MCDA
MULTIPLE CRITERIA
DECISION AIDING

A Multiple Criteria Approach for a Sustainable Urban Logistics Policies Ranking Problem

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Introduction: problem

Policymakers have 2030 sustainability targets and must address urban logistics issues through Sustainable Urban Mobility/Logistics Plans (SUMP and SULP).

Quantifying aspects for making policy choices is expensive, and concerning conflicting interests among stakeholders is difficult to consider all preferences.

Multicriteria techniques can help in evaluating scenarios characterized by different policy measures using selected criteria.

Introduction: research question

Research Question:

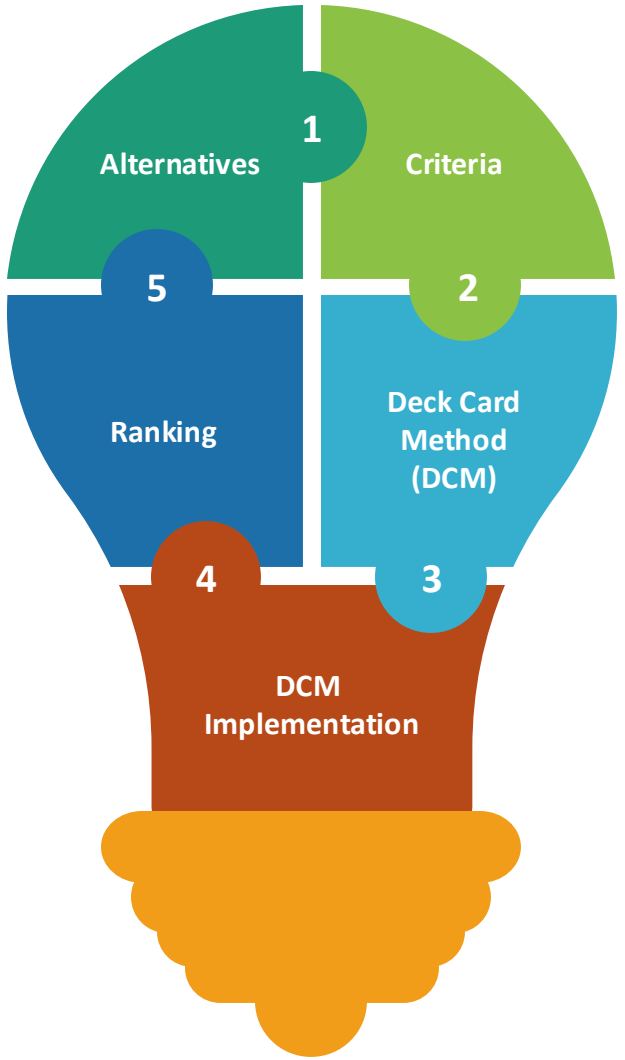
1. How can decision-makers (DMs) be assisted in ranking sustainable city logistics strategies? (and helped in measuring the strength of preferences)

The primary aim of this study is to determine the effectiveness of the Deck of Cards Method (DCM) in evaluating and ranking various urban logistics scenarios in a medium-sized city in Northern Italy. The focus is identifying the logistics strategies that best balance economic, environmental, social, and operational criteria to achieve sustainable urban logistics.

The study provides a methodological approach to help decision-makers identify effective and sustainable logistics strategies using a variant of DCM (Figueira and Roy 2002, Corrente et al. 2021, Figueira et al. 2023).

It seeks to offer practical recommendations for other cities facing similar urban logistics challenges, contributing to sustainable urban logistics planning.

DCM application for the ranking of urban logistics scenarios



1 - Identify alternative scenarios

Identify the alternative scenarios among the policies most applied in the European context. Mix of measures. (Novelog 2016, Lebeau et al. 2018, Bottero et al. 2018)

2 - Define Criteria

Define criteria and their scale levels to evaluate the alternatives. (Tadic et al. 2014, Novelog 2016, Eltis 2019)

3 - Variant of Deck Card Method (DCM)

Validate alternatives and criteria through stakeholders' involvement (Figueira and Roy 2002, Corrente et al. 2021, Figueira et al. 2023).

