MOBILITY, LOGISTICS & AUTOMOTIVE TECHNOLOGY RESEARCH CENTRE

DATA VISUALIZATION FOR REACHING CONSENSUS

IN THE MULTI-ACTOR MULTI-CRITERIA ANALYSIS

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MOBI RESEARCH CENTRE

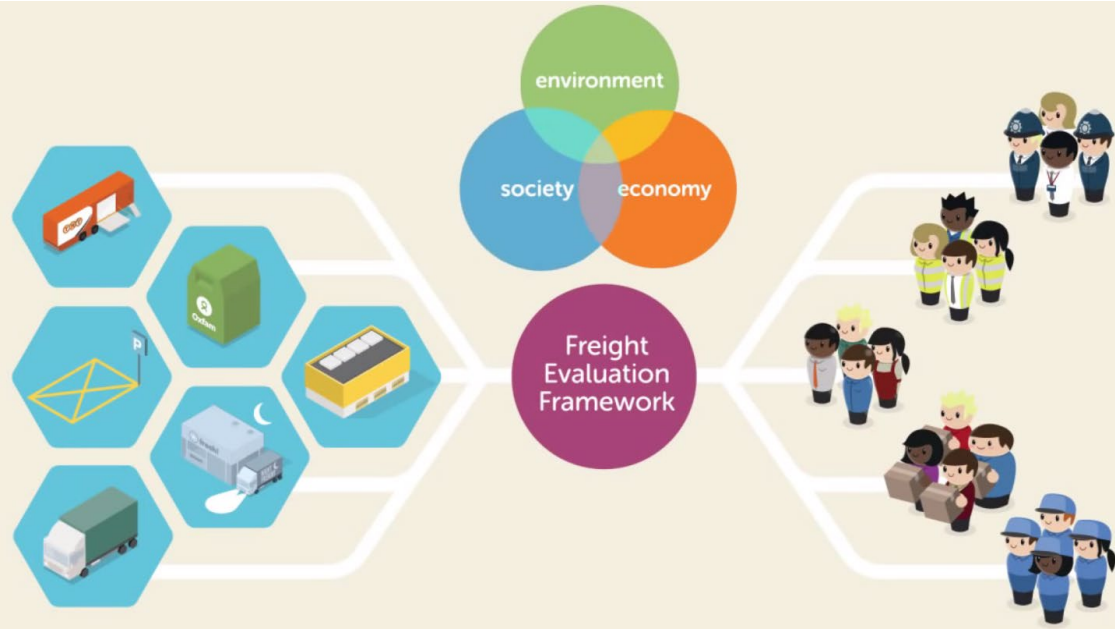
INTRODUCTION

MOBILITY, LOGISTICS & AUTOMOTIVE TECHNOLOGY RESEARCH CENTRE

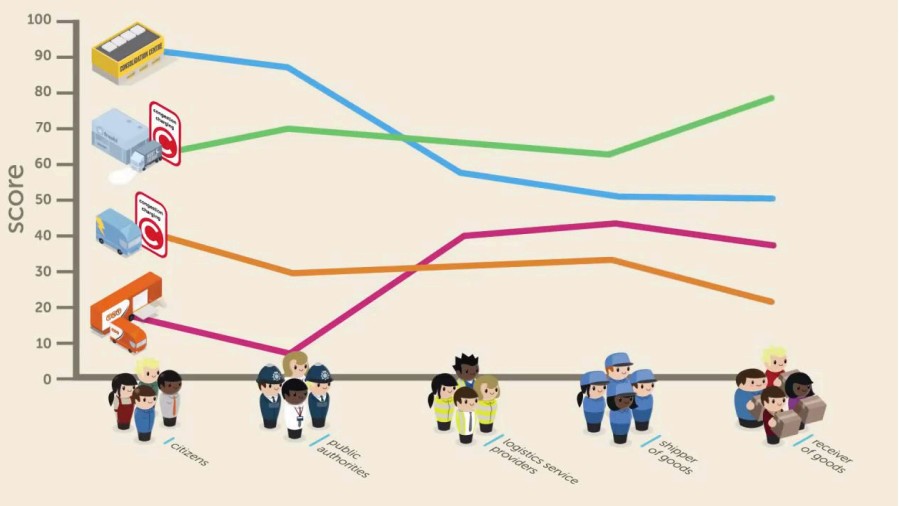
supporting and studying the transition towards a more sustainable mobility & logistics system

THE DISTINCTION OF MAMCA

MULTI-ACTOR MULTI-CRITERIA ANALYSIS

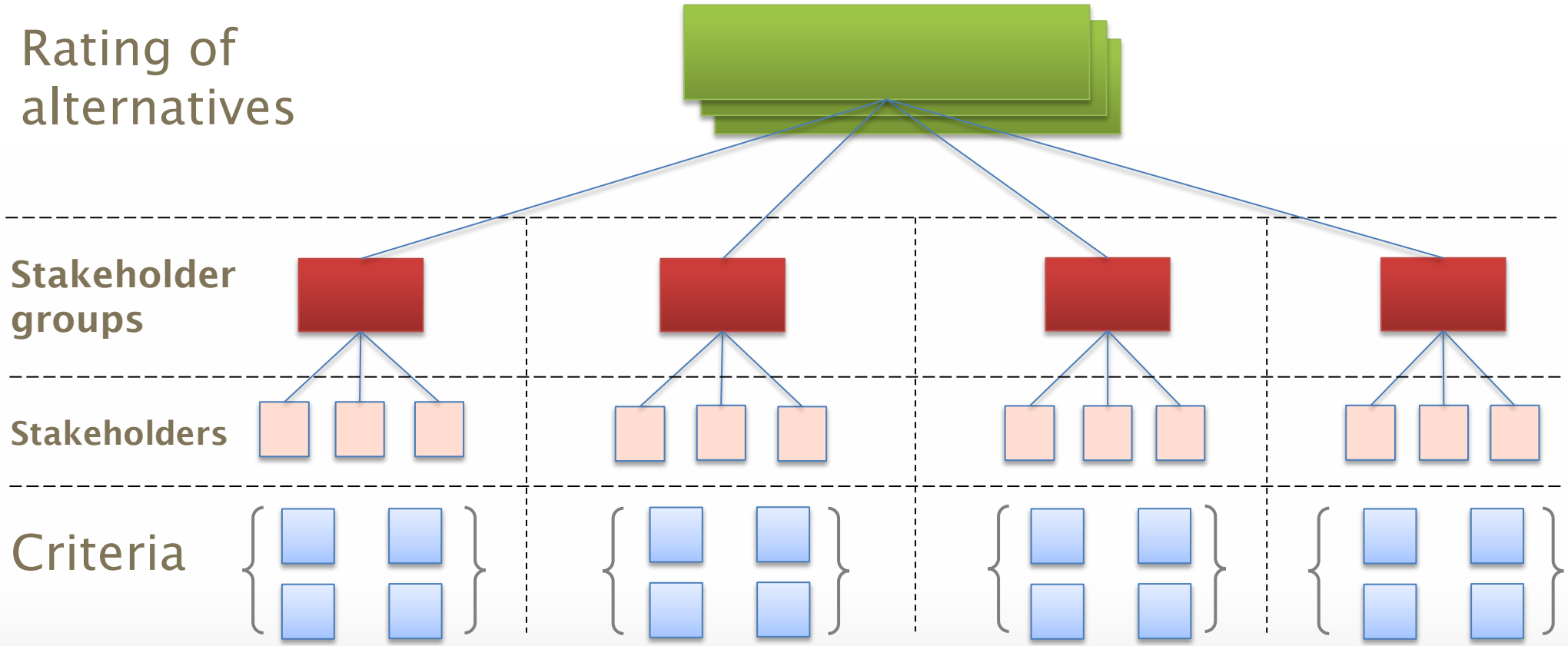


A multi-criteria decision making methodology which allows for the inclusion of multiple stakeholders



