Environment	Carbon Emissions		Numerical Input	Numerical Input	Numerical Input
Social	Ride Quality		Preset scale	Preset scale	Preset scale



INTEGRATE VIDEO

Input Values for Performance and Risk (Risk = Probability of Failure x Consequences)									
Risk	Probability of Failure					Consequences (unit of currency)			
Name	Input	Do Minimum	No RA	20% RA	50% RA	Do Minimum	No RA	20% RA	50% RA
Skid Resistance	Performance	Average	Average	Average	Average	150,000	150,000	150,000	150,000
	Uncertainty	Medium	Low	Medium	High				
	User - Numerical Input (between 0 and 1)								
	Performance								
	Uncertainty								
	User - Numerical Input (between 0 and 1)								
	Performance								
	Uncertainty								
	User - Numerical Input (between 0 and 1)								
	Performance								
	Uncertainty								
	User - Numerical Input (between 0 and 1)								
	Performance								
	Uncertainty								
	User - Numerical Input (between 0 and 1)								

INTEGRATE VIDEO

Input Value for Cost (for CPI calculation)

Not required if using NPV KPI to evaluate cost

Name	Unit	No RA	20% RA	50% RA
Cost (CPI)	Euro	300,000	250,000	270,000

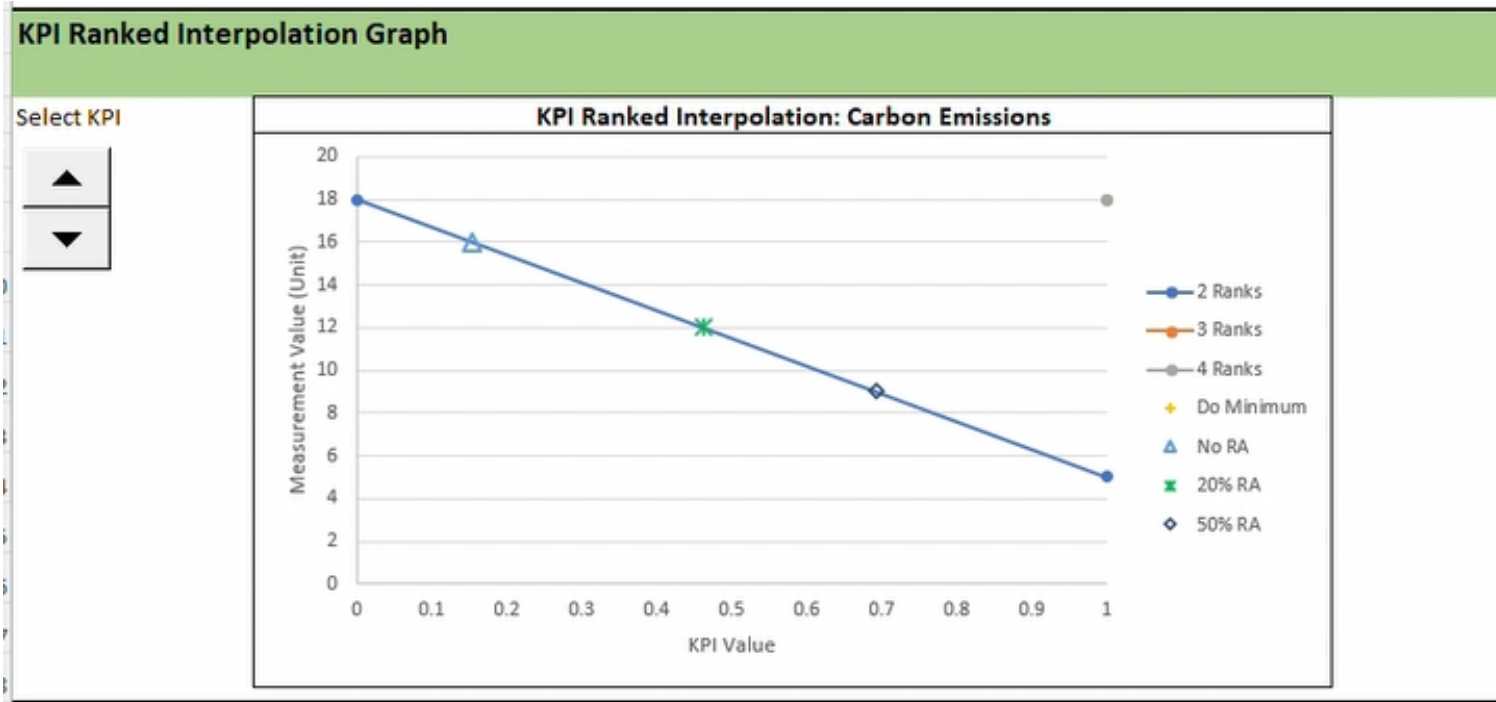
INTEGRATE VIDEO

Input Data for KPIs and Ranked Interpolation																
KPIs by Ranked Interpolation						Least Favourable Rank		Intermediate rank 1		Intermediate rank 2		Most Favourable Rank		No RA		
Category	KPI	KPI Number	Number Ranks	Interpolati on Method	Unit	Data Value	KPI	Data Value	KPI	Data Value	KPI	Data Value	KPI	Data Value	KPI calc	Select
Cost		0		Linear												
				Linear												
				Linear												
