mobilise
analysing mobility, mobilising people

MAMCABM: A DATA-DRIVEN STAKEHOLDER-BASED DECISION-SUPPORT SYSTEM

A DSS CONSIDERS UNCERTAINTIES

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MOBILISE RESEARCH GROUP

VRIJE UNIVERSITEIT BRUSSEL

- To accelerate the transition to a more sustainable and socially just mobility and logistics system:

REAL LIFE PROBLEM

BD DE LA PLAINE

REAL LIFE PROBLEM

BD DE LA PLAINE

- A street along the university campus:
  - Connected to a high-capacity boulevard;
  - Diverse types of vehicles;
  - Heavily utilized by pedestrians and cyclists.

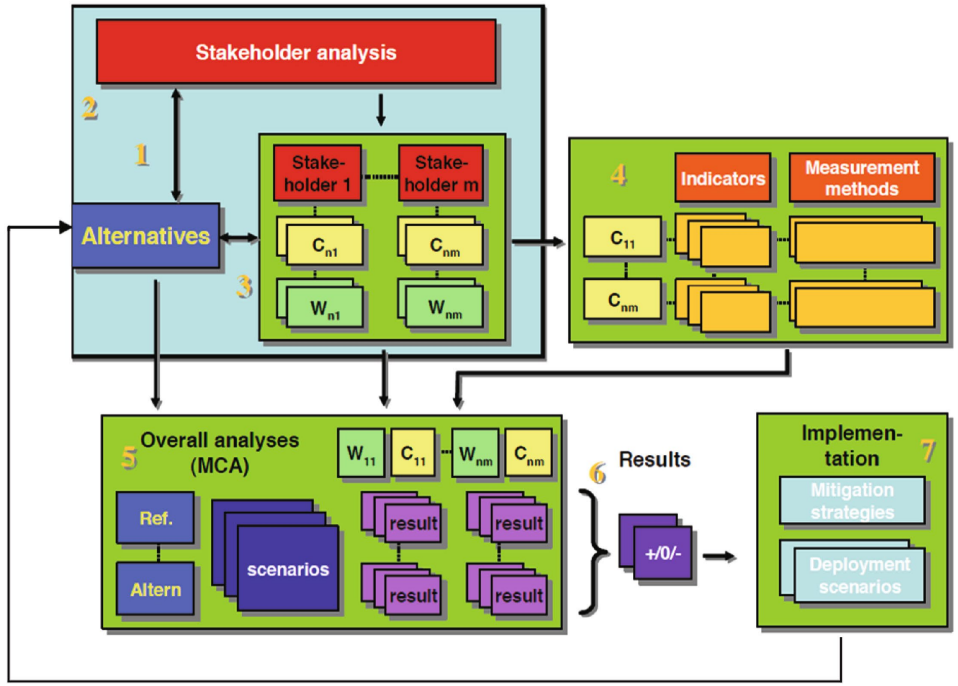
DECISION-MAKING

STAKEHOLDERS

Stakeholder group	
g_1	Local authority
g_2	Drivers
g_3	Cyclists
g_4	Pedestrians

MULTI-ACTOR MULTI-CRITERIA ANALYSIS

STAKEHOLDER INVOLVEMENT

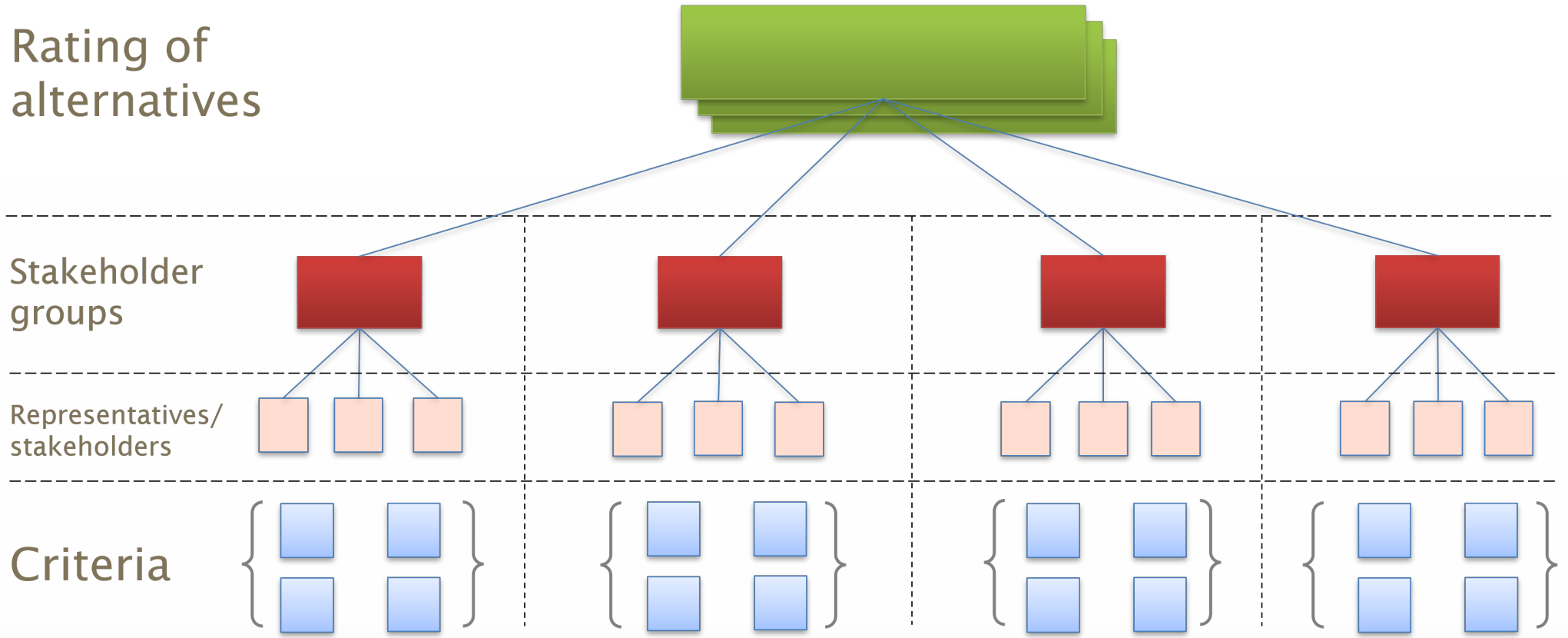


(Macharis, 2004)

1. Define alternatives
2. Stakeholder analysis
3. Define criteria and weights
4. Criteria, indicators and measurement methods
5. Overall analysis and ranking
6. Result
7. Implementation

