mobilise
analysing mobility, mobilising people

ROBUST STAKEHOLDER-BASED MCGDM

THE MULTI-ACTOR MULTI-CRITERIA ANALYSIS (MAMCA)

WITH THE INTEGRATION OF BEST-WORST METHOD (BWM)

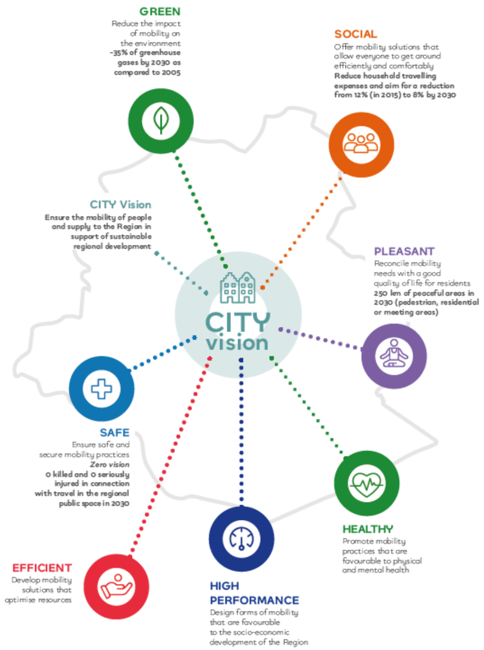
Presenter: He Huang

MOBILISE RESEARCH GROUP
VRIJE UNIVERSITEIT BRUSSEL

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

GOOD MOVE BRUSSELS

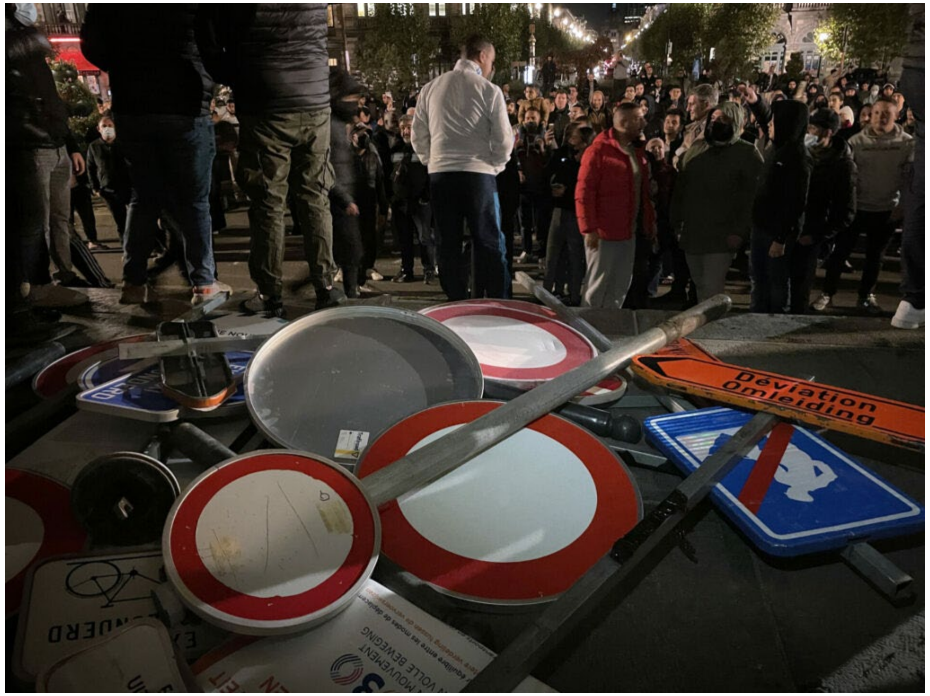
A NEW WAY OF GETTING AROUND AND LIVING IN BRUSSELS



https://mobilite-mobiliteit.brussels/en/good-move

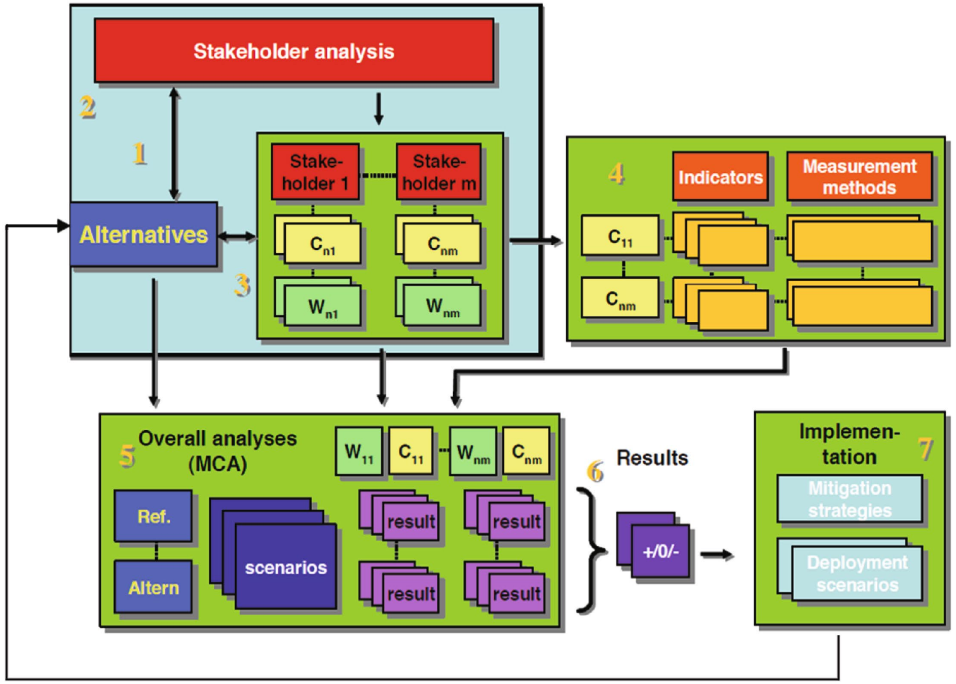
GOOD MOVE BRUSSELS

ARE WE HEARING ALL THE VOICES?



MULTI-ACTOR MULTI-CRITERIA ANALYSIS

STAKEHOLDER INVOLVEMENT

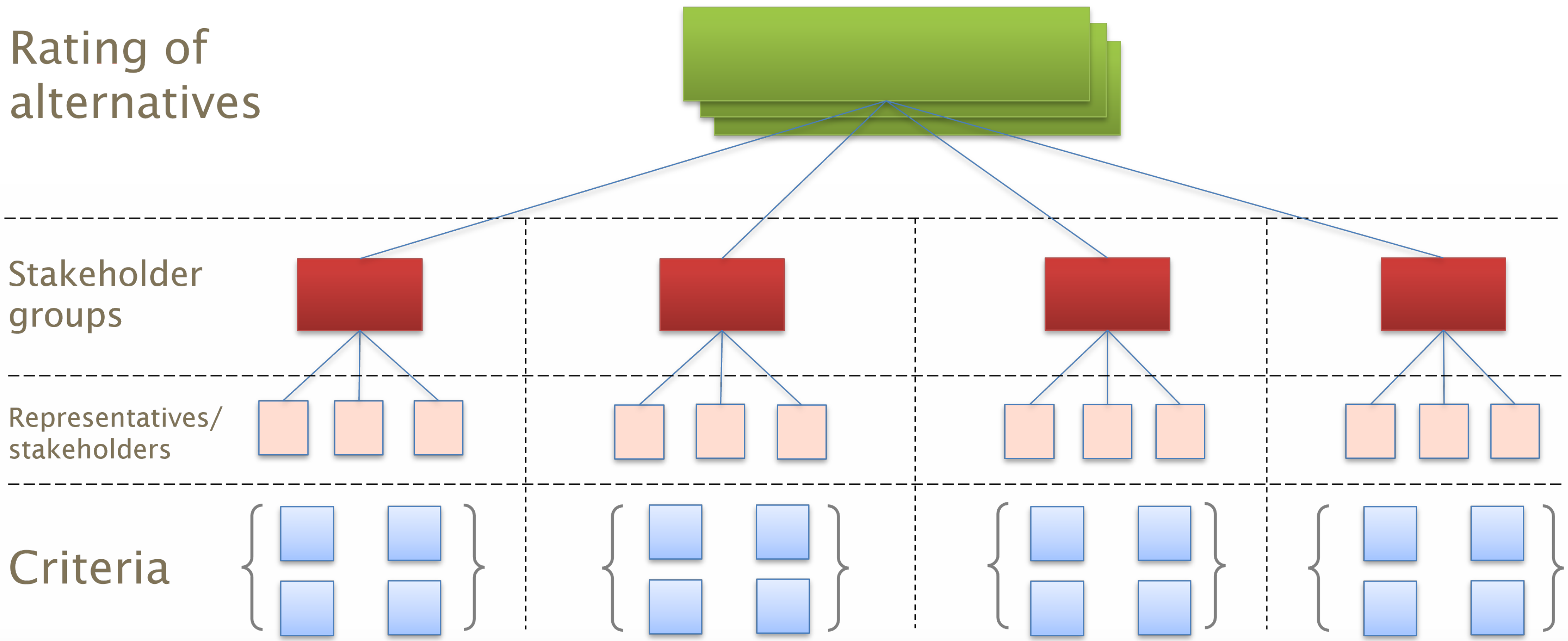


(Macharis, 2004)