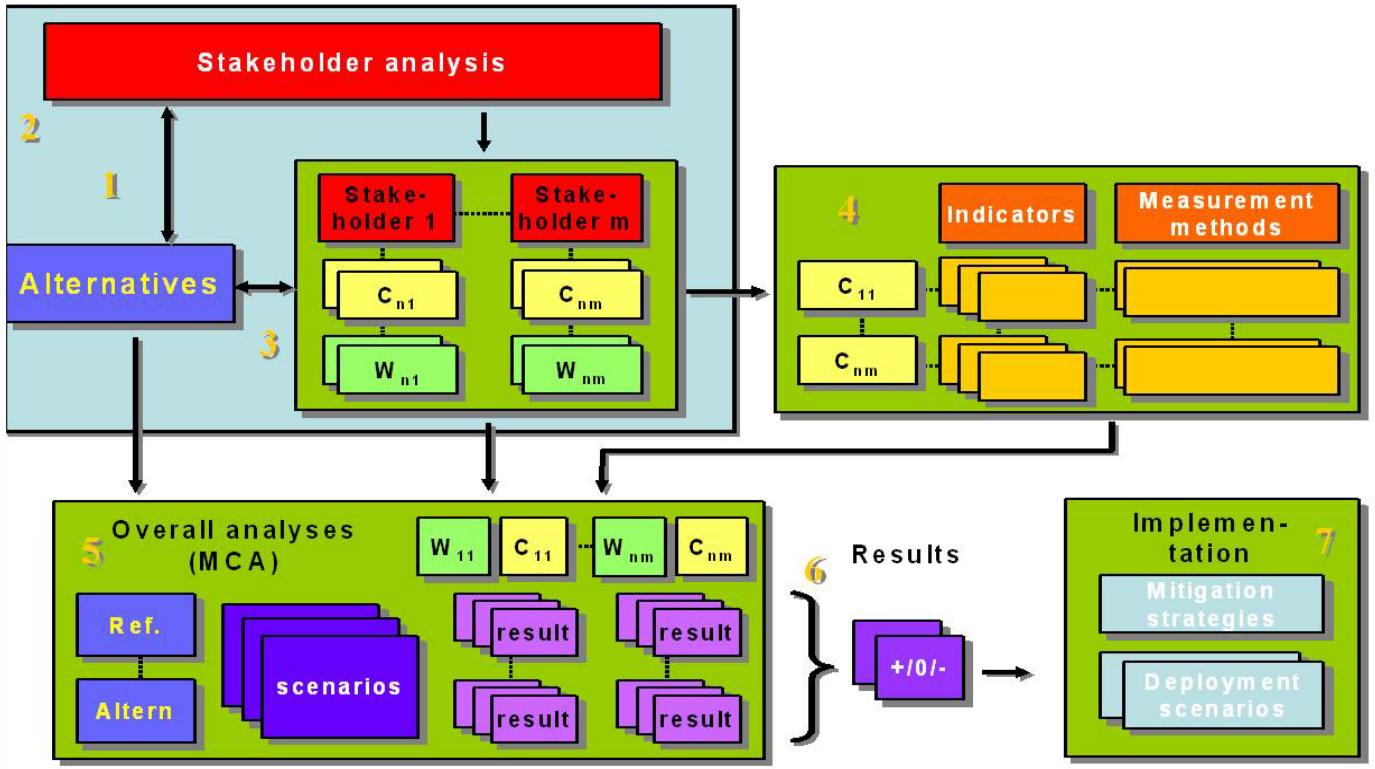
THE DISTINCTION OF MAMCA

STRUCTURE OF THE MAMCA



MAMCA METHODOLOGY

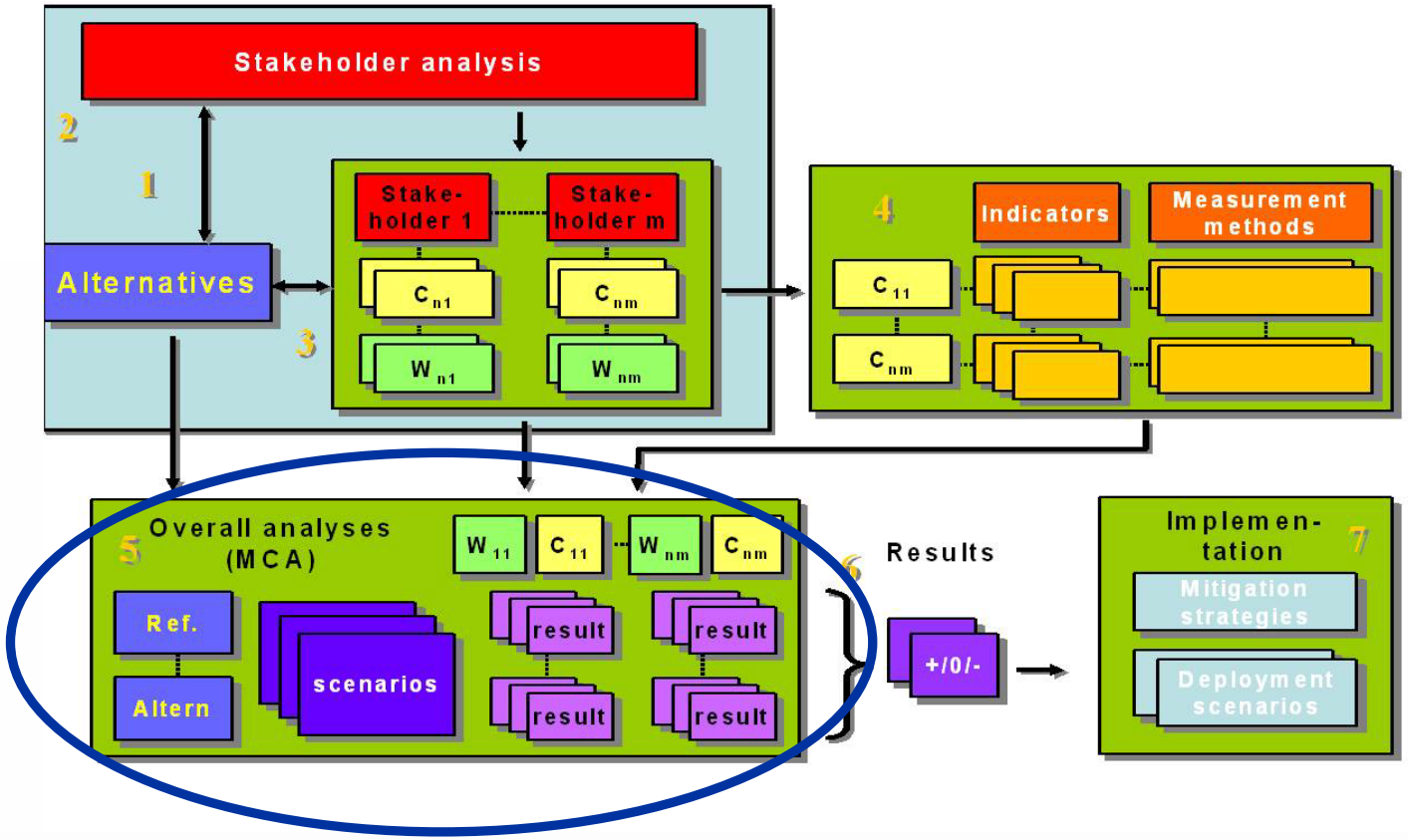
FRAMEWORK



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

MAMCA METHODOLOGY

MCDM METHODS



- AHP
- PROMETHEE
- ELECTRE
- ...

CASE STUDY

CITYLAB PROJECT CASES

The CITYLAB objective is to develop knowledge and solutions that result in up-scaling and roll-out of strategies, measures and tools for emission-free city logistics in urban centres by 2030.

http://www.citylab-project.eu
https://mamca.vub.be

CASE STUDY

ALTERNATIVES

Alternative	Pros
E-freight bikes and micro-hubs	Reduction of emission, decrease of overall operating cost
Online shop and use of spare capacity	Possibility of use spare transport capacity, no additional kilometres
Last-mile carrier and electric vans	Reduction of distance and energy, empty distance reduction
Common logistics in shopping centre	Reduction of dwell times for delivery vehicles, fewer individual transport inside the shopping centre, satisfied store employees, better waste handling
Urban warehouse and electric vans (25%)	Reduction of emission, vehicle kilometre saving
Integrated reverse logistics	Reduction of total vehicle kilometres and emission, financial viability

CASE STUDY

CRITERIA TREE

Stakeholder group	Criteria
Receiver	Positive effect on society, low cost for receiving goods, high quality deliveries, attractive shopping environment
Shipper	Positive effect on society, high quality deliveries, low cost for transport, high quality pick-ups
Shopping centre owner	Financial viability, attractive shopping environment, high quality service