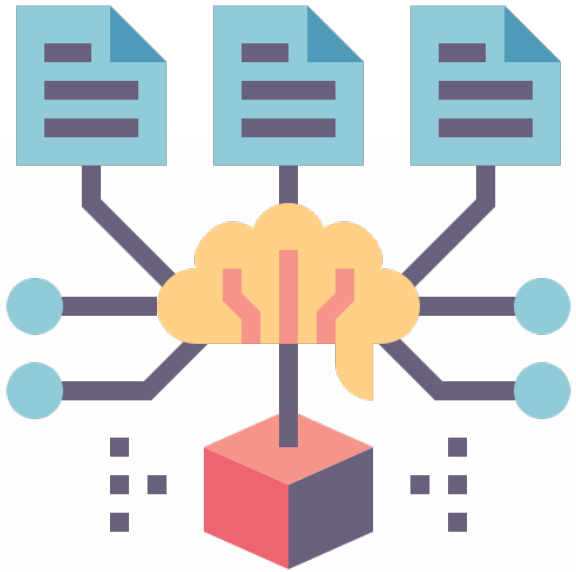
MULTI-ACTOR MULTI-CRITERIA ANALYSIS

STAKEHOLDER INVOLVEMENT



MULTI-ACTOR MULTI-CRITERIA ANALYSIS

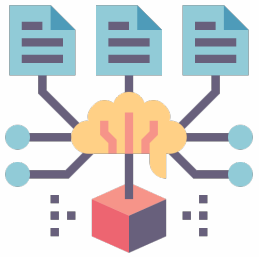
CHALLENGES IN MAMCA

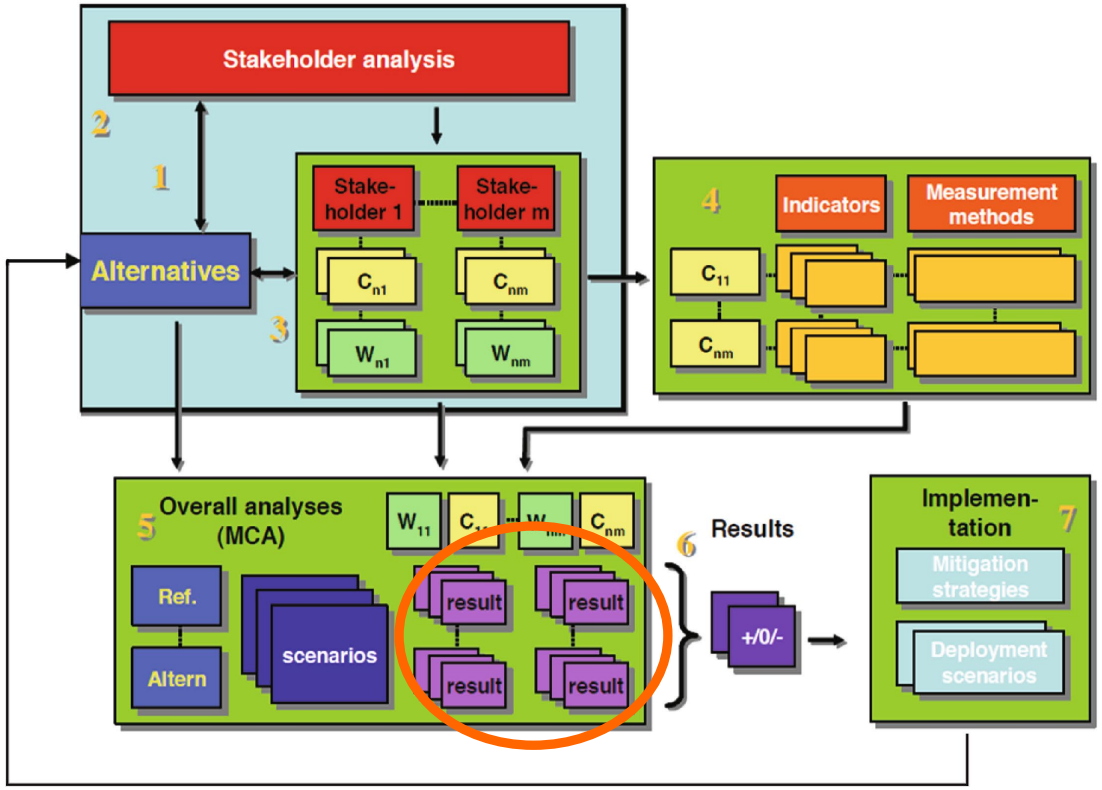


Target: micro-level transportation and mobility planning.

CHALLENGES IN MAMCA

DATA SUPPORT





MAMCABM

SCENARIOS

MAMCABM

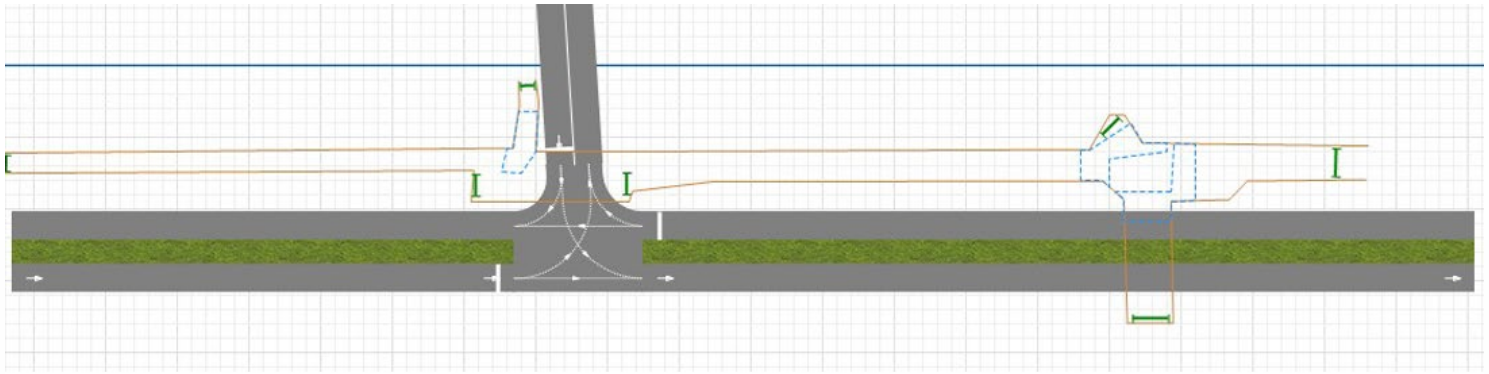
SCENARIOS

MAMCABM

SCENARIOS

DATA SUPPORT

AGENT-BASED MODELLING



pedestrian [..]

drivers [..]

cyclists [..]

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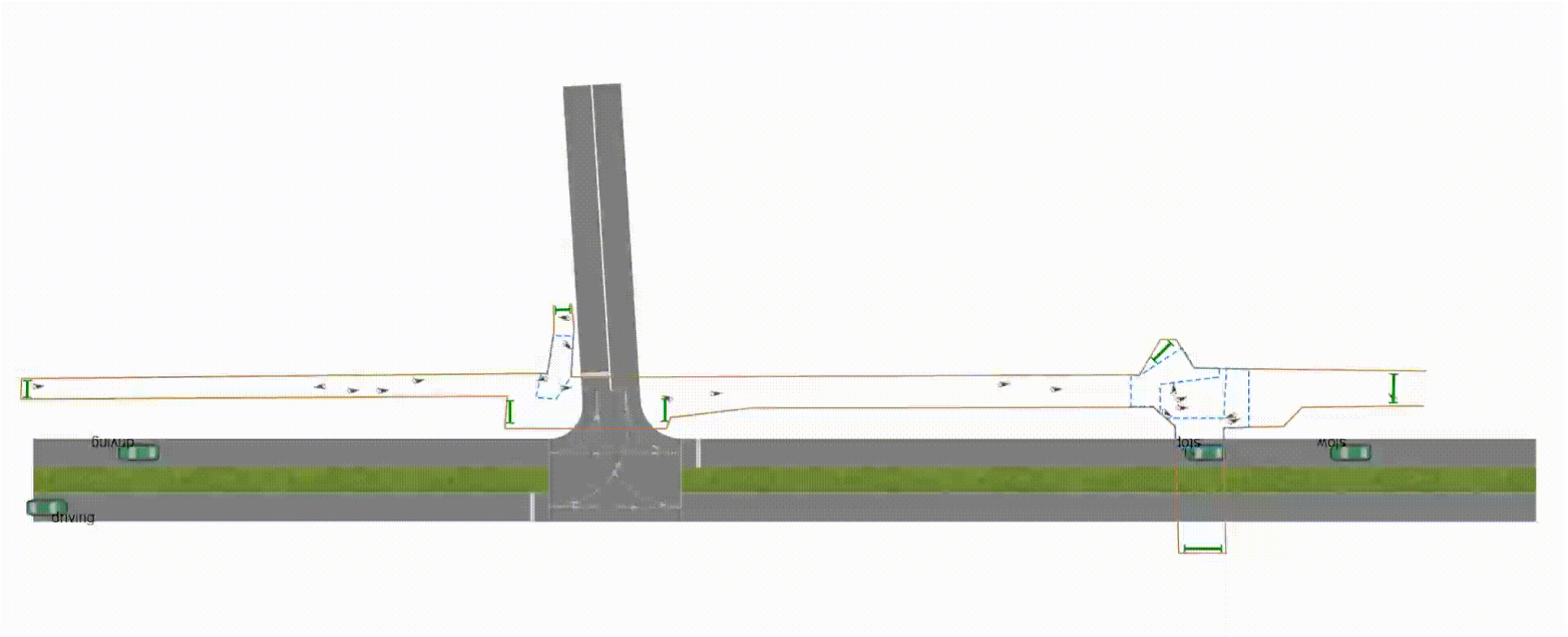
AGENTS



CONSIDERING UNCERTAINTY

UNCERTAINTY

- Stochasticity:
  - Pedestrian speed = $uniform(0.5, 1)$ m/s;
  - Drivers' decision to turn in the junction;
  - Arrival patterns.

Such stochastic values are defined in agents' behaviour logic and the environment in the ABM.