4 - DCM implementation

The DCM allows the policymaker to intuitively model preference among each criterion's levels and among criteria.

5 - Ranking of alternatives

Results and discussion.

Scenarios: policies mix

- Seven representative scenarios with distinct policy application segments have been defined.

- The performances were calculated with expected impact based on hypothetical effects imported from similar studies (Paddeu et al. 2018, Janjevic et al. 2019, Knoppen et al. 2021) to demonstrate the competitiveness of alternative logistics policies.

Piano Urbano della Mobilità Sostenibile di Padova
Report Terza Fase – Documento di Piano

PUMS Co.Me.Pa

		futuri		
	Padova	Introduzione della Low Emission Zone	X	X
	Padova	Introduzione di una Ultra Low Emission Zone		X
	Padova	Accordo volontario di accreditamento dei veicoli commerciali in funzione della tipologia di veicolo ambientalmente sostenibili	X	
	Padova	Misure di green logistics (spazi di sosta cargo bici, pack station, azioni di sensibilizzazione)	X	X
	Padova	Regolazione e gestione della sosta destinata al carico-scarico	X	

Tab. 8.7: Scenario di Piano – logistica

Cod.	Comuni coinvolti	Intervento	SP B-M PERIODO (2025)	SP M-L PERIODO (2030)
	Padova	Verifica di fattibilità di un collegamento diretto verso Est bypassando la stazione ferroviaria di Padova a servizio dell'Interporto e degli sviluppi	X	X

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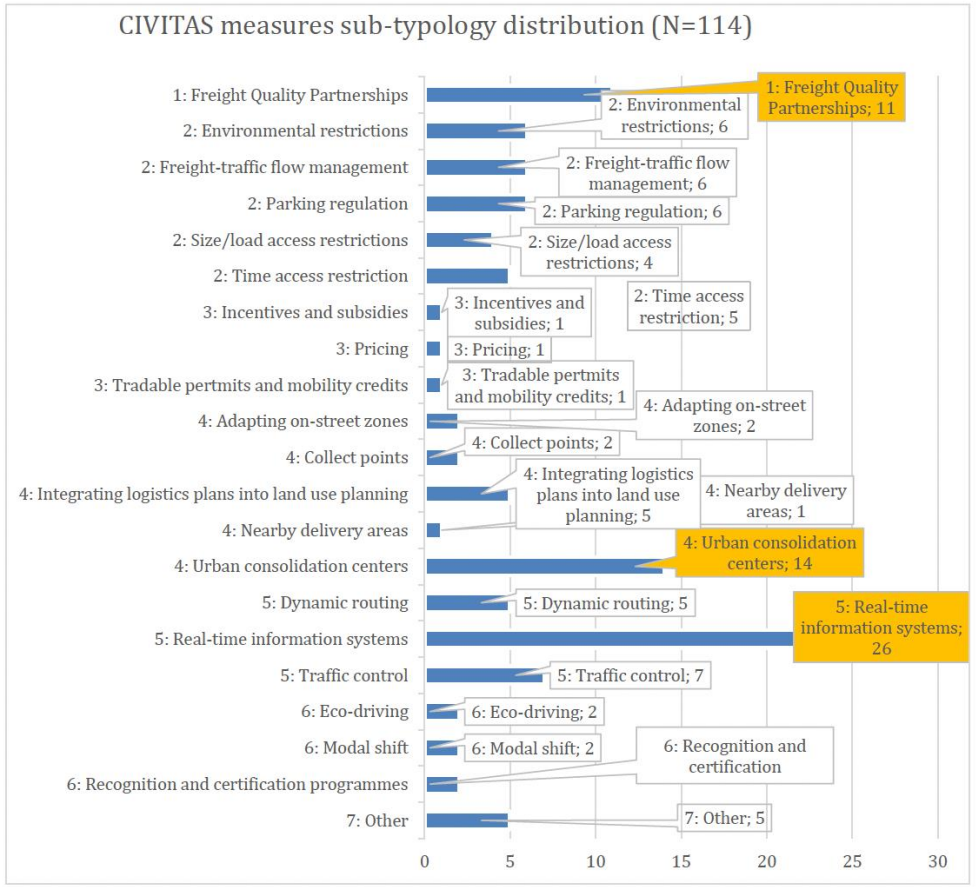
TRT · TECHNITAL · ATRAKI Advanced Transportation Knowledge & Ideas · avanzi