Society	Fluent traffic, attractive shopping environment, air quality, road safety, low exposure to noise
Transport operator	Viable investment, positive effect on society, satisfied employees, profitable operations, high quality service

MAMCA METHODOLOGY

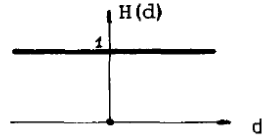
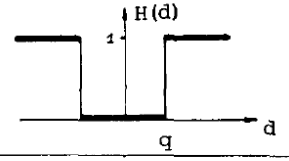
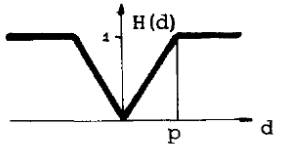
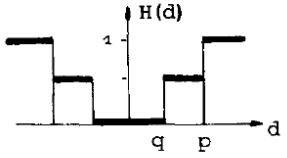
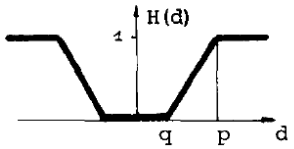
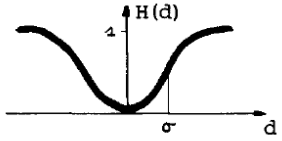
PROMETHEE RECAP

$$\mathcal{F} = \{f_1, f_2, f_3 \dots, f_m\}$$

$$P_k(a_i, a_j) = H_k(d_k(a_i, a_j))$$

$$\begin{cases} P_k(a_i, a_j) = 0, means\ an\ indifference\ between\ a_i\ and\ a_j, \\ P_k(a_i, a_j) \sim 0, means\ weak\ preference\ of\ a_i\ over\ a_j, \\ P_k(a_i, a_j) \sim 1, means\ strong\ preference\ of\ a_i\ over\ a_j, \\ P_k(a_i, a_j) = 1, means\ strict\ preference\ of\ a_i\ over\ a_j. \end{cases}$$

$$P(a_i, a_j) = \sum_{k=1}^{m} w_k \cdot P_k(a_i, a_j).$$

Types of generalized criteria		Param -eters
I. Usual criterion		-
II. Quasi-criterion		q
III. Criterion with linear preference		p
IV. Level criterion		q,p
V. Criterion with linear preference and indifference area		q,p
VI. Gaussian criterion		σ

(Brans, Vincke, & Mareschal, 1986)

MAMCA METHODOLOGY

PROMETHEE RECAP

$$\phi^+(a_i) = \frac{1}{n-1} \cdot \sum_{a_j \in \mathcal{A}, i \neq j} P(a_i, a_j),$$

The positive flow score ϕ^+

$$\phi^-(a_i) = \frac{1}{n-1} \cdot \sum_{a_j \in \mathcal{A}, i \neq j} P(a_j, a_i),$$

The negative flow score ϕ^-

$$\phi(a_i) = \phi^+(a_i) - \phi^-(a_i).$$

The net flow score ϕ

$$\phi(a_i) = \frac{1}{n-1} \sum_{k=1}^{m} \sum_{a_j \in \mathcal{A}, i \neq j} [P_k(a_i, a_j) - P_k(a_j, a_i)] \cdot w_k$$