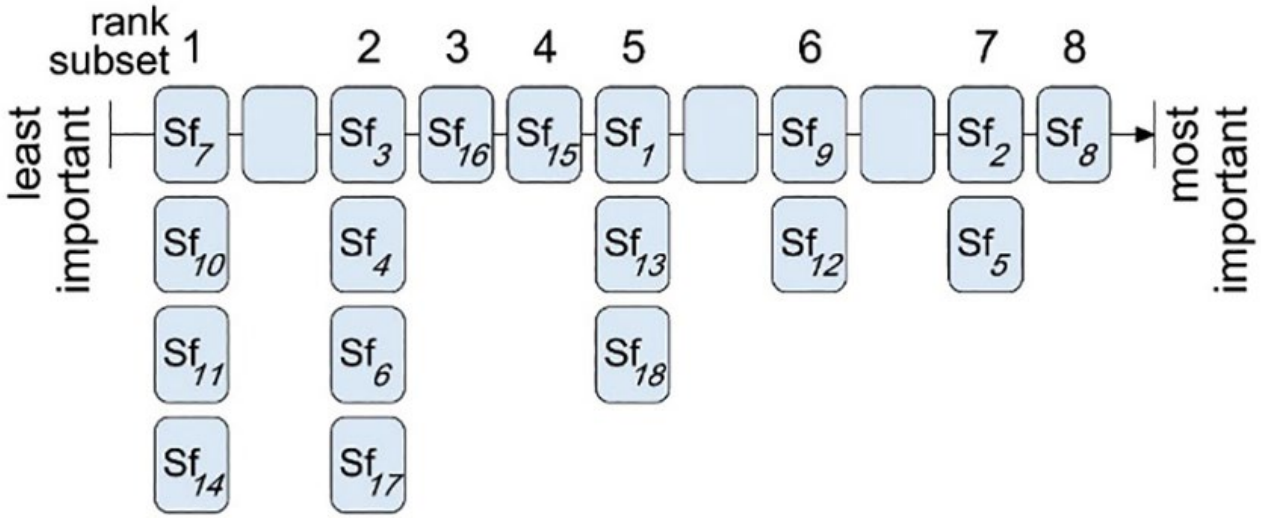
- Imprecision in MAMCA:
  - Exhibiting imprecision as the subjective nature of human judgment.

?

CONSIDERING UNCERTAINTY

RANK BASED WEIGHT ELICITATION METHOD

- Revised Simos method:
  - The stakeholders set z value expresses how the most important criterion relates to the least important criterion.



(Aşılıoğlu, 2021)

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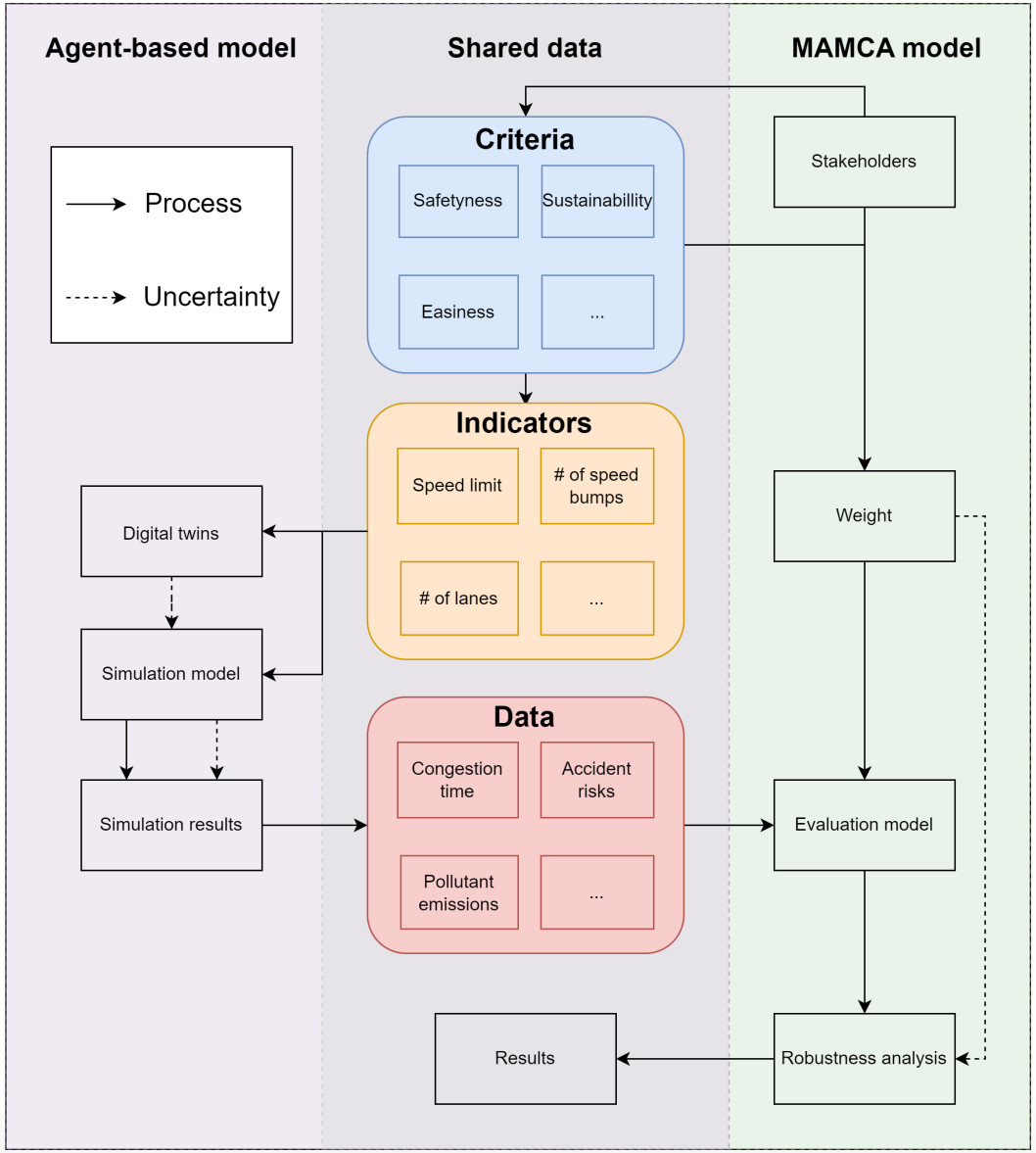
DSS

- Data-driven robust stakeholder-based group-decision making:
  - Agent-based model;
  - MAMCA frameworks;
  - Robustness analysis.



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CRITERIA SELECTION

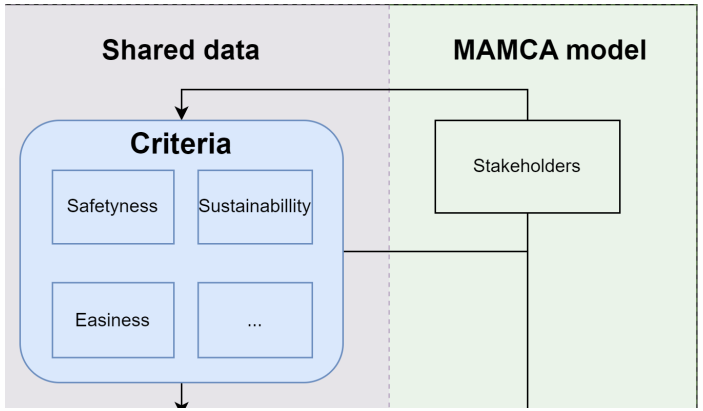

Table 3. Criteria list with attributes

Criteria Group	Criteria	Subcriteria	Description	Indicator	Unit	Promethee II Preference Model	Orientation	Selected by
Environmental	Pollution	Emission of GHGs	Green house gases (GHGs) emissions	Emission of CO2	g	V-shape	Min	g_1, g_2, g_3, g_4
		Hazardous Exaust Emissions	Emission of NOx, CO, VOC, PM	Emission of NOx, CO, VOC, PM	g	V-shape	Min	g_1, g_2, g_3, g_4
	Biodiversity	Biodiversity effect	Possible effect to the nearby creatures	/	5-point Likert scale	V-shape	Max	g_1, g_2, g_3, g_4
Social	Noise	Traffic Noise	Noise level estimation	Road-side noise level	dB	V-shape with indifference	Min	g_1, g_3, g_4
	Safety	Ambient Safety of Cyclists	Attributes of the nearby cars of cyclists	Surrounding car time * speed	s * km/h	V-shape	Min	g_1, g_3
		Ambient Safety of Pedestrians	Attributes of the nearby cars of pedestrians	Surrounding car time * speed	s * km/h	V-shape	Min	g_1, g_4
		Driving Behaviour	Reactions due to detected pedestrians/cyclists	Times to slow/stop	/	V-shape	Min	g_1, g_2
	Easiness of Use	Driving Experience	Driving time expectation	Practical time/ expected time	%	V-shape	Min	g_1, g_2
Economic	Cost	Building cost	Immediate cost incurred for the countermeasures	Building cost	Euro	V-shape	Min	g_1
		Maintenance cost	Long-term cost for the countermeasures	Maintenance cost	Euro	V-shape	Min	g_1
		Fuel consumption	Fuel consumed during the simulation span in Euro	Total fuel consumption	Euro	V-shape	Min	g_2

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PARAMETER SETTING AND OUTPUT