Sustainable Urban Mobility Plan (SUMP) of Padova and metropolitan area (europa.eu)

Scenarios: policies examples

novelog



[NOVELOG Toolkit | CIVITAS]

Annex IV:
UFT Best Practices

European Platform on Sustainable Urban Mobility Plans

The measures typology that was followed in the framework of the NOVELOG City Typology and the NOVELOG Toolkit was aligned with the CIVITAS urban freight measures typology[53] which consists of seven main clusters of UFT interventions and twenty-seven sub-clusters:

1. Stakeholder engagement
   a. Freight Quality Partnership
   b. Freight advisory boards and forums
   c. Designation of a City Logistics Manager
2. Regulatory measures
   a. Time access restriction
   b. Parking regulation
   c. Environmental restrictions
   d. Size/load access restrictions
   e. Freight-traffic flow management
3. Market-based measures
   a. Pricing
   b. Taxation and tax allowances
   c. Tradeable permits and mobility credits
   d. Incentives and subsidies
4. Land use planning & Infrastructure
   a. Adapting on-street zones
   b. Using building code regulations for off-street delivery areas
   c. Nearby delivery areas
   d. Upgrading central off-street loading areas
   e. Integrating logistics plans into land use planning
   f. Collect points
   g. Urban consolidation centres

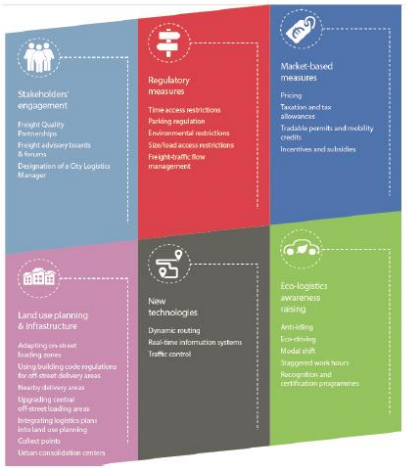


Figure 19 CIVITAS UFT measures typology as illustrated in CIVITAS Wiki consortium (2015)

5. New Technologies
   a. Dynamic routing
   b. Real-time information systems
   c. Traffic control
6. Eco-logistics awareness raising
   a. Anti-idling
   b. Eco-driving
   c. Modal shift (water, rail, cycle, walk)
   d. Staggered work hours
   e. Recognition and certification programmes

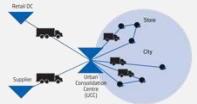
Indicative EU funded examples of UFT practices and pilot cases that have been implemented in European Cities are presented in the following Tables:

[53] CIVITAS WIKI consortium. (2015), Making urban freight logistics more sustainable, CIVITAS POLICY NOTE, www.eltis.org, available at: http://www.eltis.org/resources/tools/civitas-policy-note-making-urban-freight-logistics-more-sustainable.

[Eltis | The urban mobility observatory]

Scenarios: alternatives

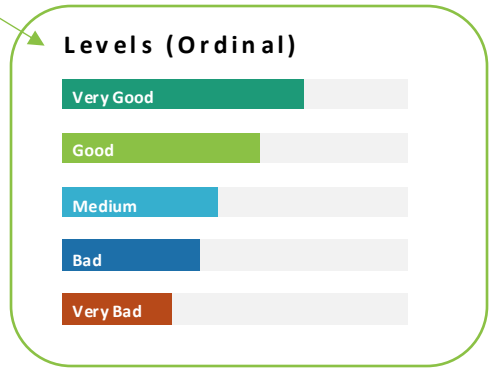
$$A = \{a_1, a_2, a_3, a_4, a_5, a_6, a_7\}$$