CE	Proportion of Recycled content	1	2	Linear	%	0	0					100	1	0	0.00	
				Linear												
				Linear												
Environment	Carbon Emissions	2	2	Linear	kg CO2/m2	18	0					5	1	16	0.15	
				Linear												
				Linear												
Social	Ride Quality	3		Linear												
				Linear												
				Linear												

INTEGRATE VIDEO

Input Data for KPIs and Ranked Interpolation																	
Least Favourable Rank		Intermediate rank 1		Intermediate rank 2		Most Favourable Rank		No RA			20% RA			50% RA			
Data Value	KPI	Data Value	KPI	Data Value	KPI	Data Value	KPI	Data Value	KPI calc	Select KPI	Data Value	KPI calc	Select KPI	Data Value	KPI calc	Select KPI	
																	Clear
																	Clear
																	Clear
0	0					100	1	0	0.00		20	0.20		50	0.50		Clear
																	Clear
																	Clear
																	Clear
18	0					5	1	16	0.15		12	0.46		9	0.69		Clear
																	Clear
																	Clear
																	Clear
										0.25 - Minimum i		0.25 - Minimum i		0.25 - Minimum i			Clear
																	Clear
																	Clear
																	Clear

INTEGRATE VIDEO



INTEGRATE VIDEO

0

1

2

3

4

5

6

7

8

9

0

1

2

3

4

5

6

7

8

9

0

1

2

3

4

5

6

7

Select Weights

(Input weight in white boxes between 0 and 1.0 - Note: Sum of weights for each option must equal 1.0)

Category	Name	No RA	20% RA	50% RA
Performance	Skid Resistance	0.3	0.3	0.3
Cost	Cost (CPI)	0.4		
CE	Proportion of Recycled content			
Environment	Carbon Emissions			
Social	Ride Quality			

ERROR - Sum of Weights for each option should equal to 1. Please revise input values.