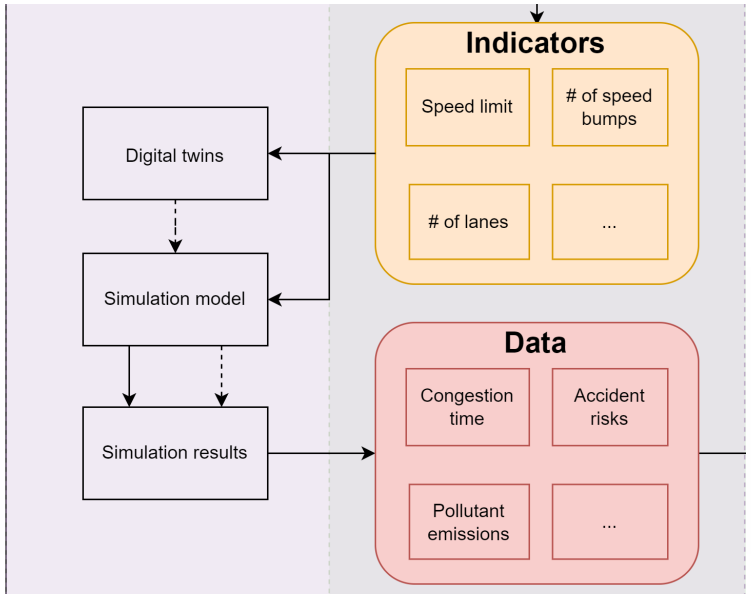

Table 1. Parameter settings

Parameter	SC1	SC2	SC3	SC4
Preferred speed (km/h)	32	32	28	28
Speed bump speed reduction	0	40%	0	40%

Table 2. Data output of ABM

Data and unit	SC1	SC2	SC3	SC4
Average speed of nearby cars of pedestrians (km/h)	7.8395	6.4117	5.7547	5.5129
Average speed of nearby cars of cyclists (km/h)	15.5732	4.6876	3.4196	6.6035
Average speed of cars (km/h)	23.5806	17.0391	19.7261	15.7378
Average times for cars to slow/stop	2.1511	2.5625	2.5000	2.5181
% more time to drive than expected	51.12	112.35	54.22	89.41
Total amount of CO_2 emission (g)	27680.8471	25930.8420	32495.6425	29916.7016
Other exhaust emissions (g)	67468.3103	53164.7391	76045.6679	62274.1123
Total petrol consumed (L)	70.3805	44.6895	53.0422	63.5022
Total diesel consumed (L)	4.1342	4.0831	4.5447	3.7483
Noise (dB)	65.3856	65.6373	65.4314	65.8116

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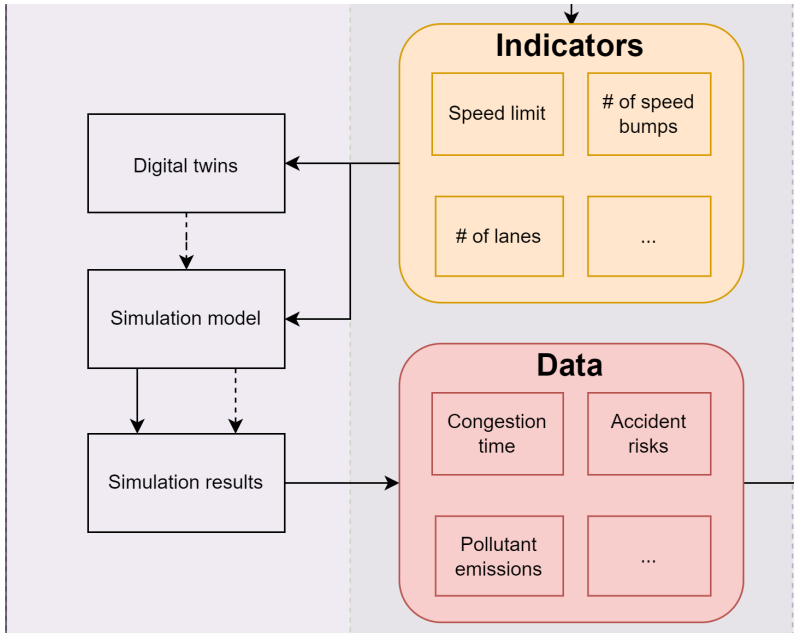
CRITERIA TABLE



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	Maintenance cost	Long-term cost for the countermeasures	Maintenance cost	Euro	V-shape	Min	g_1
	Fuel consumption	Fuel consumed during the simulation span in Euro	Total fuel consumption	Euro	V-shape	Min	g_2

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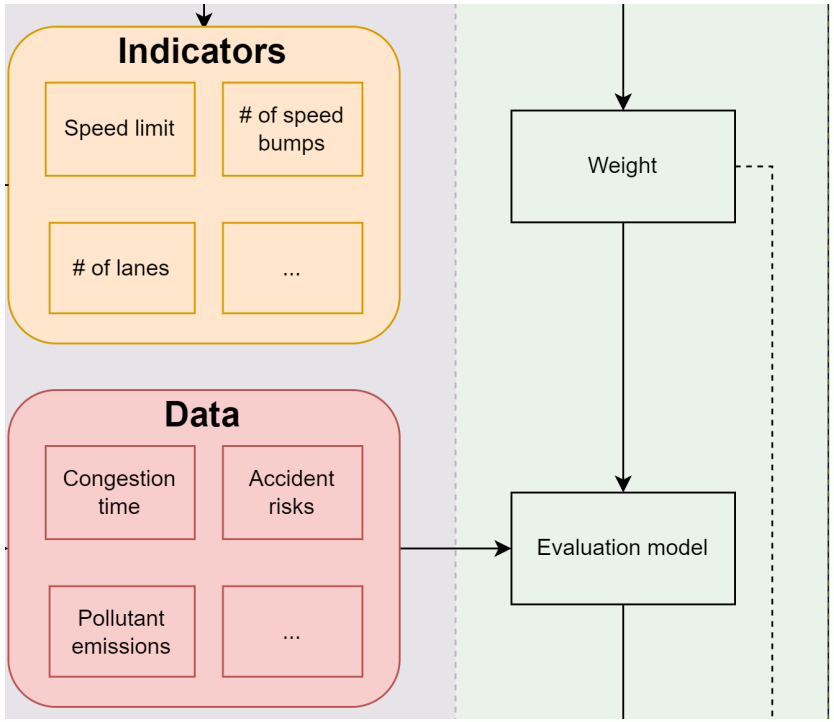
WEIGHT ELICITATION AND APPRAISAL



- Weight elicitation: Revised Simos method
- Alternative appraisal: Preference ranking organization method for enrichment evaluation (PROMETHEE) (Brans & De Smet, 2016)

Preferences aggregation (for one stakeholder group):

$$P(a_m) = \sum_{n=1}^{N} w_n \times p_{m,n}.$$

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WEIGHT ELICITATION AND APPRAISAL

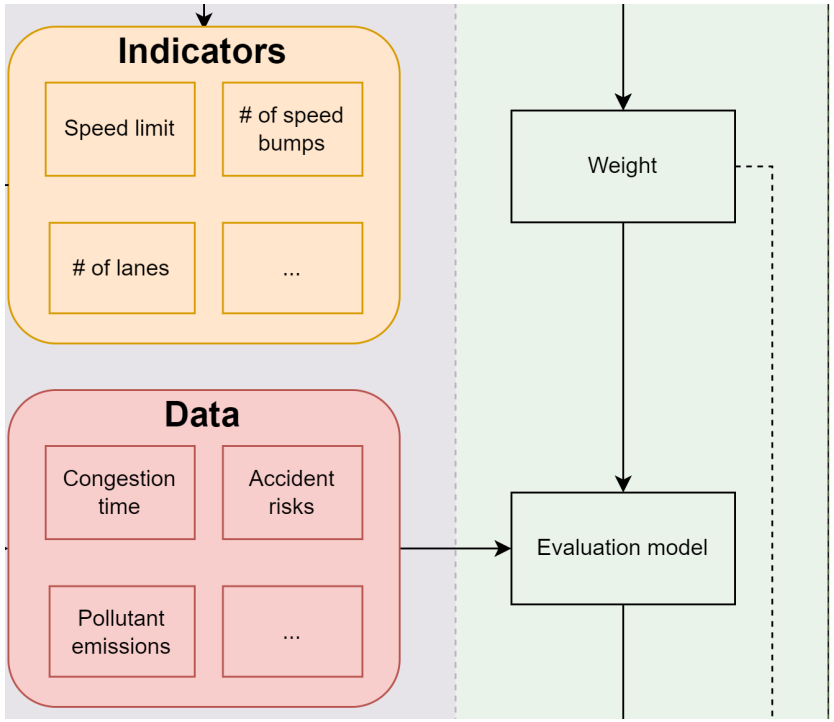

Table. Criteria weight elicitation and alternative appraisal result

Bikers	Weight	SC1	SC2	SC3	SC4
Emission of GHGs	0,26	0,1767	0,41	-0,4653	-0,1214
Emission of NOx, CO, VOC, PM	0,2	-0,3292	0,4336	-0,052	-0,052
Biodivesity	0,14	0,2	-0,0667	-0,0667	-0,0667
Traffic Noise	0,08	0	0	0	0
Ambient Safety of Cyclists	0,32	-0,9657	0,355	0,4817	0,129
Overall	1	-0,30092	0,297582	0,013428	-0,01002