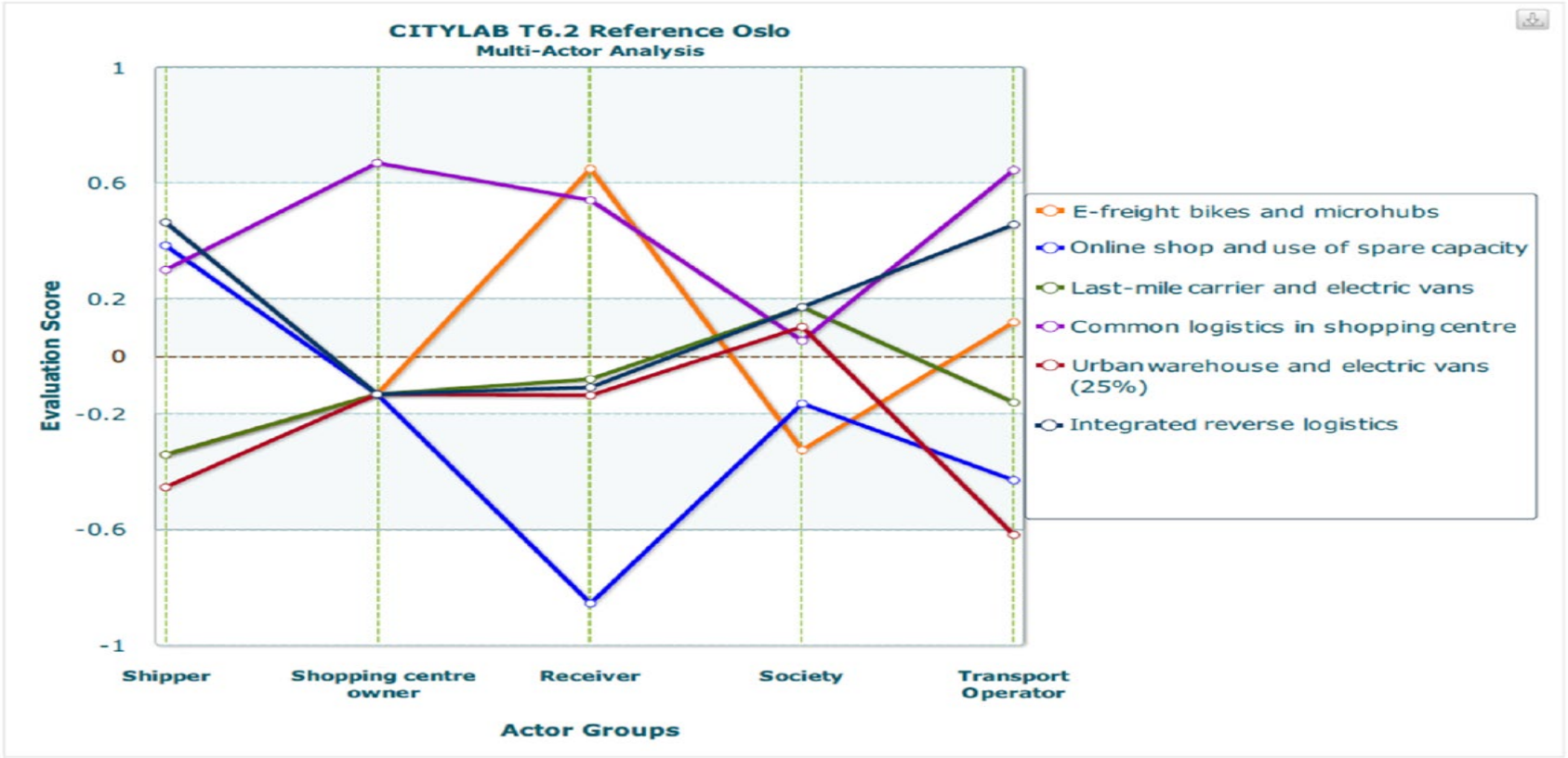
$$= \sum_{k=1}^{m} \phi_k(a_i) \cdot w_k$$

$$\begin{cases} a_i P_{\text{II}} a_j \ (a_i \ outranks \ a_j) \Leftrightarrow \phi(a_i) > \phi(a_j), \\ a_i I_{\text{II}} a_j \ (a_i \ is \ indifferent \ to \ a_j) \Leftrightarrow \phi(a_i) = \phi(a_j). \end{cases}$$

The procedure comes to an end by calculating the net outranking flow for each alternative and completing the ranking. The maximum amount of net flow denotes the best alternative.

CASE STUDY

MULTI-ACTOR VIEW

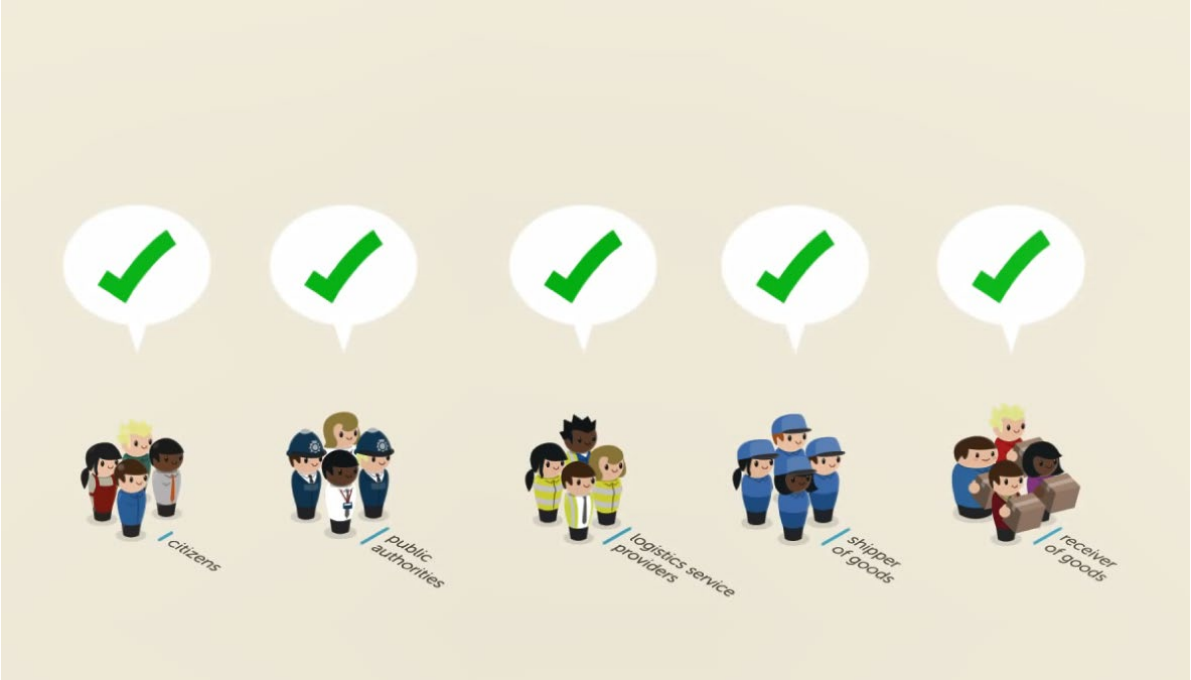


MAMCA METHODOLOGY

REACHING CONSENSUS

MAMCA METHODOLOGY

REACHING CONSENSUS



Find a consensus based on the use of a weight sensitivity analysis model in the context of the PROMETHEE methods and which is based on inverse mixed-integer linear optimization.

Huang, H., De Smet, Y., Macharis, C., & Doan, N. A. V. (2021).
Collaborative decision-making in sustainable mobility: identifying possible consensuses in the multi-actor multi-criteria analysis based on inverse mixed-integer linear optimization.
International Journal of Sustainable Development & World Ecology, 28(1), 64-74.