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

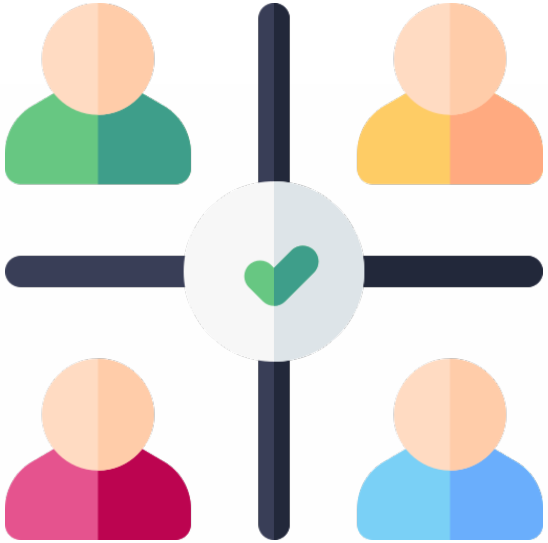
STAKEHOLDER INVOLVEMENT



(Huang et al., 2021)

MULTI-ACTOR MULTI-CRITERIA ANALYSIS

CHALLENGES IN MAMCA



CHALLENGES IN MAMCA

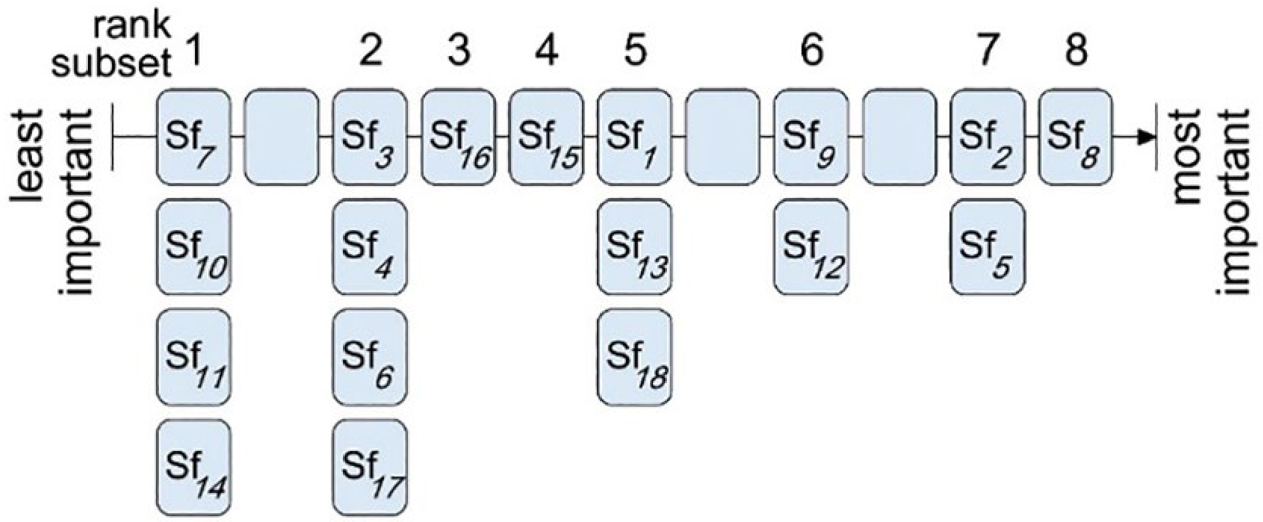
WEIGHT ELICITATION

- Challenges for stakeholders:
  - Limited expertise in decision-making;
  - Time constraints: The process of eliciting relevant information can be time-consuming, which may not align with stakeholders' busy schedules;
  - Subjectivity: As humans, stakeholders' judgments can be subjective and exhibit imprecision (Stewart, 2005).

IMPRECISION WEIGHT ELICITATION

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.

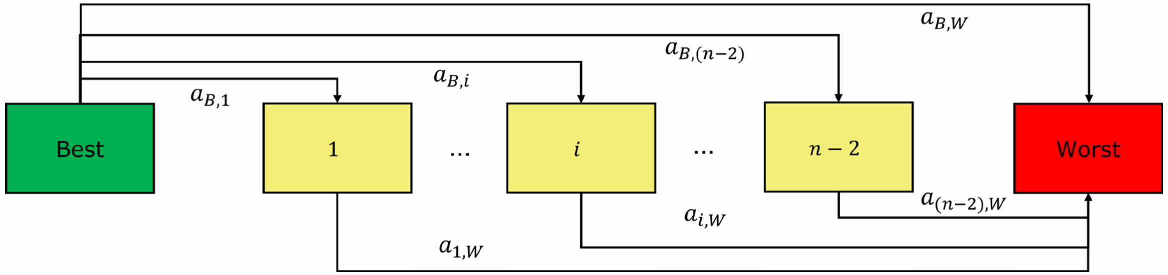


(Aşılıoğlu, 2021)

IMPRECISION WEIGHT ELICITATION

PAIRWISE COMPARISON

- Best-Worst Method (BWM):
  - Stakeholders/DMs only need to compare the criteria to the most and least important ones.



(Rezaei, 2016)

IMPRECISION WEIGHT ELICITATION

BEST-WORST METHOD (BWM)

$$C_k = \{c_1, \dots, c_n, \dots, c_{N_k}\}$$

$$A_{BO_k} = \left(a_{B_k 1}, a_{B_k 2}, \cdots, a_{B_k n_k}\right)$$

$$A_{OW_k} = \left(a_{1W_k}, a_{2W_k}, \cdots, a_{n_k W_k}\right)$$

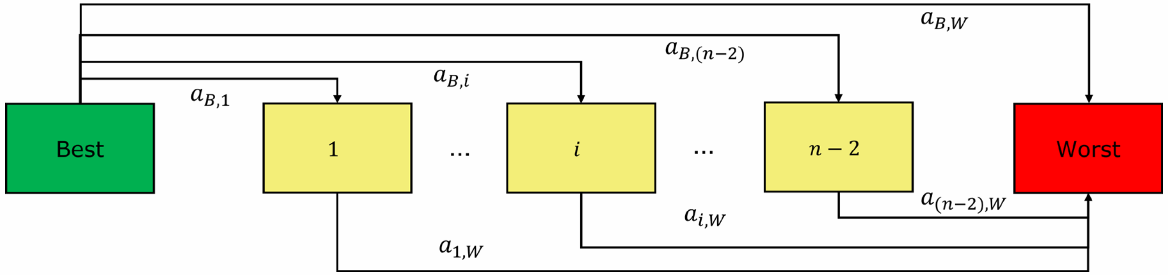
$$min\ \xi^L,$$

s.t.

$$\left|\omega_{B_k} - a_{B_k n_k} \cdot \omega_{n_k}\right| \le \xi^L, \forall n_k \in \{1,2, \dots, N_k\},$$

$$\left|\omega_{n_k} - a_{n_k W_k} \cdot \omega_{W_k}\right| \le \xi^L, \forall n_k \in \{1,2, \dots, N_k\},$$

$$\sum_{n_k=1}^{N_k} \omega_{n_k} = 1.$$



$$\Longrightarrow \quad \omega_1^*, \omega_2^*, \cdots, \omega_{n_k}^*$$

(Rezaei, 2016)

IMPRECISION WEIGHT ELICITATION
A RELIEF FOR STAKEHOLDERS

Pairwise comparison

X

Criteria group pairwise comparison

Air pollution	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	Climate change
Air pollution	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	Noise pollution
Air pollution	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	Traffic safety impacts
Air pollution	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	Societal and economic revitalization
Air pollution	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	Enforcement costs
Climate change	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	Noise pollution
Climate change	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	Traffic safety impacts
Climate change	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	Societal and economic revitalization
Climate change	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	Enforcement costs