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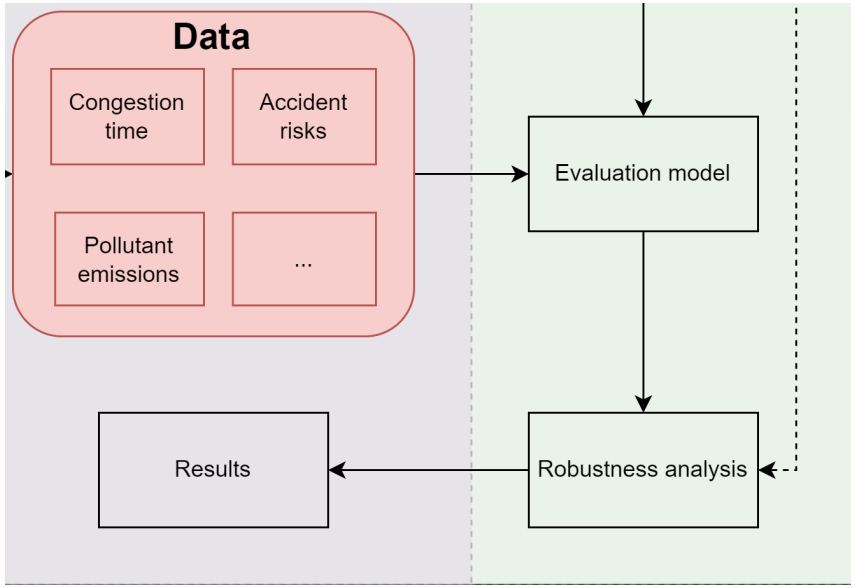
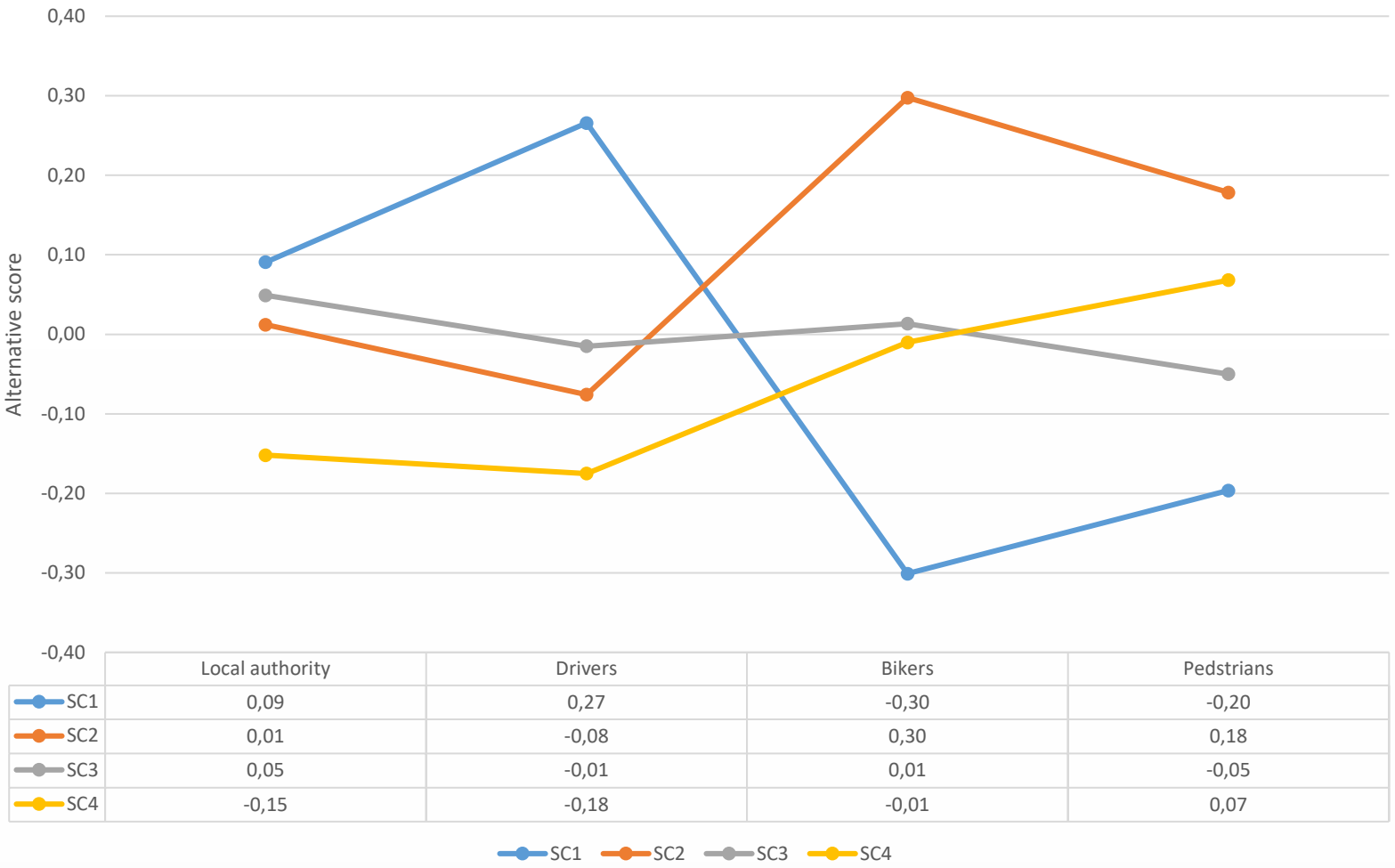
MAMCA VIEW