WEIGHT SENSITIVITY ANALYSIS MODEL

PROMETHEE SENSITIVITY ANALYSIS

$$\phi(a_i) = \frac{1}{n-1}\sum_{k=1}^{m}\sum_{a_j \in \mathcal{A}, i \neq j}\left[P_k(a_i, a_j) - P_k(a_j, a_i)\right] w_k = \sum_{k=1}^{m}\phi_k(a_i)\, w_k$$

What would be the minimum modifications that should be accepted by the different stakeholder groups such that a common alternative would get a higher position in the different rankings

The objective is to minimize the distances of these new weights compared to the initial ones:

$$\min z = \sum_{k=1}^{m}\left|w_{k,p} - w'_{k,p}\right|$$

WEIGHT SENSITIVITY ANALYSIS MODEL

INDICATORS

z	Weight distance	Modification of the weight allocation that leads to the change of ranking
o	Ranking distance	Deviation of the ranking position of one alternative to the top ranking

REACHING CONSENSUS

OSLO CASE

Stakeholder group	Original weight allocation	Original first ranked alternative
Shipper	[0.0944, 0.0702, 0.5826, 0.2528]	Integrated reverse logistics
Shopping centre owner	[0.3333, 0.3333, 0.3333]	Common logistics in shopping centre
Receiver	[0.0673, 0.0367, 0.1745, 0.7215]	E-freight bikes and micro-hubs
Society	[0.0919, 0.6209, 0.1809, 0.0238, 0.0825]	Last-mile carrier and electric vans
Transport operator	[0.1738, 0.0691, 0.1496, 0.0338, 0.5737]	Common logistics in shopping centre

E-freight bikes and micro-hubs

	z_1	z_2	z_3	z_4	z_5	o_1	o_2	o_3	o_4	o_5	Z	O
1	0	0	0	0	0	0	1	2	3	5	0	11
2	0	0	0	0	0.1	0	1	2	3	4	0.1	10
3	0	0	0.306	0	0.1	0	1	1	3	4	0.406	9
4	0	0	0.306	0	0.315	0	1	1	3	3	0.621	8
5	0	0	0.306	0.354	0	0	1	1	2	3	0.66	7
6	0	0.409	0.306	0	0	0	0	1	1	3	0.715	5
7	0	0.409	0.306	0	0.453	0	0	1	1	2	1.168	4
8	0	0.409	0.602	0	0.453	0	0	0	1	2	1.464	3
9	0	0.409	0.602	0	0.643	0	0	0	1	1	1.654	2
10	0	0.409	0.602	0.902	0	0	0	0	0	1	1.913	1
11	0	0.409	0.602	0.902	1.333	0	0	0	0	0	3.246	0

REACHING CONSENSUS

OSLO CASE

Stakeholder group	Original weight allocation	Original first ranked alternative
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Alternative	Z	O
E-freight bikes and microhubs	0	11
	0.1	10
	0.406	9
	0.621	8
	0.66	7
	0.715	5
	1.168	4
	1.464	3
	1.654	2
	1.913	1
	3.246	0

Alternative	Z	O
Online shop and use of spare capacity	0	15
	0.059	14
	0.302	13
	0.437	12
	0.846	11
	1.011	8
	1.266	7
	1.988	6
	2.004	5
	2.02	3
	2.269	2
	3.602	1
	4.322	0

Alternative	Z	O
Last-mile carrier and electric vans	0	9
	0.38	8
	0.833	7
	1.023	6
	1.712	5
	2.138	4
	2.397	3
	2.618	2
	3.62	1
	4.147	0

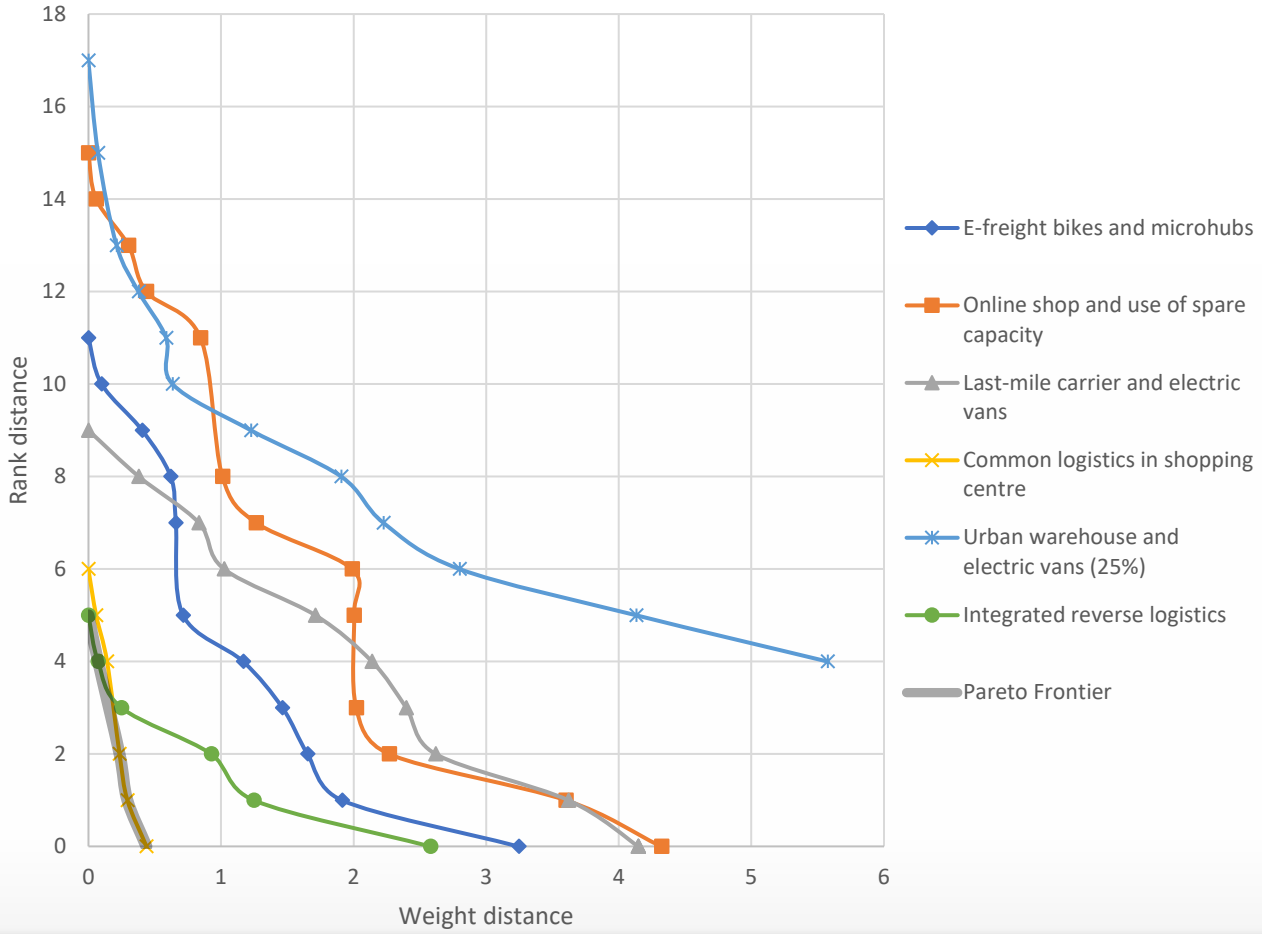
Alternative	Z	O
Common logistics in shopping centre	0	6
	0.059	5
	0.141	4
	0.235	2
	0.294	1
	0.438	0

Alternative	Z	O
Urban warehouse and electric vans (25%)	0	17
	0.073	15
	0.213	13
	0.378	12
	0.587	11
	0.635	10
	1.226	9
	1.907	8
	2.225	7
	2.8	6
	4.133	5
	5.576	4

Alternative	Z	O
Integrated reverse logistics	0	5
	0.073	4
	0.249	3
	0.926	2
	1.248	1
	2.581	0