	Alternatives	Infrastructure	Vehicles (>7-ton Truck, >3.5-ton Van, <3.5-ton Ebikes. Diesel / Electric)	Consolidation & Regulations	Graphic
1	"Promote and regulate"	**Land:** neutral **Parking:** neutral	TruckD, allowed w/restriction. TruckE, incentive. VanD, allowed w/restriction. VanE, incentive. Ebikes, incentive.	**MicroCons**: No **LTZ:** neutral **UCC:** incentive	
2	"Plan and build"	**Land:** microhubs **Parking:** reserved areas	TruckD, allowed w/restriction. TruckE, allowed w/restriction. VanD, incentive. VanE, incentive. Ebikes, incentive.	**MicroCons**: Yes **LTZ:** neutral **UCC:** neutral	
3	"Charge and Provide"	**Land:** neutral, recharge station **Parking:** reserved areas	TruckD, fee charges. TruckE, incentive. VanD, fee charges. VanE, incentive. Ebikes, incentive.	**MicroCons:** No **LTZ:** charges **UCC:** incentive	
4	Mix 4	**Land:** microhubs, UCC expansion, recharge station. **Parking:** reserved areas	TruckD, fee charges. TruckE, incentive. VanD, fee charges. VanE, incentive. Ebikes, incentive.	**MicroCons:** Yes **LTZ:** charges **UCC:** incentive	
5	UCC hard	**Land:** UCC expansion **Parking:** reserved areas	TruckD, NOT allowed. TruckE, NOT allowed. VanD, incentive. VanE, incentive. Ebikes, neutral.	**MicroCons:** No **LTZ:** forced **UCC:** forced	
6	Electric Vehicles	**Land:** microhubs, recharge station **Parking:** neutral	TruckD, NOT allowed. TruckE, mandatory. VanD, NOT allowed. VanE, mandatory. Ebikes, mandatory.	**MicroCons:** Yes **LTZ:** forces **UCC:** neutral	
7	BAU	**Land:** neutral **Parking:** neutral	TruckD, allowed. TruckE, neutral. VanD, allowed. VanE, neutral. Ebikes, neutral	**MicroCons:** No **LTZ:** neutral **UCC:** neutral	

Criteria: definition

$$G = \{g_1, g_2, g_3, g_4, g_5, g_6\}$$

	Unit	Direction	Description
1 – Transportation Cost	€ Continuous	Minimization	The average cost for private transportation or UCC services per delivery
2 - Business Climate	Qualitative Judgement – Ordinal levels	Maximization	Impact on local economic competitiveness and people's satisfaction.
3 - Logistics Infrastructure	Qualitative Judgement – Ordinal levels	Minimization	Space occupancy of parking areas, roads, and dedicated spaces
4 - Environmental Impact	Monetary€ - Continuous	Maximization	Benefit from reduction of CO2, PM, NOx, SO2, NMVOC, and noise emissions.
5 - Safety	Monetary€ - Continuous	Maximization	Benefit from reduction of accidents and injuries in an urban context per type of vehicles.
6 - Logistics Performance	Qualitative Judgement – Ordinal levels	Maximization	Performance regarding the load rate of the vehicles leaving their depot weighted by the number of km driven.



Methods: Deck Card Method (DCM)

a) **Why this method?** Among several MCDA methods, **a Deck Card Method (DCM) variant** has been selected for its **intuitiveness** in ranking different alternatives and **adaptability** to a problem (Dinis et al. 2023).

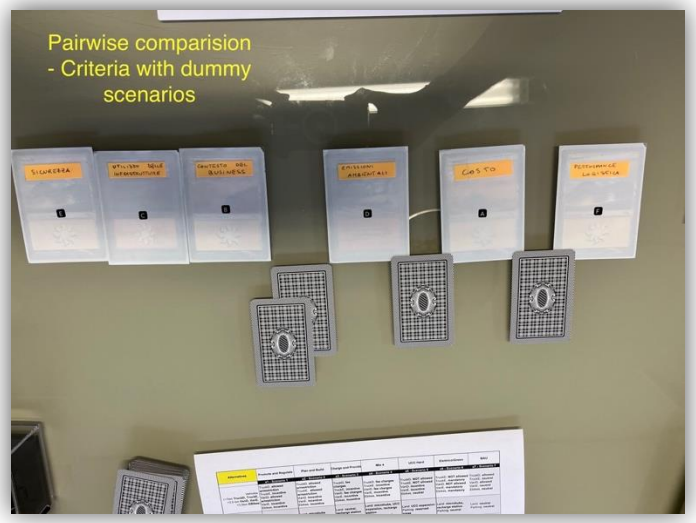
b) The value functions and the criteria weights were constructed using an improved version of the **Deck of Cards Method** (Figueira and Roy 2002, Corrente et al. 2021, Figueira et al. 2023).