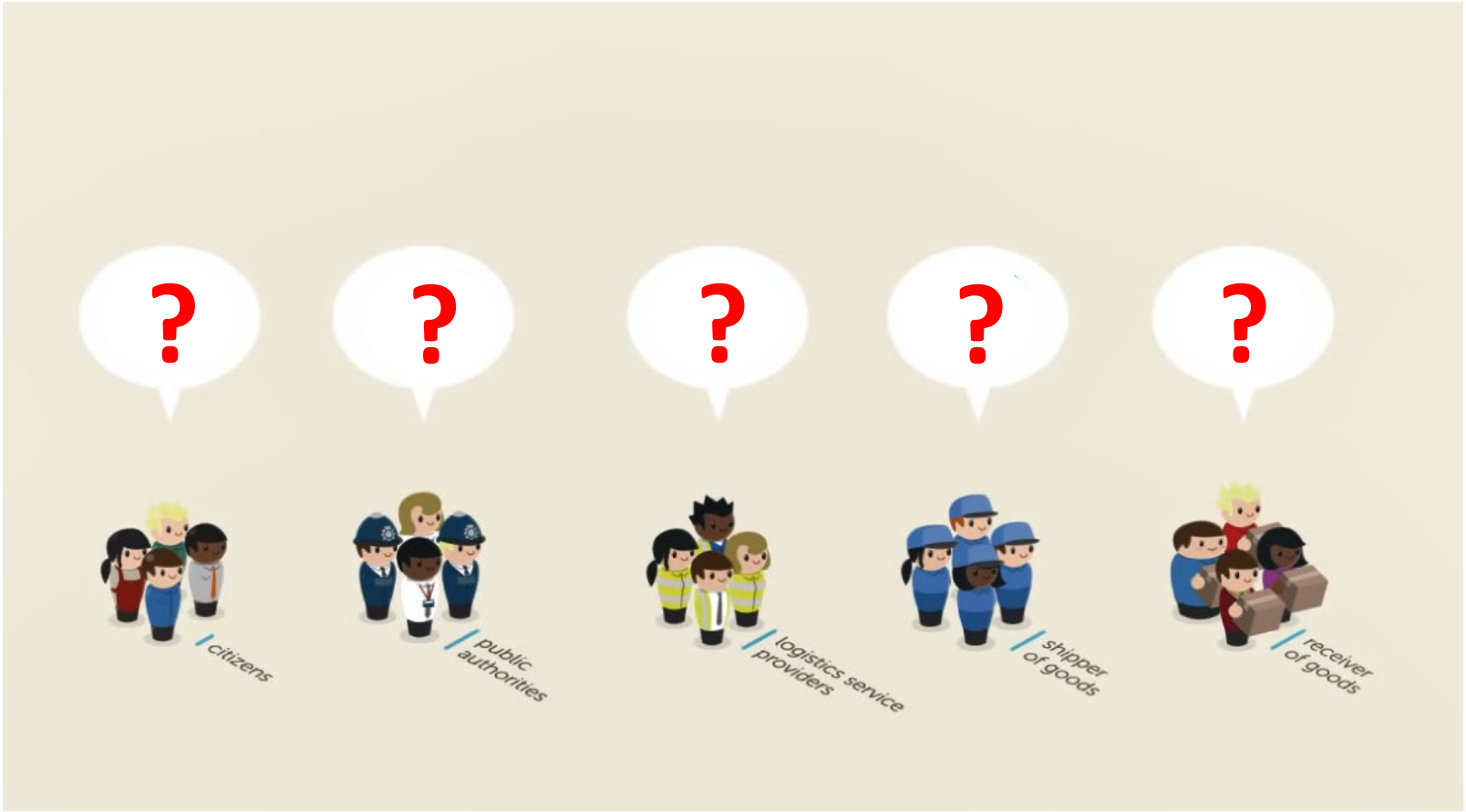




	Local authority	Drivers	Bikers	Pedstrians
SC1	0,09	0,27	-0,30	-0,20
SC2	0,01	-0,08	0,30	0,18
SC3	0,05	-0,01	0,01	-0,05
SC4	-0,15	-0,18	-0,01	0,07

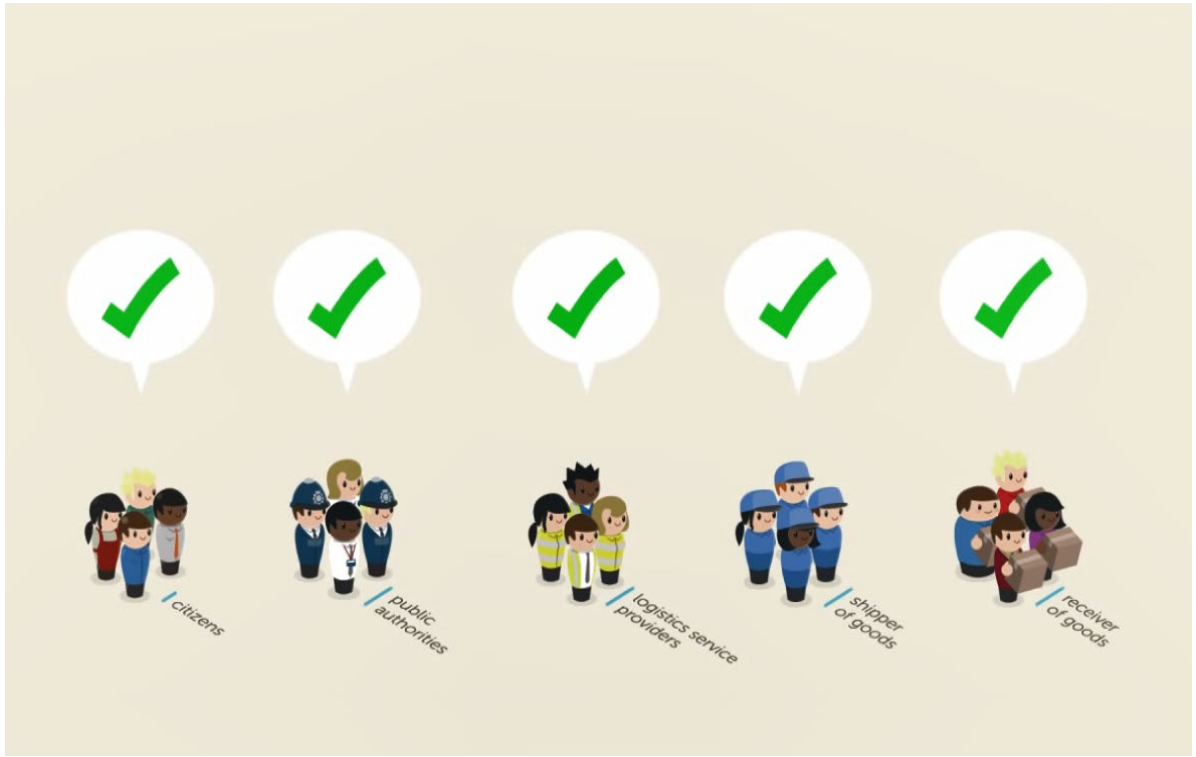
MULTI-ACTOR MULTI-CRITERIA ANALYSIS

CONSENSUS REACHING



CONSENSUS REACHING MODEL

HOW TO ADDRESS CONFLICTS OF POINTS OF VIEW



Find a consensus based on the use of a weight sensitivity analysis model (Huang et al., 2021).

Consensus reaching process (CRP) featuring minimum modifications (Zhang et al., 2019).

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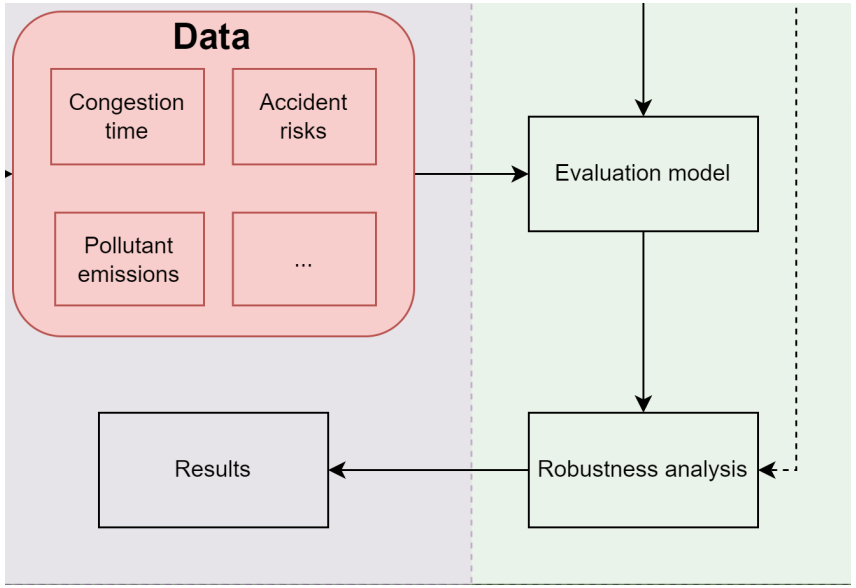
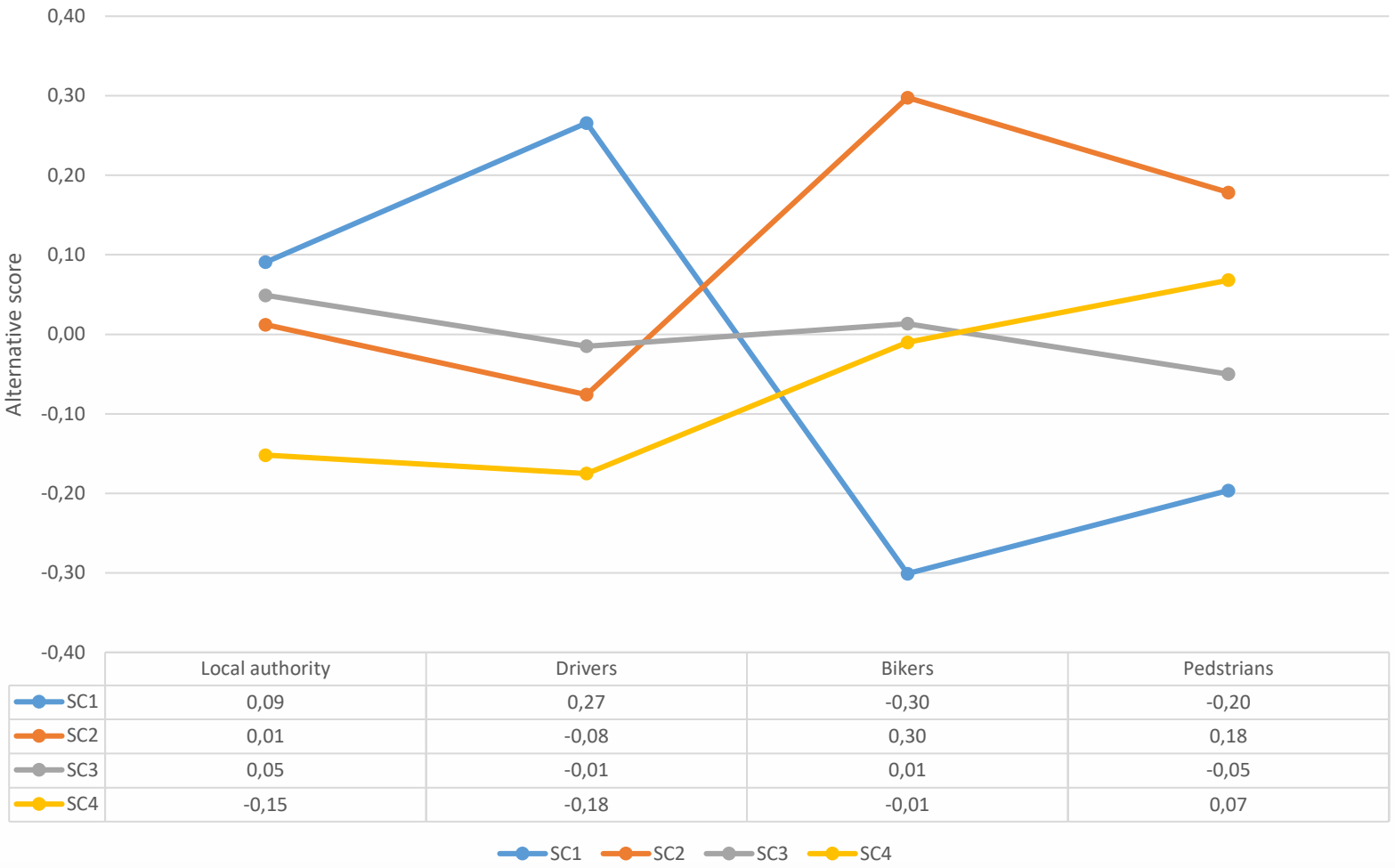
MAMCA VIEW