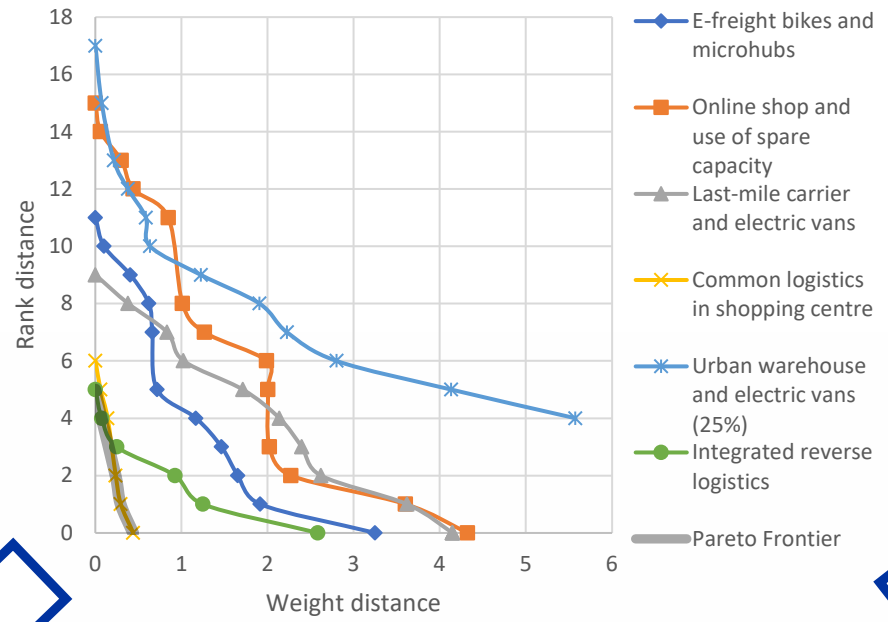
REACHING CONSENSUS

PARETO FRONTIER



REACHING CONSENSUS

TWO DIRECTION



Stakeholder group perspective

Alternative perspective

REACHING CONSENSUS

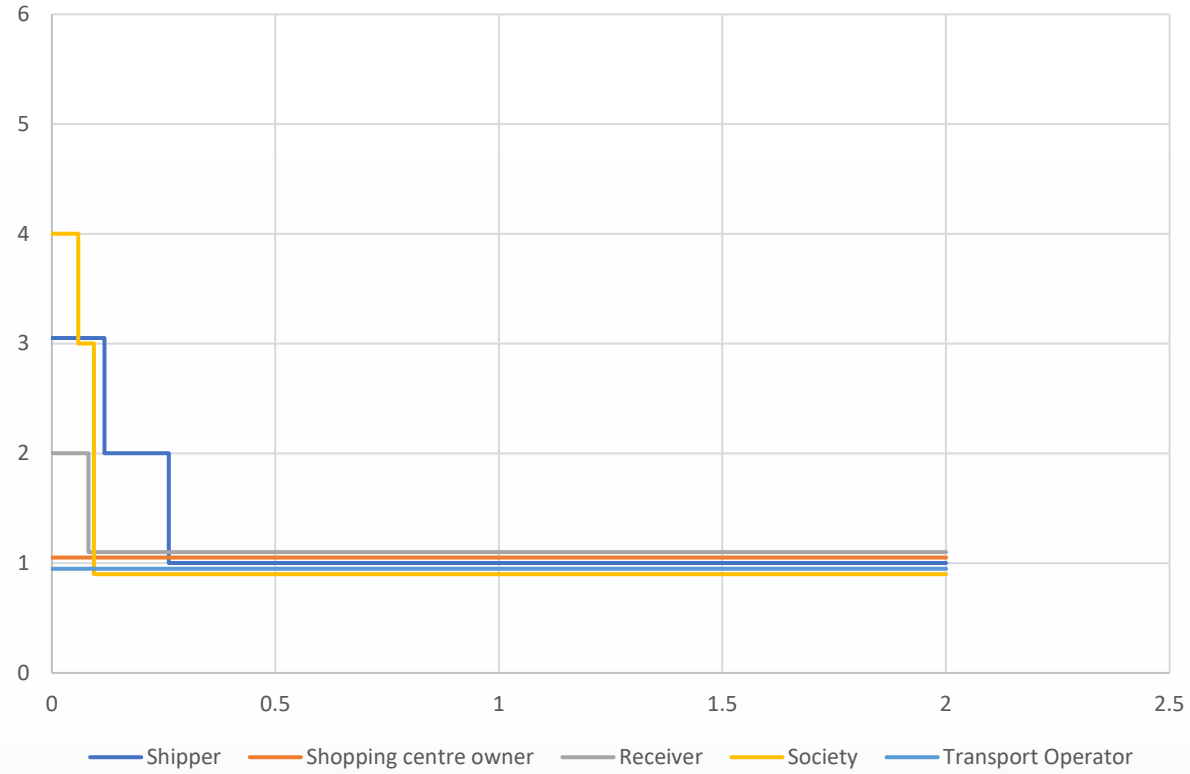
RANKING STEP TABLE

Receiver	C1	C2	C3	C4	Rank original	Z	New Rank
w (Integrated reverse logistics)	0.067	0	0.211	0.722	4	0	/
w1	0.444	0	0.174	0.381	4	0.073	3
w2	0.444	0	0.333	0.2222	4	0.754	2
w3	0.067	0	0.211	0.722	4	1.072	1