c) It combines **DCM's simplicity of interpretation** and **visual support of cards** with richer information from the DMs' judgments in pairing elements in the comparison tables (Corrente et al. 2021, Figueira et al. 2023).

d) This variant of the DCM allows the evaluation of criterion weights on ratio scales and constructing value functions for each criterion on an interval scale, ensuring a comprehensive evaluation process.

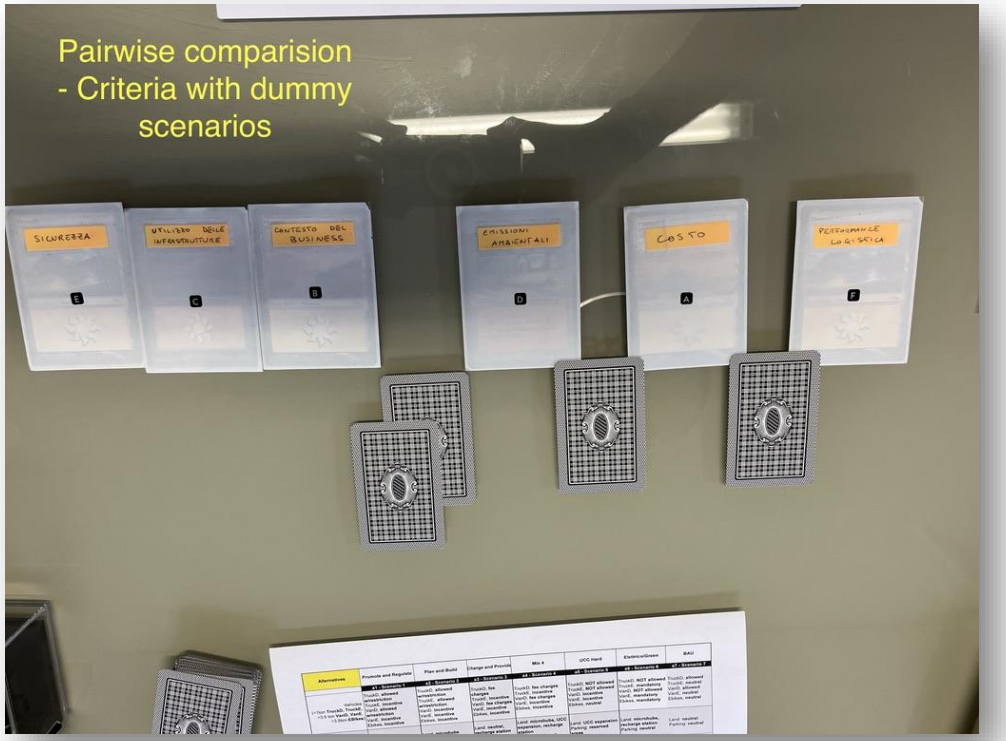
Methods: DCM - Validation

- This method requires **interaction between analysts and Decision Makers (DMs)**.
- The authors were part of the analyst's team in this work. The DM is a local policymaker who works as a logistics operator's top manager and has a background in urban logistics.
- The **validation** phase, a dynamic and ongoing process, was pivotal in **constructing the value functions.**
- Meetings with the client (local authorities and interested stakeholders) were held to ensure that alternatives and criteria were adjusted and refined for the tool application.