ALERTNATIVE APPRAISAL

PROMETHEE

Alternatives: $A = \{a_1, \dots, a_m, \dots, a_M\}$

Stakeholder groups: $S = \{s_1, \dots, s_k, \dots, s_K\}$

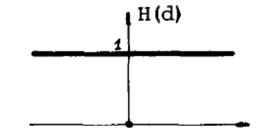
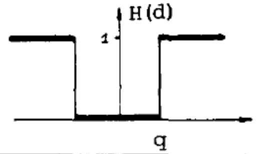
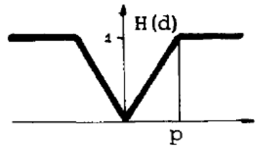
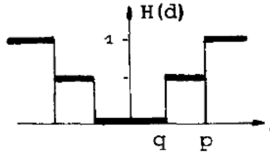
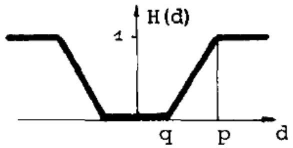
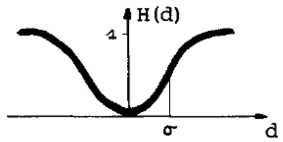
Criteria for s_k : $C_k = \{c_1, c_2, c_3 \dots, c_{N_k}\}$

The net flow score:

$$\phi(a_i) = \frac{1}{M-1} \sum_{n=1}^{N_k} \sum_{a_j \in A, i \neq j} [P_n(a_i, a_j) - P_n(a_j, a_i)] \cdot \omega_n = \sum_{n=1}^{N_k} \phi_n(a_i) \cdot \omega_n$$

Performance score matrix:

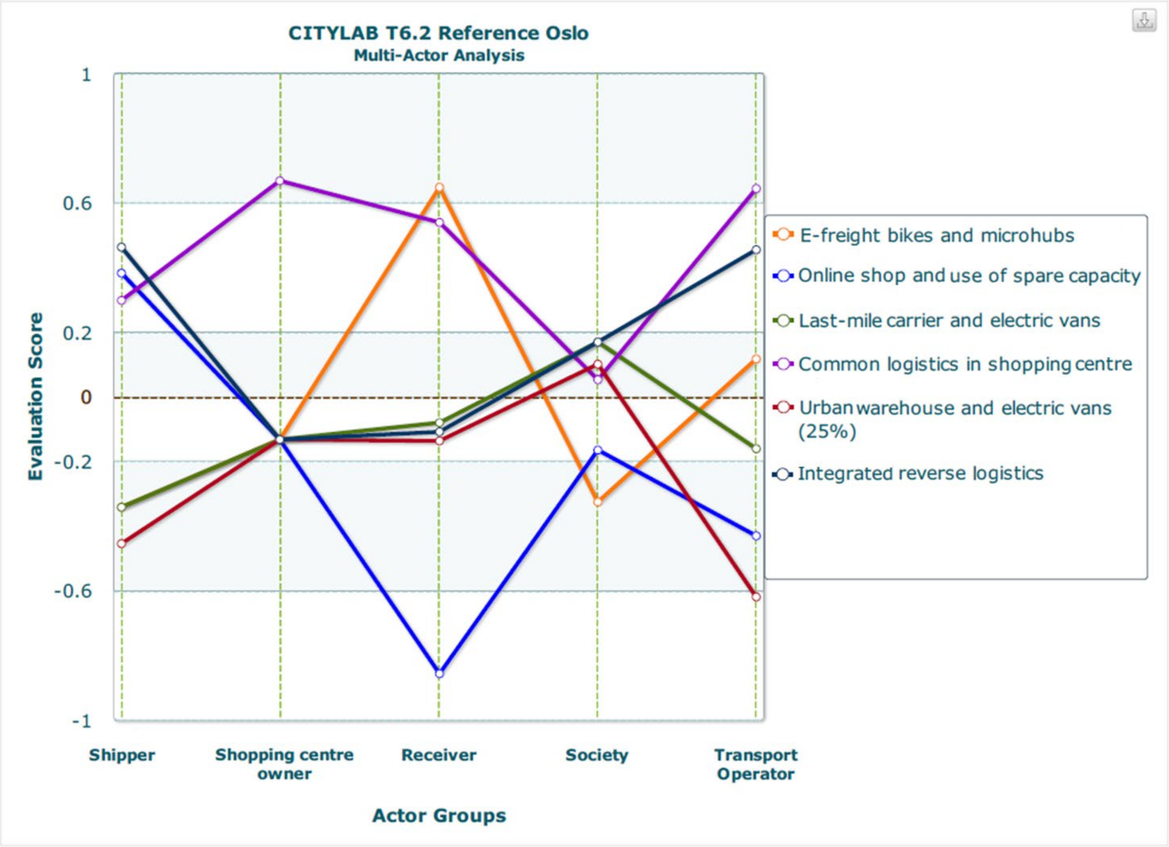
$$\Phi = \begin{bmatrix} \phi_1^1 & \cdots & \phi_1^M \\ \vdots & \ddots & \vdots \\ \phi_K^1 & \cdots & \phi_K^M \end{bmatrix}$$

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)

MULTI-ACTOR MULTI-CRITERIA ANALYSIS

MULTI-ACTOR VIEW

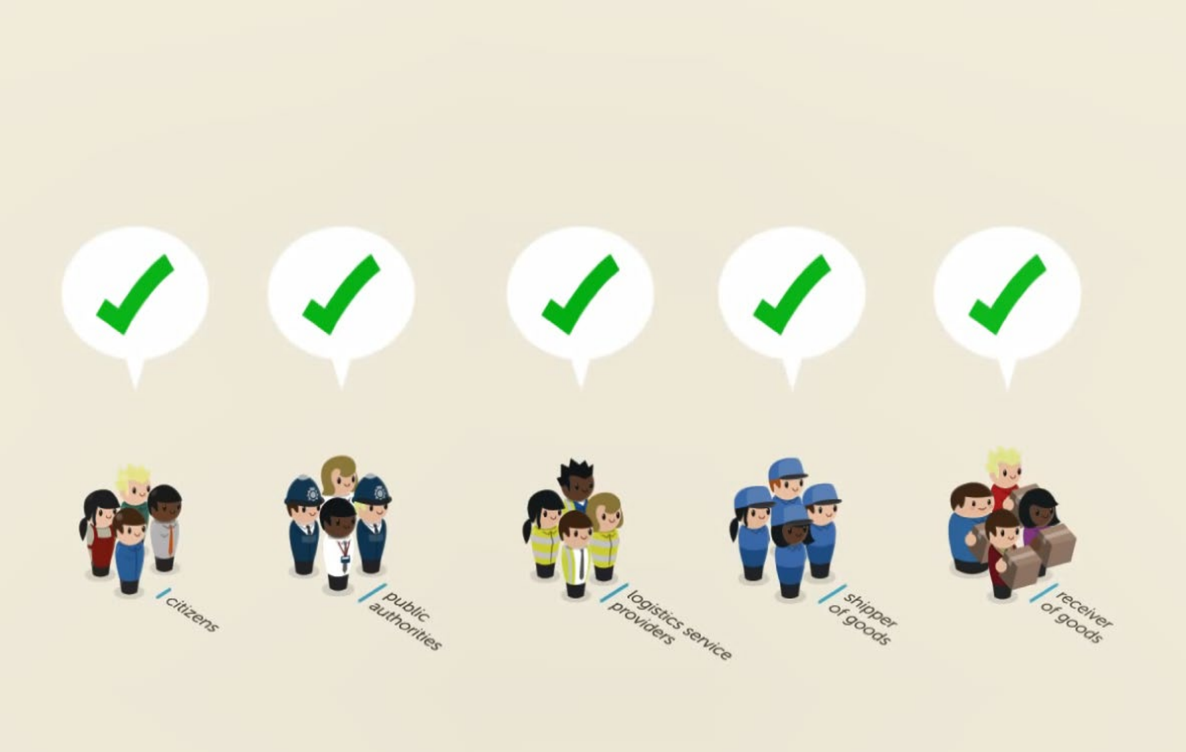


MULTI-ACTOR MULTI-CRITERIA ANALYSIS

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).

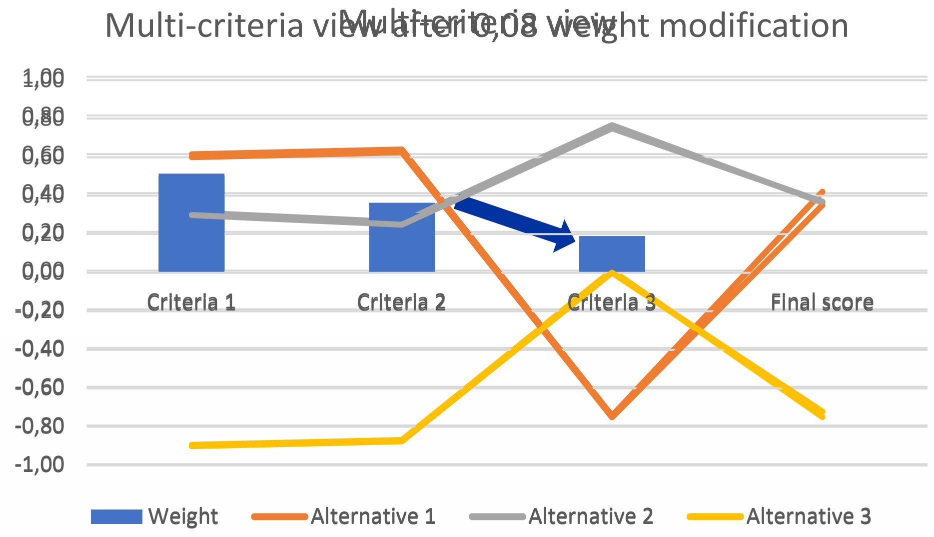
⇩

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

CONSENSUS REACHING MODEL

WEIGHT SENSITIVITY ANALYSIS

	Criterion 1	Criterion 2	Criterion 3	Final score	Rank
Weight	0,50	0,31	0,19	1,00	
Alternative 1	0,60	0,63	-0,75	0,35125	**2**
Alternative 2	0,30	0,25	0,75	0,37	**1**
Alternative 3	-0,90	-0,88	0,00	-0,72125	3



What would be the **minimum** weight modifications that can be accepted by all stakeholder groups such that a common alternative can be ranked at the top position?