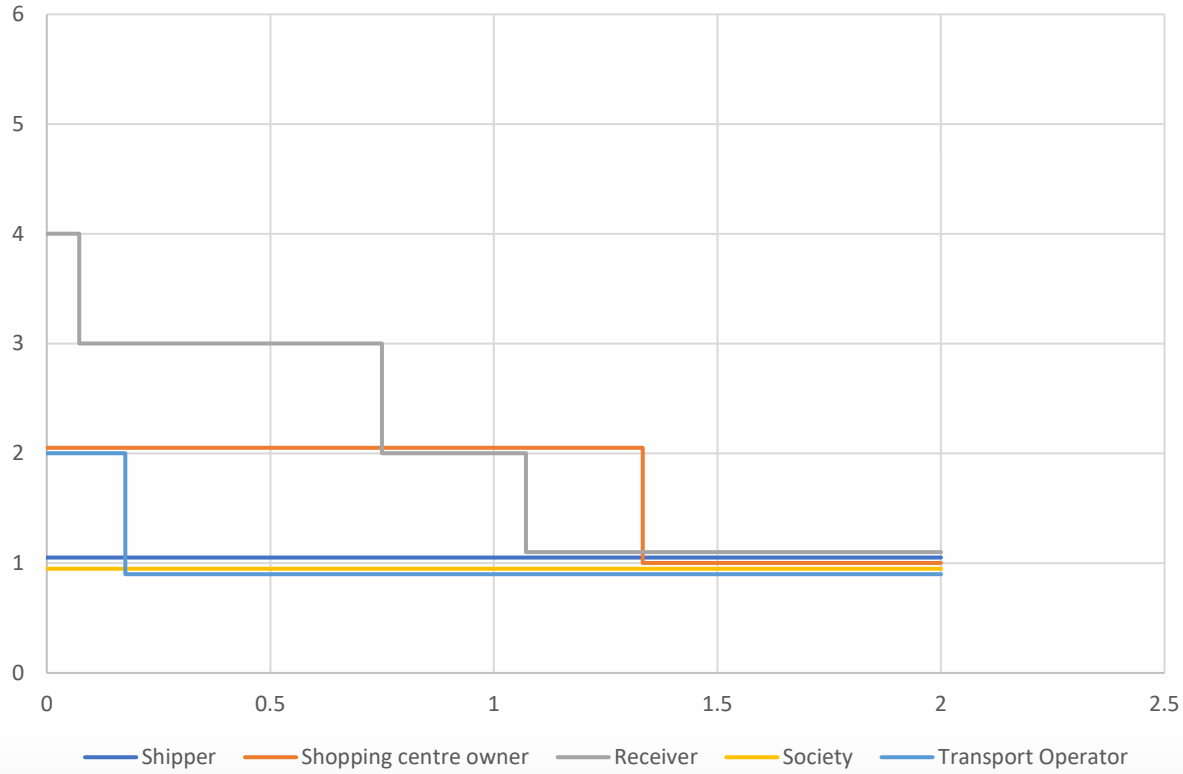
REACHING CONSENSUS

RANKING STEP CHART

Common logistics in shopping centre



Integrated reverse logistics



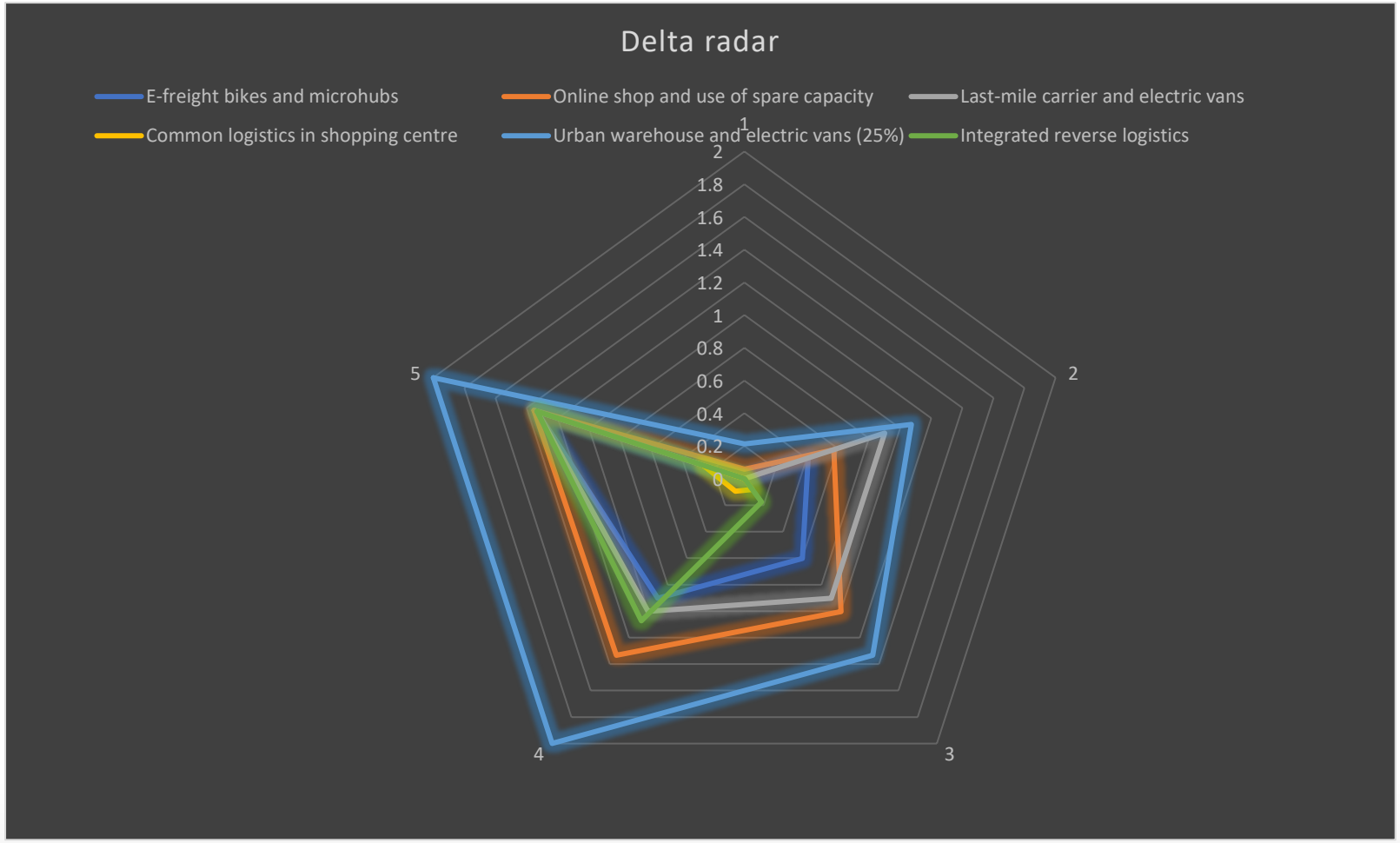
REACHING CONSENSUS

DELTA TABLE

δ = 0		
Alternative	I1 (The number of stakeholders rank this alternative first)	I2 (The number of stakeholders would have modified weight to rank one alternative first)
E-freight bikes and microhubs	1	0
Online shop and use of spare capacity	0	0
Last-mile carrier and electric vans	1	0
Common logistics in shopping centre	2	0
Urban warehouse and electric vans (25%)	0	0
Integrated reverse logistics	2	0
δ = 0.059		
Alternative	I1 (The number of stakeholders rank this alternative first)	I2 (The number of stakeholders would have modified weight to rank one alternative first)
E-freight bikes and microhubs	1	0
Online shop and use of spare capacity	1	1
Last-mile carrier and electric vans	1	0
Common logistics in shopping centre	2	0
Urban warehouse and electric vans (25%)	0	0
Integrated reverse logistics	2	0