DCM implementation – Criteria weights

The procedure for assessing the criteria weights required dummy alternative scenarios built with the highest evaluation on a specific criterion and the lowest on the others and then compared by the DM (Corrente et al. 2021)



Dummy Scenario	C_5	C_3	C_2	C_4	C_1	C_6
Criterion 5		0				
Criterion 3			0			
Criterion 2				2		
Criterion 4					1	
Criterion 1						1
Criterion 6						

Zero card does not mean the same weight, but that difference is minimal (one unit); one blank card implies that the difference in weights is twice the minimal, and so on.

DCM implementation – Criteria weights

The procedure for assessing the criteria weights required dummy alternative scenarios built with the highest evaluation on a specific criterion and the lowest on the others and then compared by the DM (Corrente et al. 2021)

g_3= (Very Bad, Bad, **Very Good**, 0, 0, Very low)
≡ (0, 0, **100**, 0, 0, 0)

is preferred to

g_5 = (0, 0, 0, 0, **100**, 0)

Example ranking:
$g_6 \prec g_1 \prec g_4 \prec g_2 \prec g_3 \prec g_5$

Dummy Scenario	C_5	C_3	C_2	C_4	C_1	C_6
Criterion 5		**0**				
Criterion 3			**0**			
Criterion 2				**2**		
Criterion 4					**1**	
Criterion 1						**1**
Criterion 6						

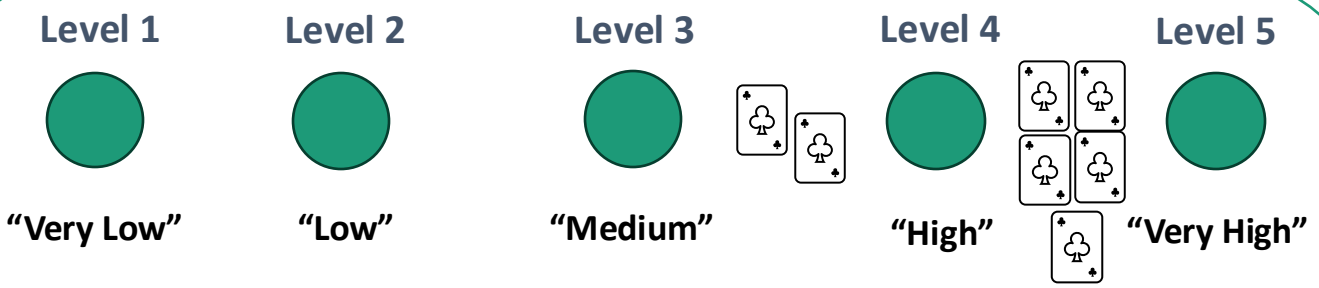
z–ratio intended as the substitution rate between the criterion with the highest weight and the criterion with the lowest weight

z-ratio = ($w6/w5$)	**11,00**
α	**1,11**
$w5$	**1,00**
$w3$	**2,11**
$w2$	**3,22**
$w4$	**6,56**
$w1$	**8,78**
$w6$	**11,00**
	32,67

3%
6%
10%
20%
27%
34%
100%

DCM implementation - Scale Levels

Criterion 6 "Logistics Performance" – Ordinal



$$E_6 = \{l_{6,1}, l_{6,2}, l_{6,3}, l_{6,4}, l_{6,5}\}$$

Levels	L1	L2	L3	L4	L5
Level 1		**0**			
Level 2			**0**		
Level 3				**2**	
Level 4					**5**
Level 5					

$v6(l_{6,1})$	**0,00**	Very Low
$v6(l_{6,2})$	**9,09**	Low
$v6(l_{6,3})$	**18,18**	Medium
$v6(l_{6,4})$	**45,45**	High
$v6(l_{6,5})$	**100,00**	Very High

$$\alpha = \frac{100-0}{(0+1)+(0+1)+(2+1)+(5+1)} = 9{,}09$$

«**Medium**»