Weighted sum method (Fishburn, 1967):

$$\phi(a_i) = \sum_{n}^{N_k} \phi_n \cdot \omega_n$$

$$min\, z = \sum_{n=1}^{m} \left|\omega_{n,p} - \omega'_{n,p}\right|$$

CONSENSUS REACHING MODEL

FIND THE MINIMUM WEIGHT MODIFICATIONS

$$min\ z_k^m = \sum_{n_k=1}^{N_k} \left|\omega_{k,n_k} - \omega'_{k,n_k}\right| = \sum_{n_k=1}^{N_k} \left(d_{1,n_k,k} + d_{2,n_k,k}\right),$$

s.t. $\omega_{k,n_k} - \omega'_{k,n_k} = \begin{cases} d_{1,n_k,k}, if\ \omega_{k,n_k} - \omega'k, n_k \geq 0 \\ -d_{2,n_k,k}, if\ otherwise \end{cases}, d_{1,n_k,k}, d_{2,n_k,k} \geq 0$

$\sum_{n_k=1}^{N_k} \omega_{k,n_k}{}' = 1, \forall k = 1,2,\ldots,K$ (Weights constraint)

$\phi_k'^m = \sum_{n_k=1}^{N_k} p_{n_k}^m \times \omega'_{k,n_k}, \forall n_k \in \{1,2,\ldots,N_k\},$ (Alternative scores computation)

$\phi_k'^m - \phi_k'^{m'} \leq \epsilon \cdot r_k^m,$

$\phi_k'^m - \phi_k'^{m'} \geq \epsilon\,(r_k^m - 1),$ (Rank change of a_m)

$\boldsymbol{\sum_{m'=1,m'\neq m}^{M} r_k^m = M - g, \forall g = 1,2,\ldots,M-1,}$

$\omega_{k,n_k}, d_{1,n_k,k}, d_{2,n_k,k} \geq 0,, \forall k \in \{1,\ldots,K\}, \forall n_k \in \{1,2,\ldots,N_k\}$ (Domain)

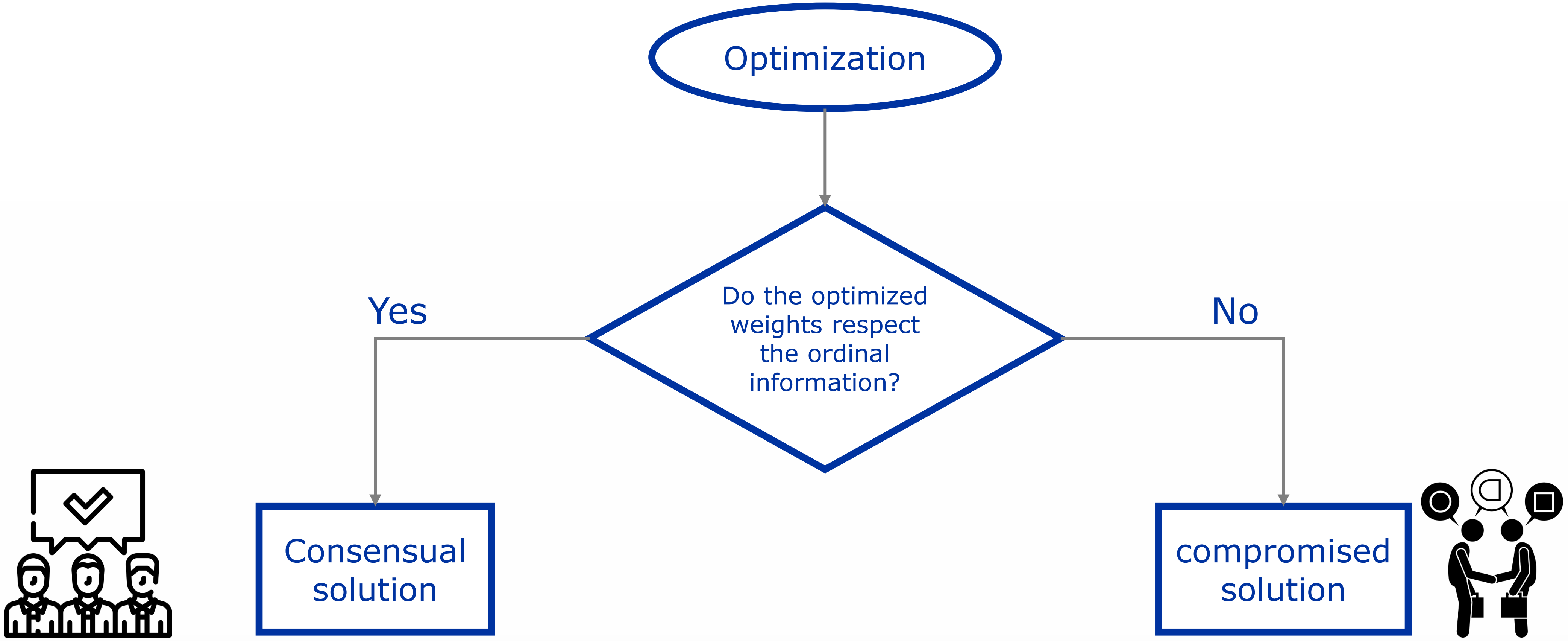
CHALLENGES IN MAMCA

ROBUSTNESS ANALYSIS

- Ordinal consistency:
  - Without a consistency threshold, stakeholders/DMs face the challenge of determining when to revise or accept their judgments;
  - It's crucial in BWM to check ordinal consistency, ensuring that criteria rankings from A_{BO_k} and A_{OW_k} comparison vectors align (Liang et al, 2019);
  - The optimization should consider the ordinal information provided by the stakeholders.