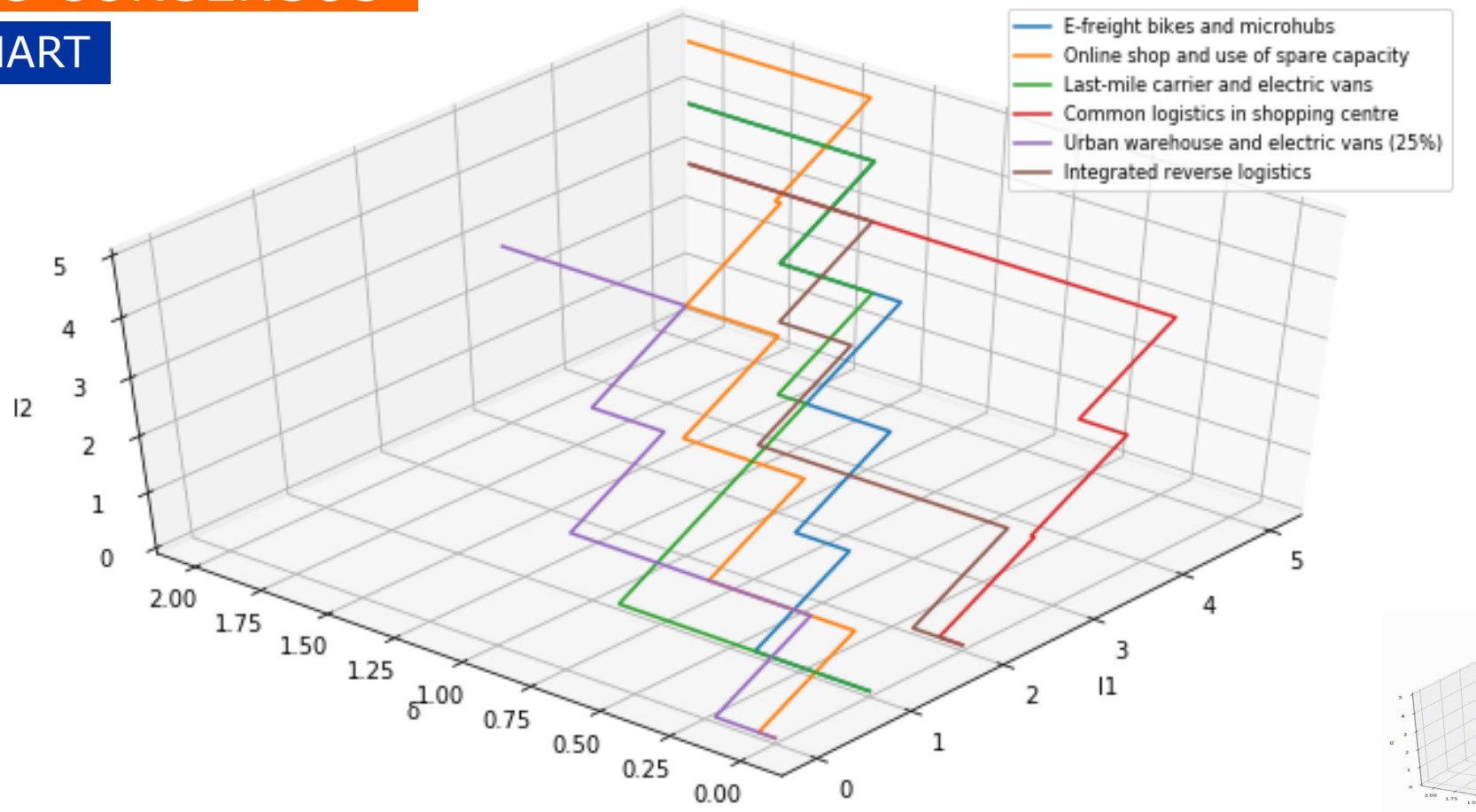
REACHING CONSENSUS

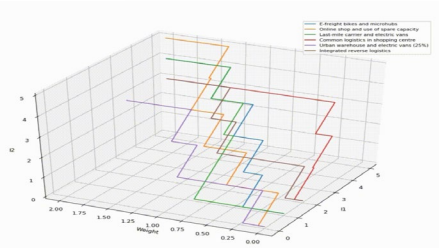
DELTA RADAR



REACHING CONSENSUS

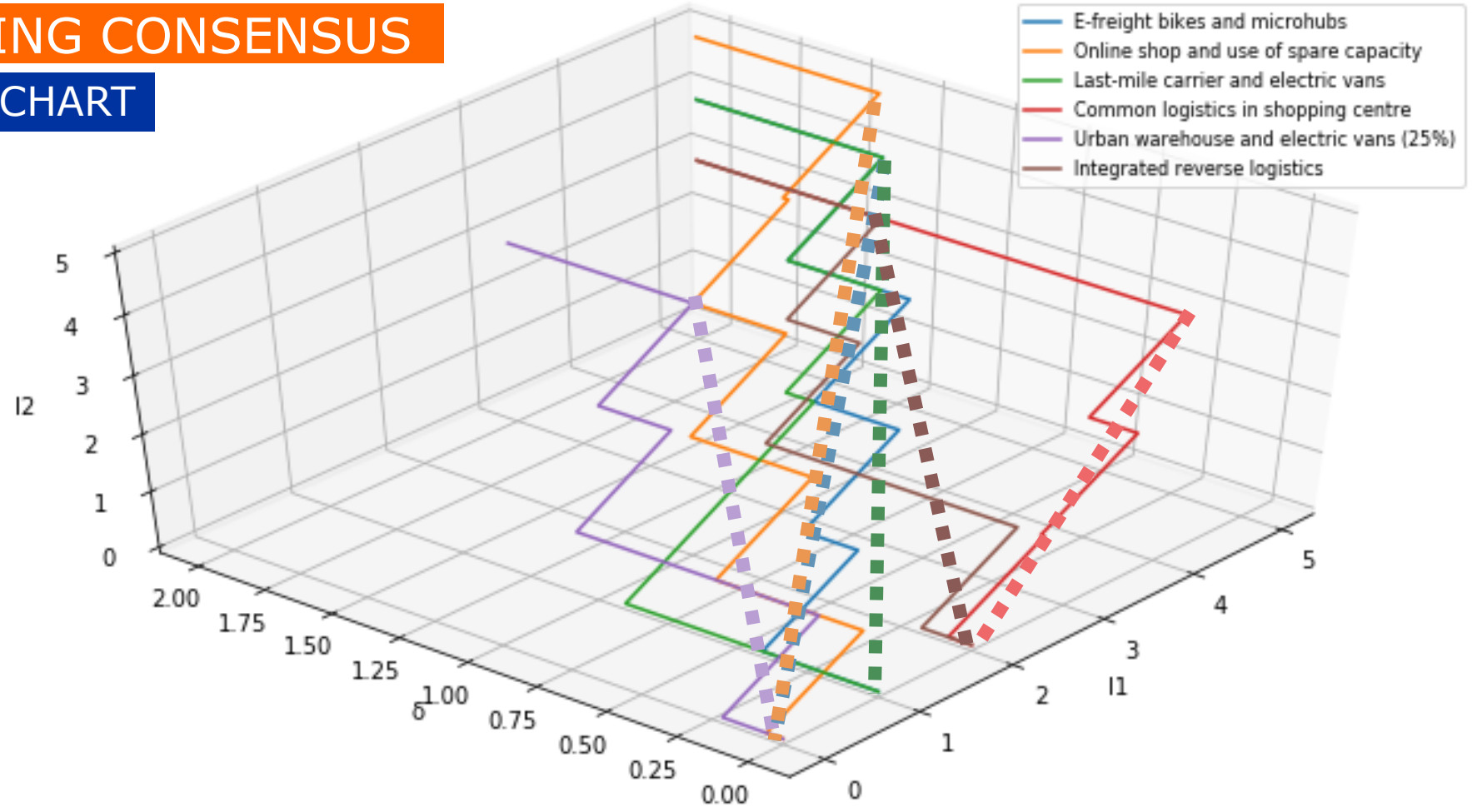
3D STEP CHART





REACHING CONSENSUS

3D STEP CHART



CONCLUSION

IDENTIFY POSSIBLE CONSENSUS

- Limit the set of good options
- Indicators to represent alternative performances
- Give visual arguments that could be communicated to the stakeholders in order to reach a consensus
- Data visualizations from different perspectives
- Leave room for discussions

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