	Local authority	Drivers	Bikers	Pedstrians
SC1	0,09	0,27	-0,30	-0,20
SC2	0,01	-0,08	0,30	0,18
SC3	0,05	-0,01	0,01	-0,05
SC4	-0,15	-0,18	-0,01	0,07

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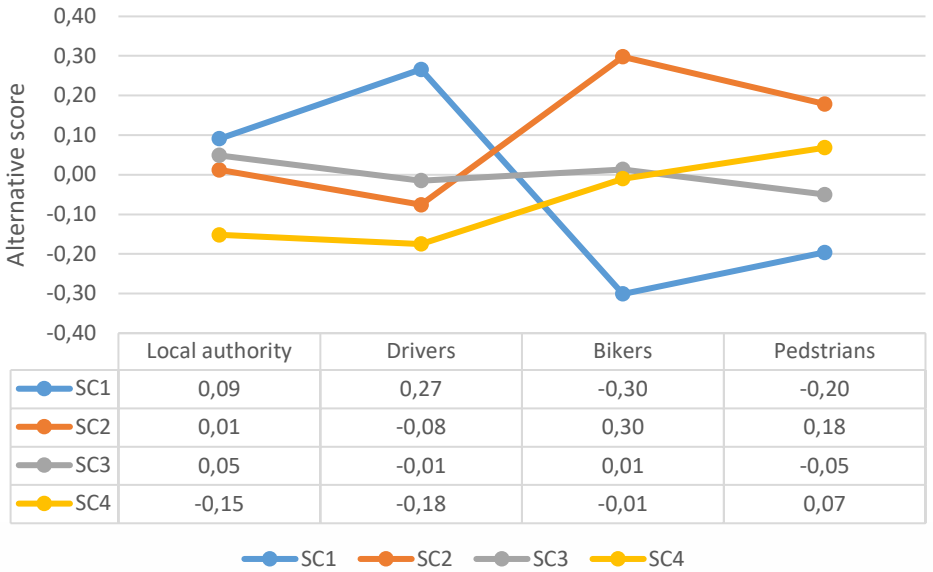
OPTIMIZATION

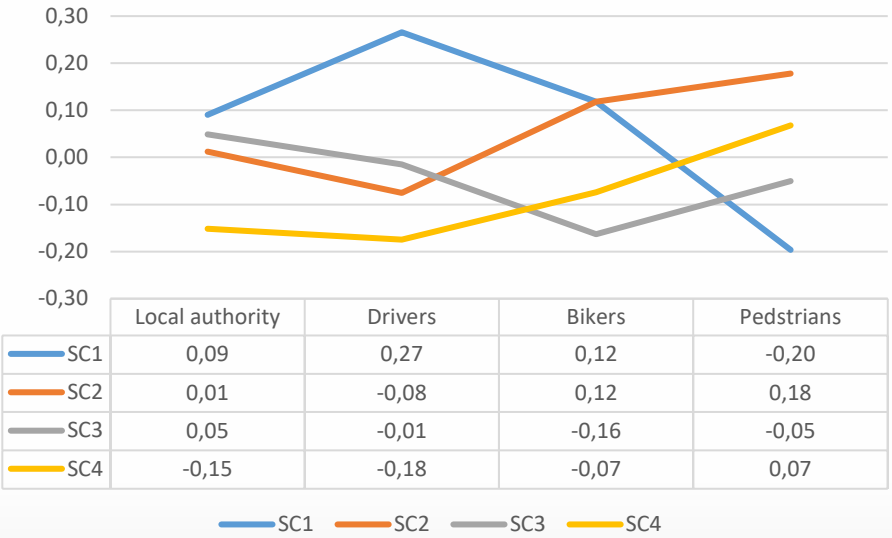
$$min\ z_k^m = \sum_{n_k=1}^{N_k} \left|\omega_{k,n_k} - \omega'_{k,n_k}\right|.$$

(Huang et al., 2021).

Bikers	Emission of GHGs	Emission of NOx, CO, VOC, PM	Driving behavior	Driving experience	Fuel consumption
Before optimization	0,26	0,2	0,14	0,08	0,32
After optimization	0,26	0,112	0,548	0,08	0



	Local authority	Drivers	Bikers	Pedstrians
SC1	0,09	0,27	-0,30	-0,20
SC2	0,01	-0,08	0,30	0,18
SC3	0,05	-0,01	0,01	-0,05
SC4	-0,15	-0,18	-0,01	0,07



	Local authority	Drivers	Bikers	Pedstrians
SC1	0,09	0,27	0,12	-0,20
SC2	0,01	-0,08	0,12	0,18
SC3	0,05	-0,01	-0,16	-0,05
SC4	-0,15	-0,18	-0,07	0,07

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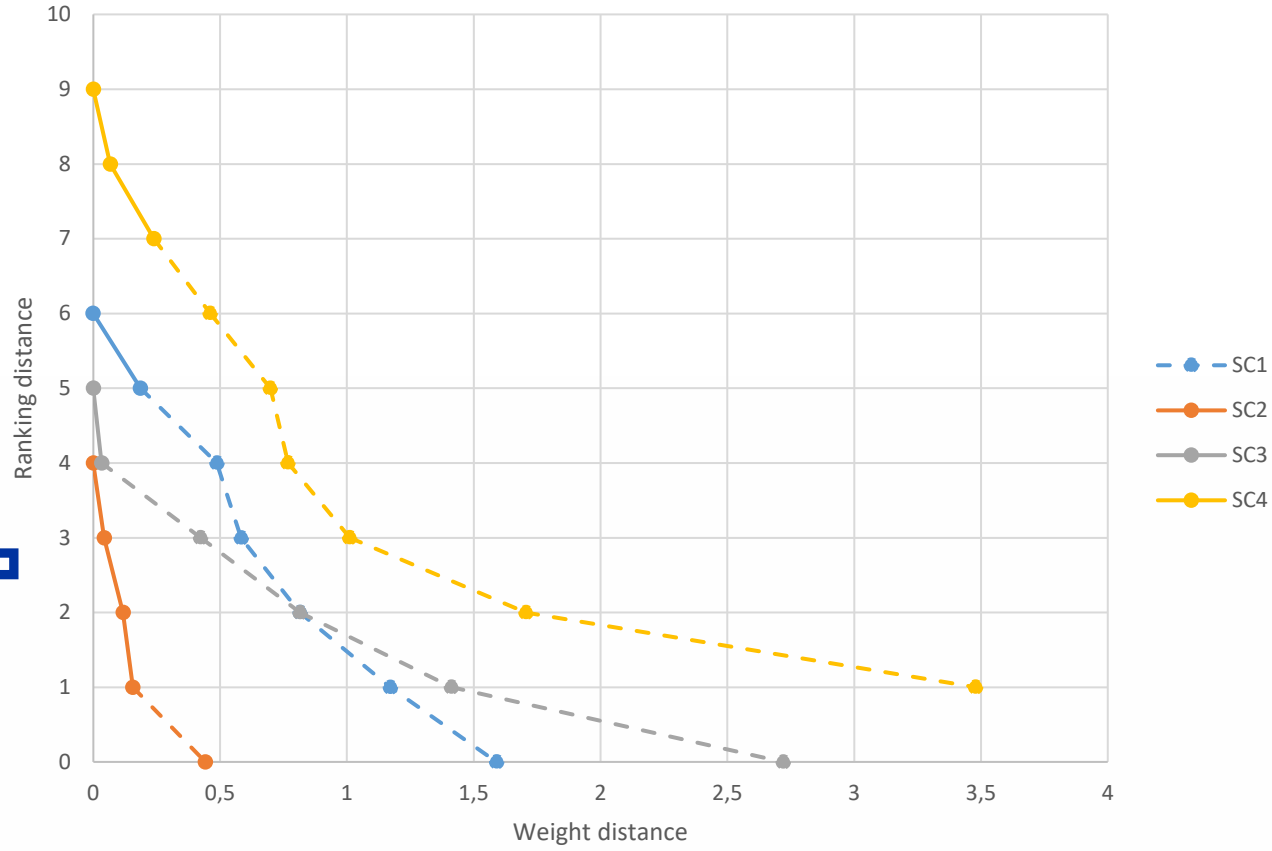
CONSENSUS REACHING