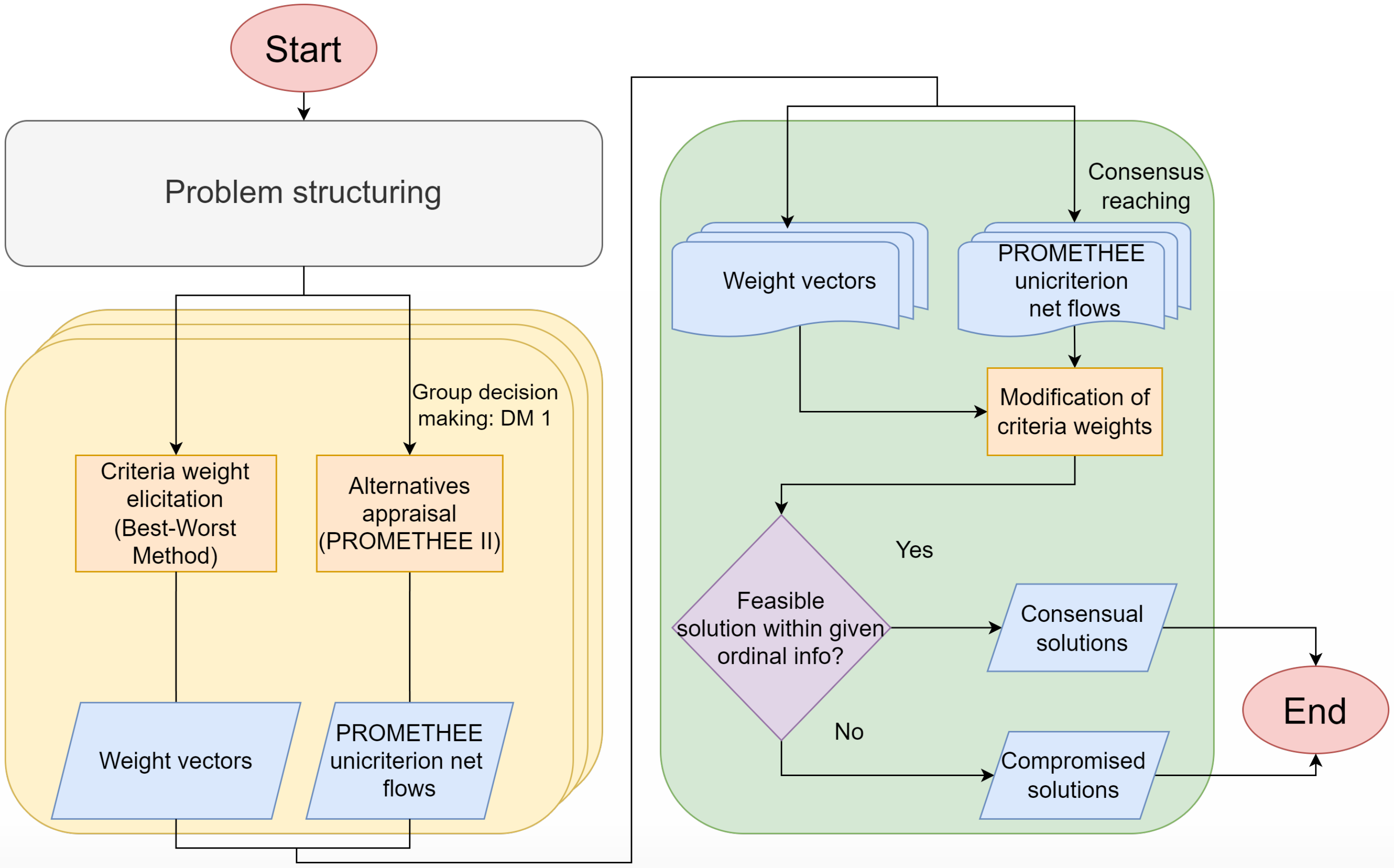
CHALLENGES IN MAMCA

CONSENSUS REACHING OR COMPROMISE SEEKING



ROBUST STAKEHOLDER-BASED MCGDM

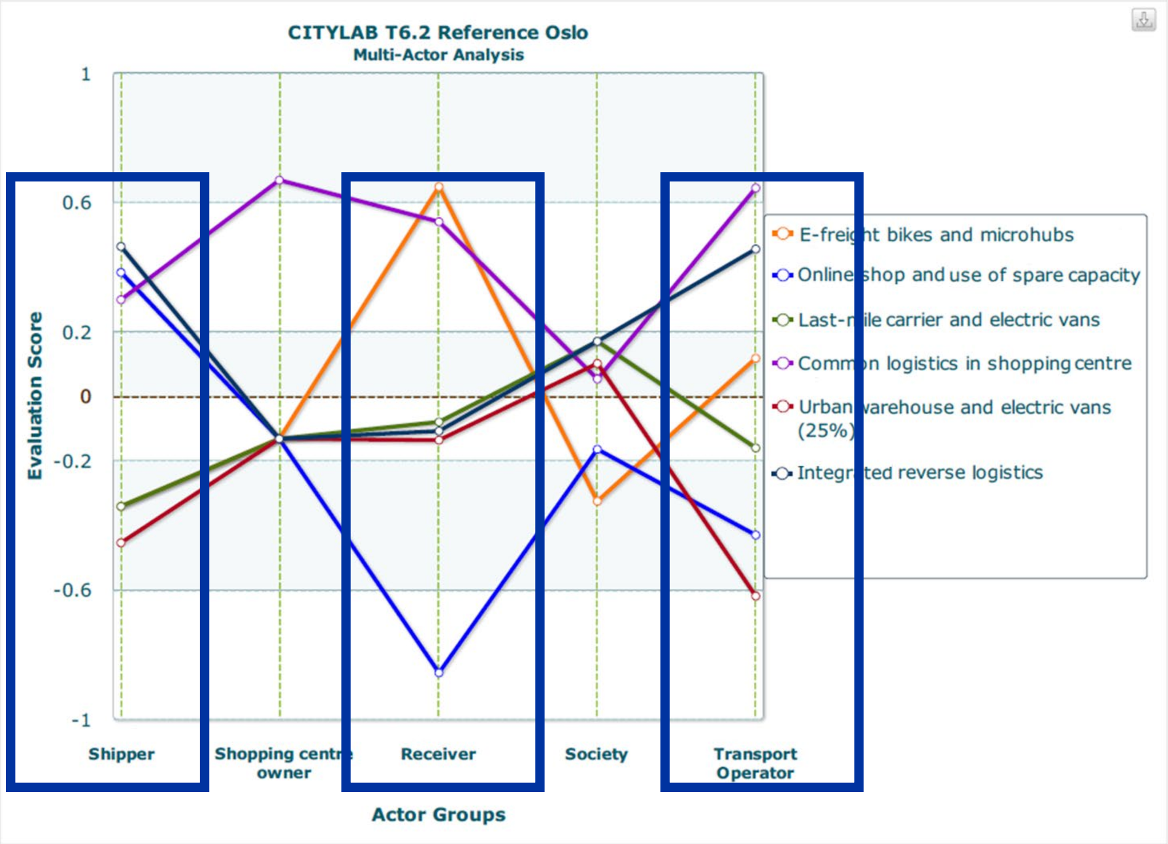
FLOWCHART

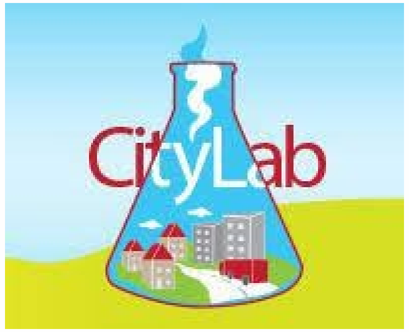


ROBUST STAKEHOLDER-BASED MCGDM

CASE STUDY

- CITYLAB project





http://www.citylab-project.eu

CITYLAB PROJECT CASE

CASE ILLUSTRATION

	Shipper	Receiver	Transport operator
E-freight bikes and micro-hubs	3rd	1st	3rd
Common logistics in shopping center	2nd	2nd	1st
Integrated reverse logistics	1st	3rd	2nd

CITYLAB PROJECT CASE

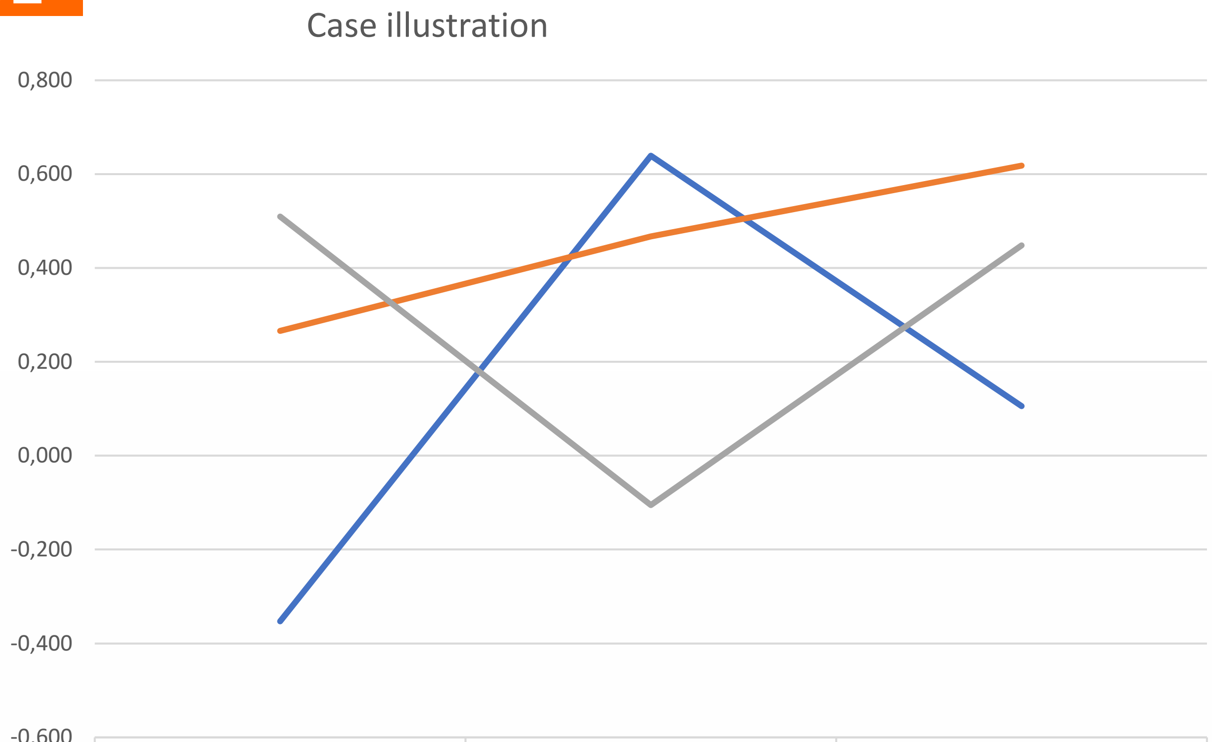
BWM RECREATION

Table 5 Best-to-others (BO) and others-to-worst (OW) pairwise comparison vectors for three stakeholders