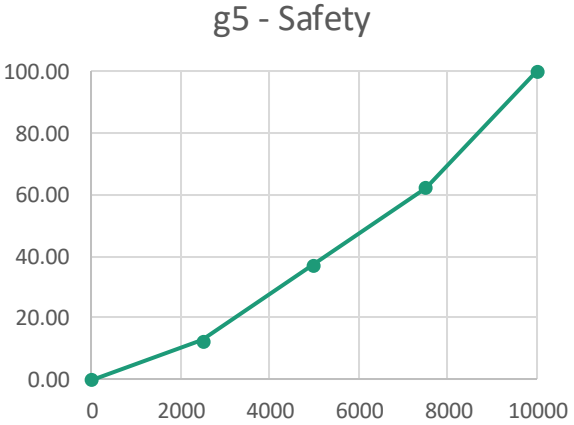
$$v6(l6,3) = (0+1+0+1) * \alpha = 18{,}18$$

Criterion 5 "Safety" - Continuous

Levels	L_1	L_2	L_3	L_4	L_5
Level 1		**0**			
Level 2			**1**		
Level 3				**1**	
Level 4					**2**
Level 5					

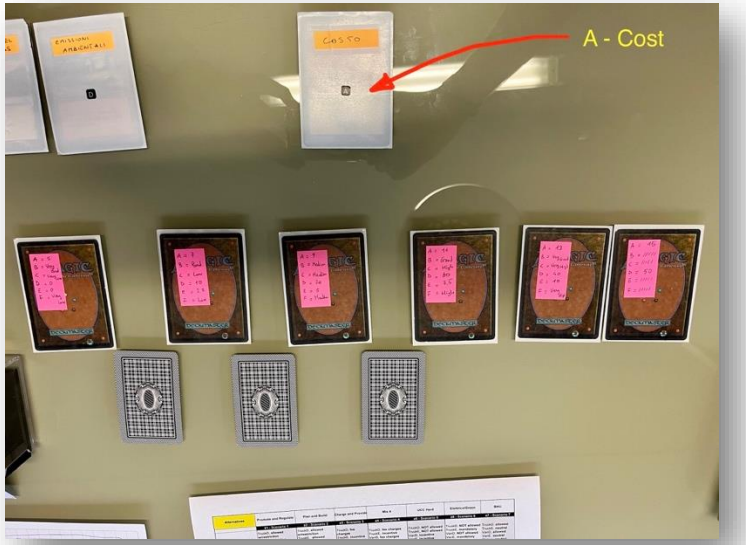
		X	Y
$v5(l_{5,1})$	**0,00**	0	0,00
$v5(l_{5,2})$	**12,50**	2500	12,50
$v5(l_{5,3})$	**37,50**	5000	37,50
$v5(l_{5,4})$	**62,50**	7500	62,50
$v5(l_{5,5})$	**100,00**	10000	100,00