The sum of their current rankings compared to the first position



When rank distance is 0, the alternative is ranked as 1st for all stakeholder groups

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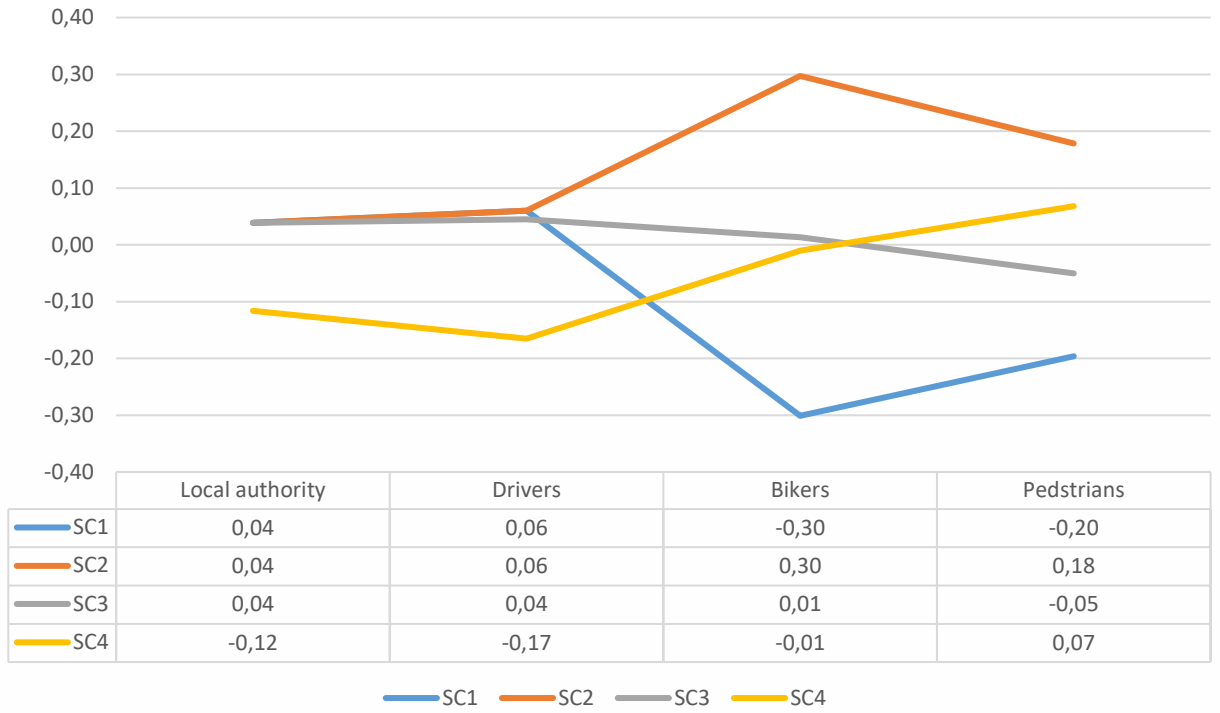
CONSENSUS REACHING

Drivers	Emission of GHGs	Emission of NOx, CO, VOC, PM	Driving behavior	Driving experience	Fuel consumption
Before optimization	0,133	0,068	0,333	0,267	0,200
After optimization	0,133	0,068	0,152	0,267	0,380



	Local authority	Drivers	Bikers	Pedstrians
SC1	0,04	0,06	-0,30	-0,20
SC2	0,04	0,06	0,30	0,18
SC3	0,04	0,04	0,01	-0,05
SC4	-0,12	-0,17	-0,01	0,07

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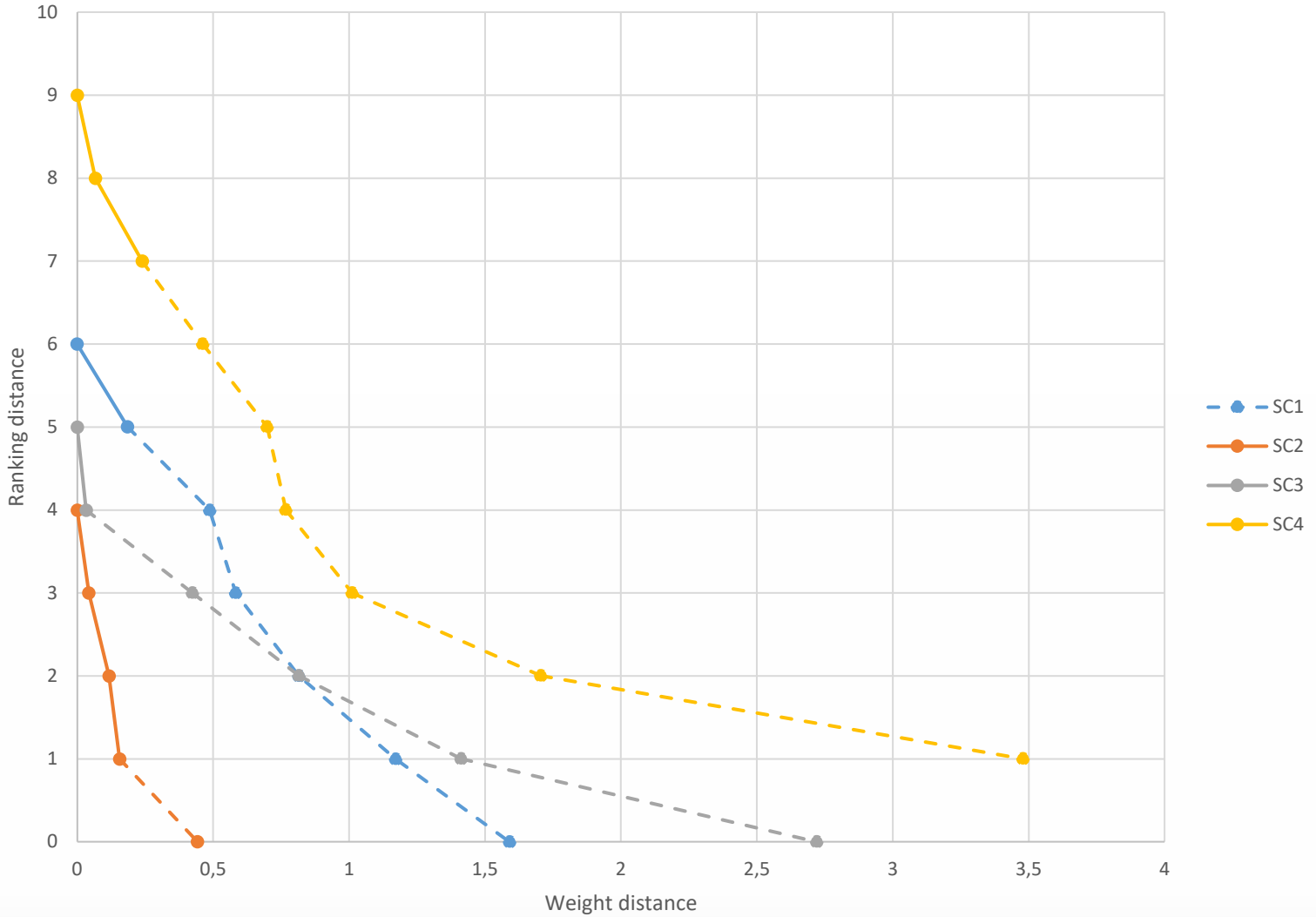
CONSENSUS REACHING

Compromise solution: SC2



CONCLUSION

MAMCABM

- A data-driven stakeholder-based decision-support system :
  - Leverages data generated by simulations to inform decision-making;
  - Considers uncertainties that arise from both the complexity of Agent-Based Modelling (ABM) and the inherent variability of human judgments;
  - Suggests consensual solutions that align with the priorities of stakeholders;
- Future research:
  - Digital twins;
  - Consider other indicators.

THANK YOU

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VUB mobilise

analysing mobility, mobilising people