Shipper					
BO		Positive effect on society	Low cost for receiving goods	High quality deliveries	Attractive shopping environment
Best criterion: high quality deliveries		8	9	1	2
OW					Worst criterion: low cost for receiving goods
Positive effect on society					2
Low cost for receiving goods					1
High quality deliveries					9
Attractive shopping environment					8
Receiver					
BO		Positive effect on society	Low cost for receiving goods	High quality deliveries	Attractive shopping environment
Best criterion: attractive shopping environment		8	9	4	1
OW					Worst criterion: low cost for receiving goods
Positive effect on society					2
Low cost for receiving goods					1
High quality deliveries					4
Attractive shopping environment					9
Receiver					
BO	Viable investment	Positive effect on society	Satisfied employees	Profitable operations	High quality service
Best criterion: high quality service	5	8	4	9	1
OW					Worst criterion: profitable operations
Viable investment					5
Positive effect on society					2
Satisfied employees					4
Profitable operations					1
High quality service					9

CITYLAB PROJECT CASE

MULTI ACTOR VIEW



	Shipper	Receiver	Transport operator
E-freight bikes and micro-hubs	-0,353	0,639	0,105
Common logistics in shopping center	0,266	0,467	0,618
Integrated reverse logistics	0,509	-0,105	0,448

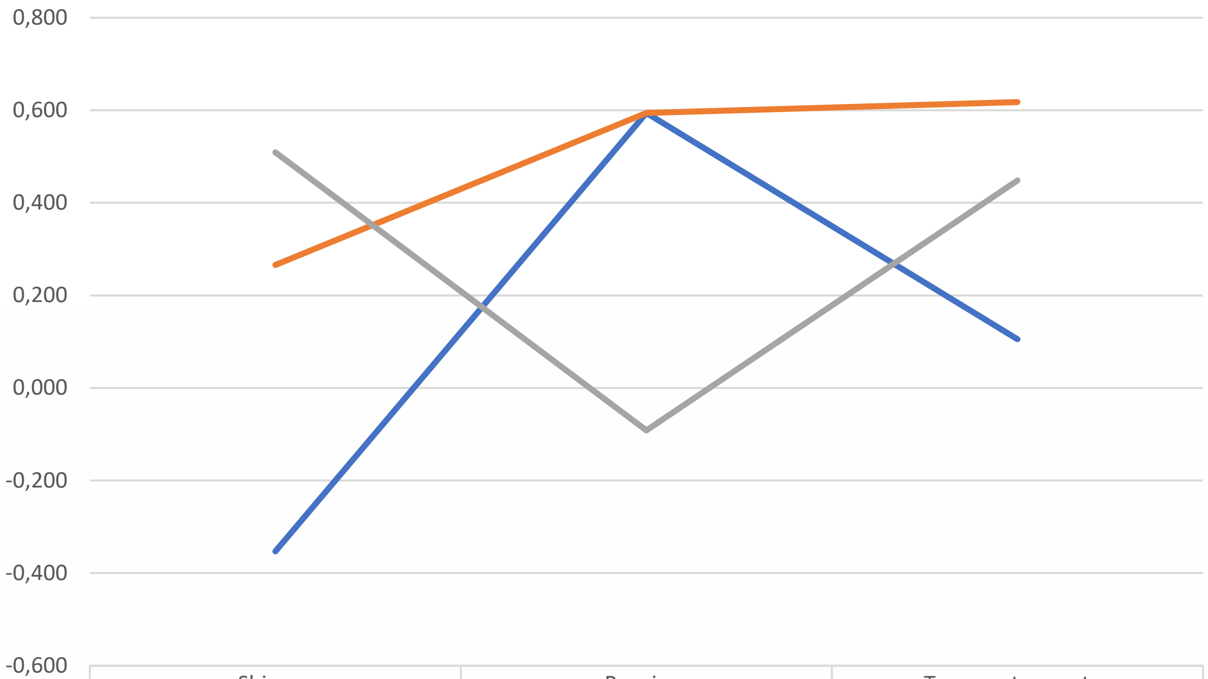
E-freight bikes and micro-hubs   Common logistics in shopping center   Integrated reverse logistics

CITYLAB PROJECT CASE

OPTIMIZATION

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

Case illustration



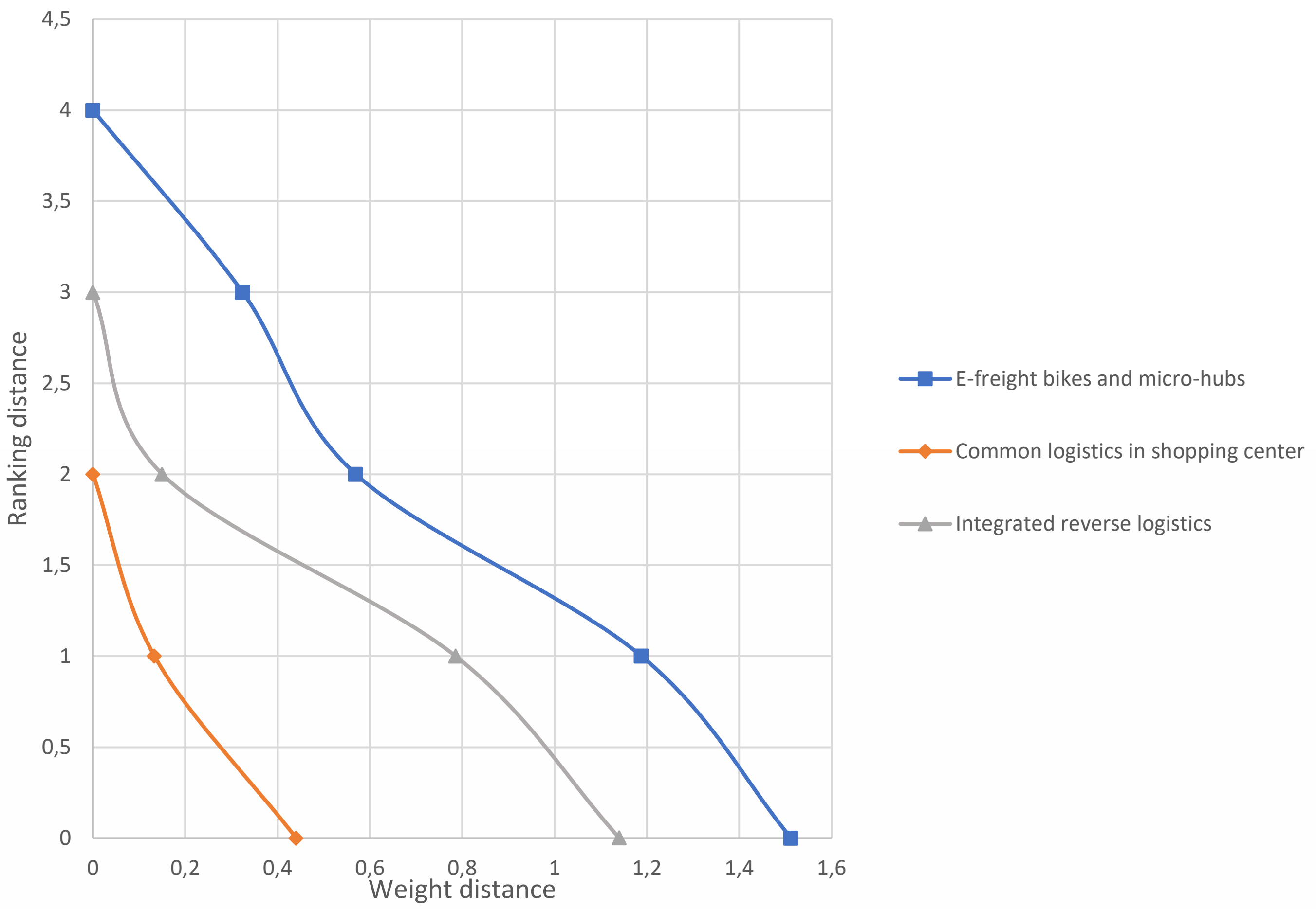
	Shipper	Receiver	Transport operator
E-freight bikes and micro-hubs	-0,353	0,5942	0,105
Common logistics in shopping center	0,266	0,594	0,618
Integrated reverse logistics	0,509	-0,0914	0,448

E-freight bikes and micro-hubs   Common logistics in shopping center   Integrated reverse logistics