INTEGRATE VIDEO

0

1

2

3

4

5

6

7

8

9

0

1

2

3

4

5

6

7

8

9

0

1

2

3

4

5

6

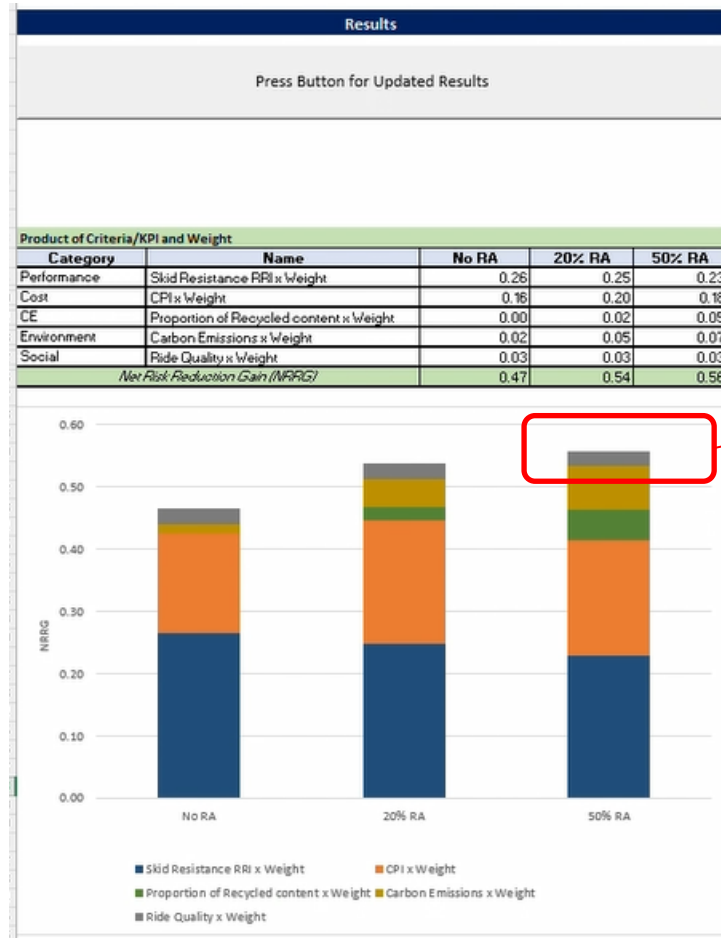
7

Select Weights

(Input weight in white boxes between 0 and 1.0 - Note: Sum of weights for each option must equal 1.0)

Category	Name	No RA	20% RA	50% RA
Performance	Skid Resistance	0.3	0.3	0.3
Cost	Cost (CPI)	0.4	0.4	0.4
CE	Proportion of Recycled content	0.1	0.1	0.1
Environment	Carbon Emissions	0.1	0.1	0.1
Social	Ride Quality	0.1	0.1	0.1

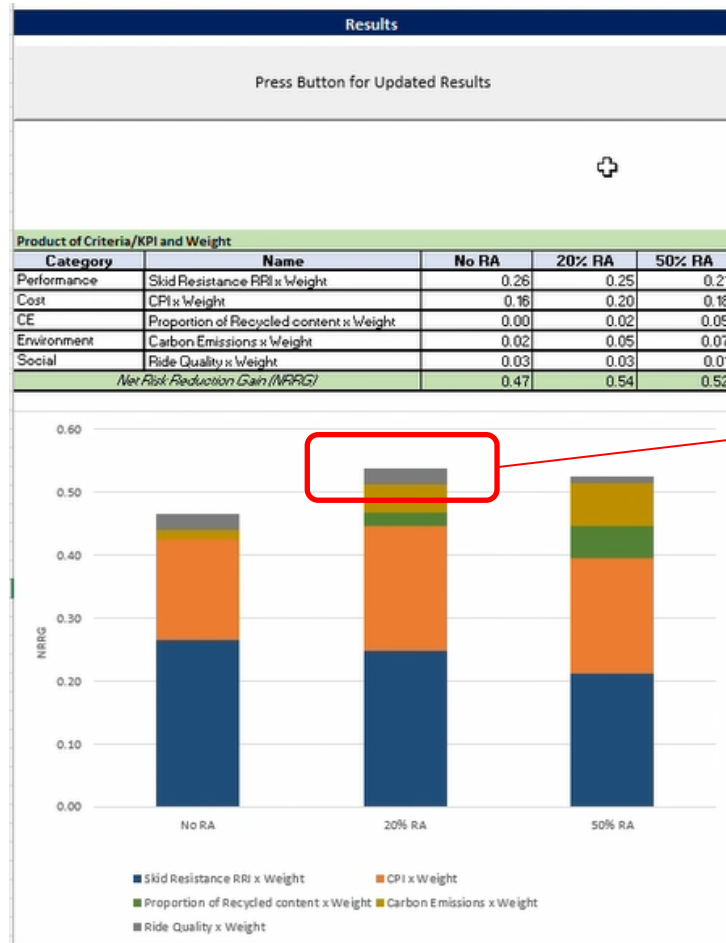
INTEGRATE VIDEO



Optimal solution

29

INTEGRATE VIDEO



Optimal results following changes to input values

Thank you!

Any questions?