CITYLAB PROJECT CASE

CONSENSUS REACHING

The sum of their current rankings compared to the first position

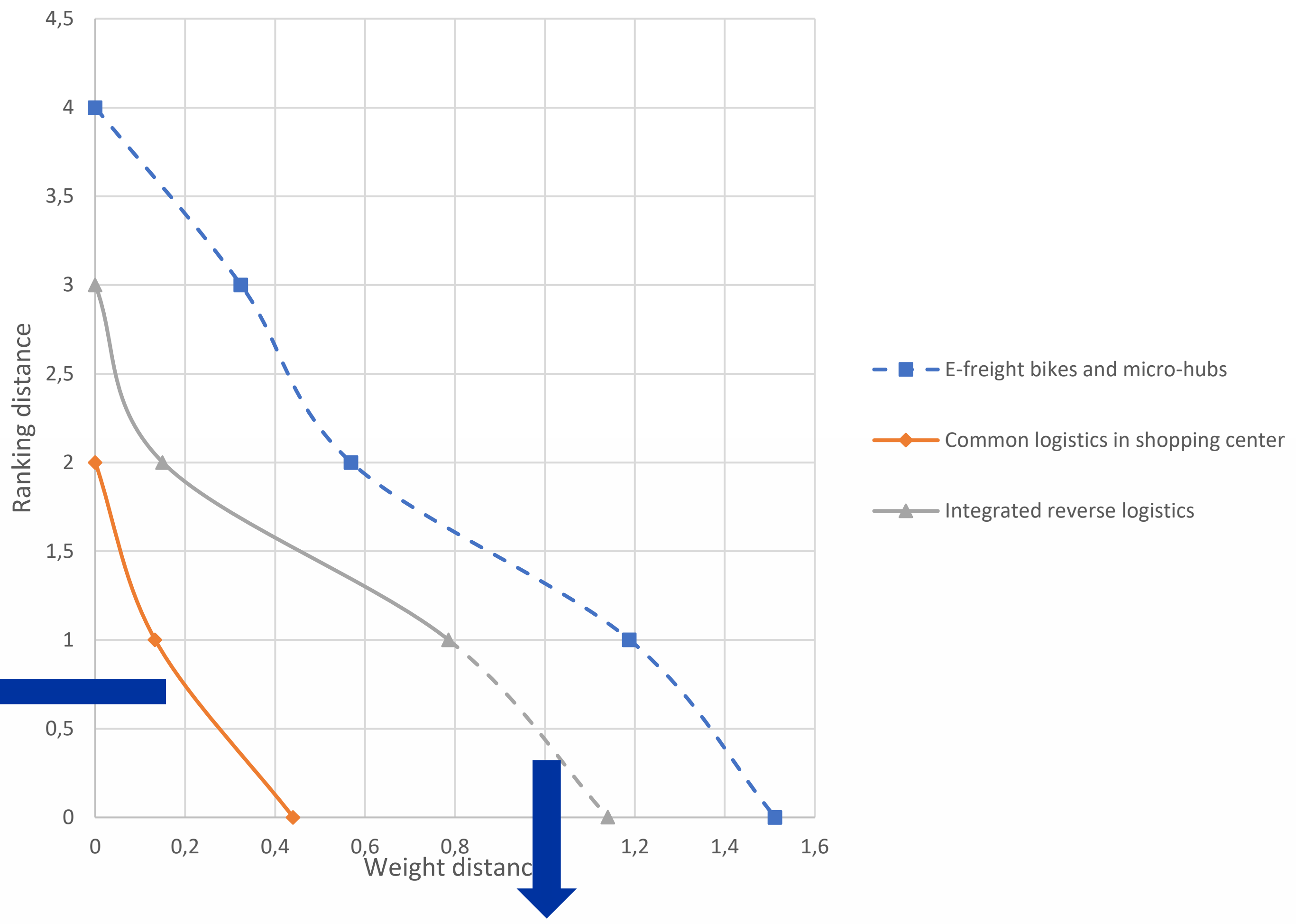


When rank distance is 0, the alternative is ranked as 1st for all stakeholder groups

The sum of their weight modification to improve the ranking

CITYLAB PROJECT CASE

ROBUSTNESS ANALYSIS

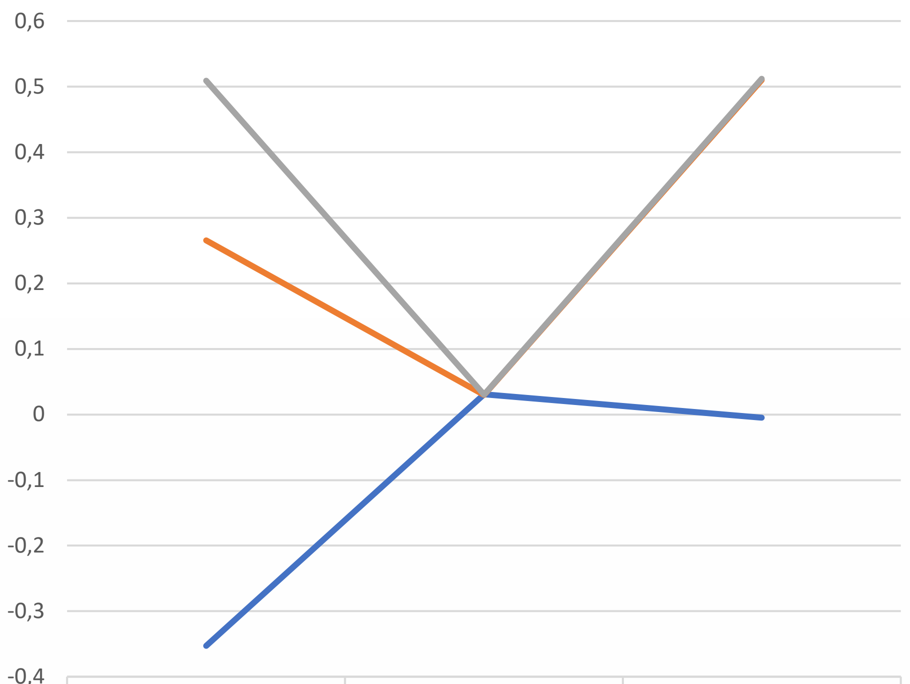


Consensual solution

Compromised solution

CONSENSUS REACHING

INTEGRATED REVERSE LOGISTICS



	Shipper	Receiver	Transport operator
E-freight bikes and micro-hubs	-0,352715655	0,0308	-0,005
Common logistics in shopping center	0,265814696	0,03	0,51
Integrated reverse logistics	0,509265176	0,0304	0,512

E-freight bikes and micro-hubs   Common logistics in shopping center   Integrated reverse logistics

CONSENSUS REACHING

RECEIVER

Attractive shopping environments >
High quality deliveries >
Positive effect on society >
Low cost for receiving goods

Table 5 Best-to-others (BO) and others-to-worst (OW) pairwise comparison vectors for three stakeholders

Shipper					
BO		Positive effect on society	Low cost for receiving goods	High quality deliveries	Attractive shopping environment
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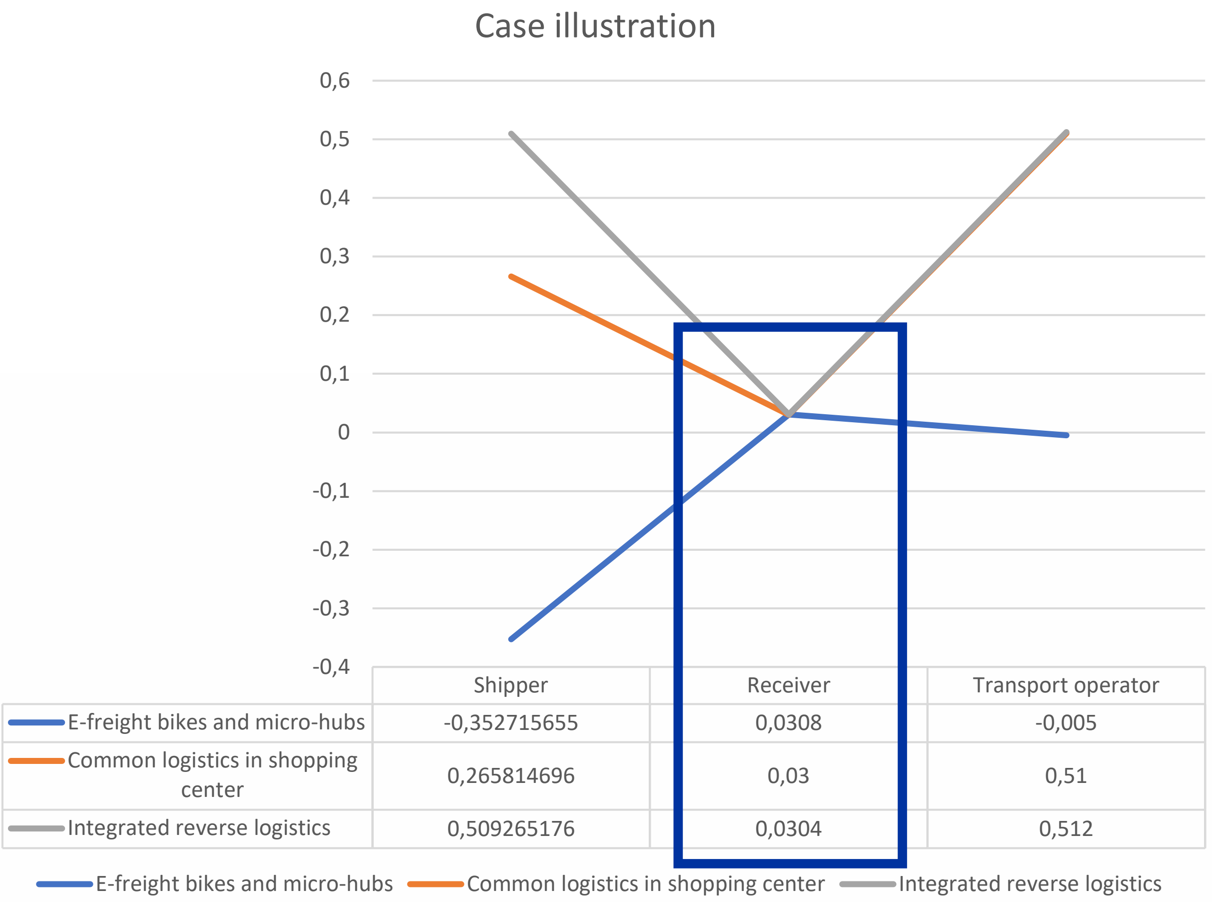
OW					Worst criterion: low cost for receiving goods
Positive effect on society					2
Low cost for receiving goods					1
High quality deliveries					9
Attractive shopping environment					8
Receiver					
BO		Positive effect on society	Low cost for receiving goods	High quality deliveries	Attractive shopping environment
Best criterion: attractive shopping environment		8	9	4	1
OW					Worst criterion: low cost for receiving goods
Positive effect on society					2
Low cost for receiving goods					1
High quality deliveries					4
Attractive shopping environment					9
Receiver					
BO	Viable investment	Positive effect on society	Satisfied employees	Profitable operations	High quality service
Best criterion: high quality service	5	8	4	9	1
OW					Worst criterion: profitable operations
Viable investment					5
Positive effect on society					2
Satisfied employees					4
Profitable operations					1
High quality service					9

CONSENSUS REACHING

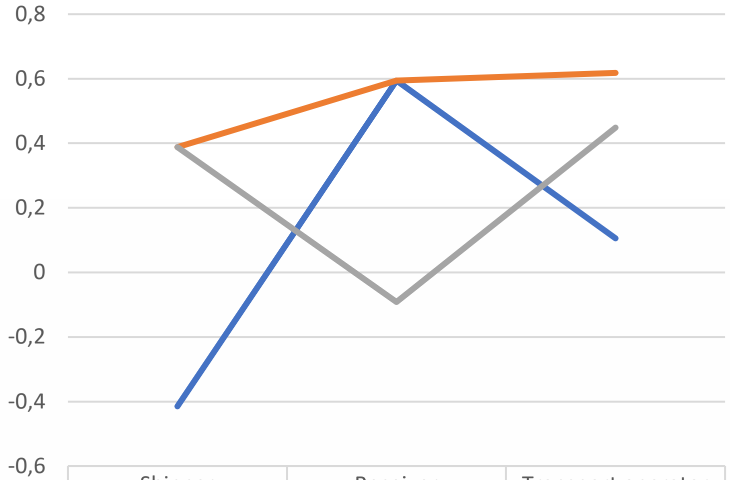
RECEIVER

Receiver	Positive effect on society	low cost for receiving goods	high quality deliveries	attractive shopping environment
Before optimization	0,097814	0,064442	0,156502	0,681243
After optimization	0,418	0,06	0,337	0,185



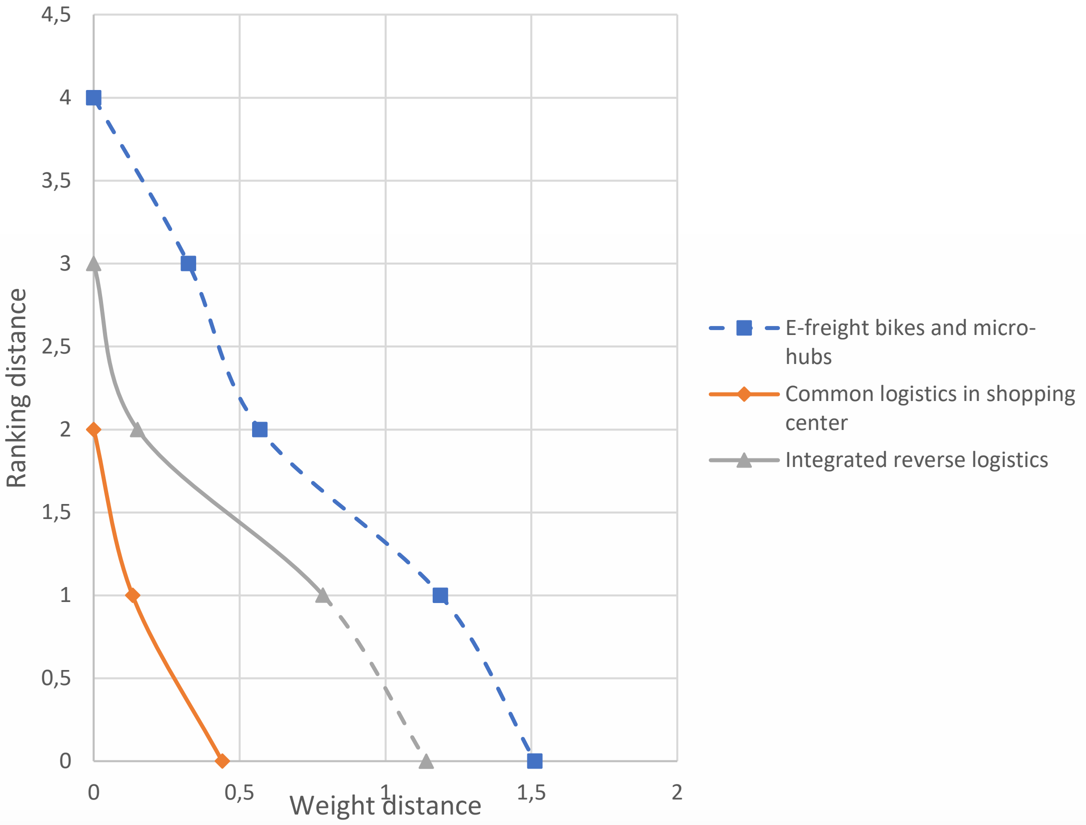
CONSENSUS REACHING

CONSENSUS REACHING



	Shipper	Receiver	Transport operator
E-freight bikes and micro-hubs	-0,4152	0,5942	0,105
Common logistics in shopping center	0,3884	0,594	0,618
Integrated reverse logistics	0,3876	-0,0914	0,448

E-freight bikes and micro-hubs Common logistics in shopping center
Integrated reverse logistics



CONCLUSION

ROBUST STAKEHOLDER-BASED MCGDM

- A stakeholder-based multi-criteria group decision making framework:
  - The BWM presents a simplified and more efficient approach to address challenges of complexity and time in the weight elicitation process within the MAMCA framework;
  - The consensus model utilizes information provided by BWM to seek consensual/compromised solutions among all stakeholders;
  - The framework provides stakeholders suggestions towards better negotiation and discussion, thereby facilitating more informed decision-making among stakeholders.

THANK YOU

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mobilise
analysing mobility, mobilising people

CITYLAB PROJECT CASE

STAKEHOLDERS

Table 4 Original criteria weights and uni-criteron net flows

Stakeholders	Criteria	Weight	Score of (1) E-freight bikes and micro-hubs	Score of (2) common logistics in shopping center	Score of (3) integrated reverse logistics	ξ^L	Ranking
Shipper	Positive effect on society	0,0799	0	0	1	0.090	(3)>(2)>(1)
	Low cost for receiving goods	0,0511	0,8	0	0		
	High quality deliveries	0,550	-0,6	0,6	0,2		
	Attractive shopping environment	0,319	-0,2	-0,2	1		
	Weighted sum performance score	/	-0,353	0,266	0,509		
Receiver	Positive effect on society	0,091	0	-1	0	0.076	(1)>(2)>(3)
	Low cost for receiving goods	0,066	0,8	0	0		
	High quality deliveries	0,184	-0,6	1	0,2		
	Attractive shopping environment	0,660	1	0,6	-0,2		
	Overall performance score	/	0,601	0,487	-0,095		
Transport operator	Viable investment	0,197	-0,6	0,6	0,6	0.062	(2)>(3)>(1)
	Positive effect on society	0,073	0,8	0,8	0		
	Satisfied employees	0,148	-0,6	-0,6	0,8		
	Profitable operations	0,052	0,8	0	0		
	High quality service	0,530	0,4	1	0,4		
	Overall performance score	/	0,105	0,618	0,448		

CHALLENGES IN MAMCA

ORDINAL CONSISTENCY