$$E_5 = \{l_{5,1}, l_{5,2}, l_{5,3}, l_{5,4}, l_{5,5}\}$$

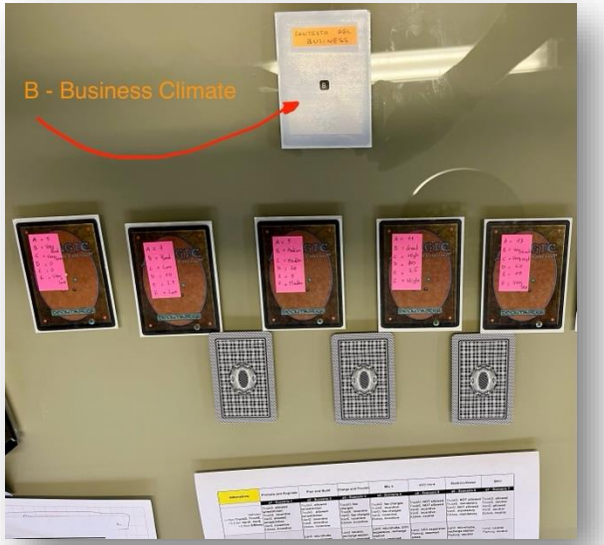


$$\alpha = \frac{100-0}{(0+1)+(1+1)+(1+1)+(2+1)} = 12{,}5$$

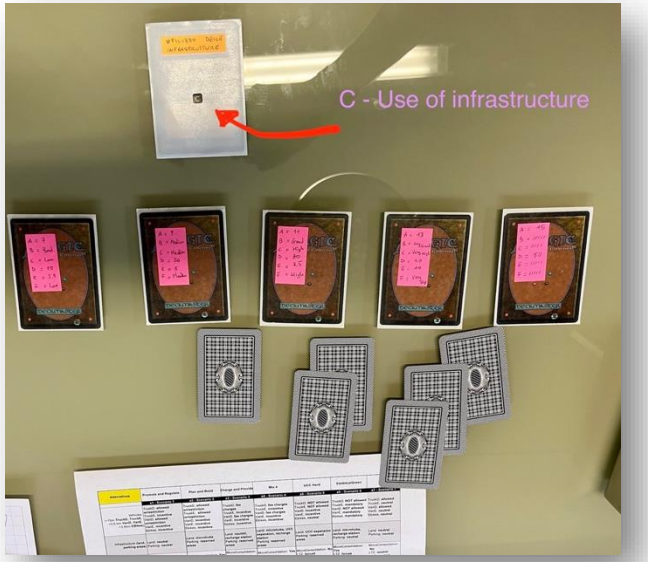
DCM implementation - criteria



Levels	L1	L2	L3	L4	L5	L6
Level 1		1				
Level 2			1			
Level 3				1		
Level 4					0	
Level 5						0
Level 6						

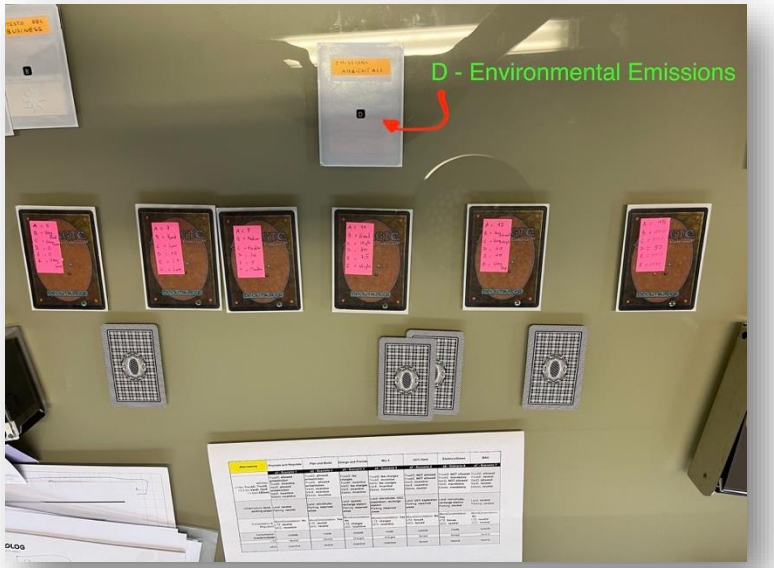


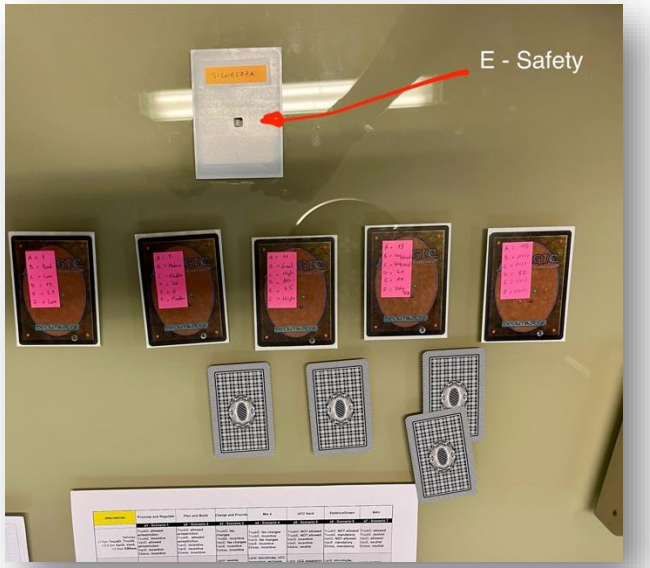
Levels	L1	L2	L3	L4	L5
Level 1		0			
Level 2			1		
Level 3				1	
Level 4					1
Level 5					

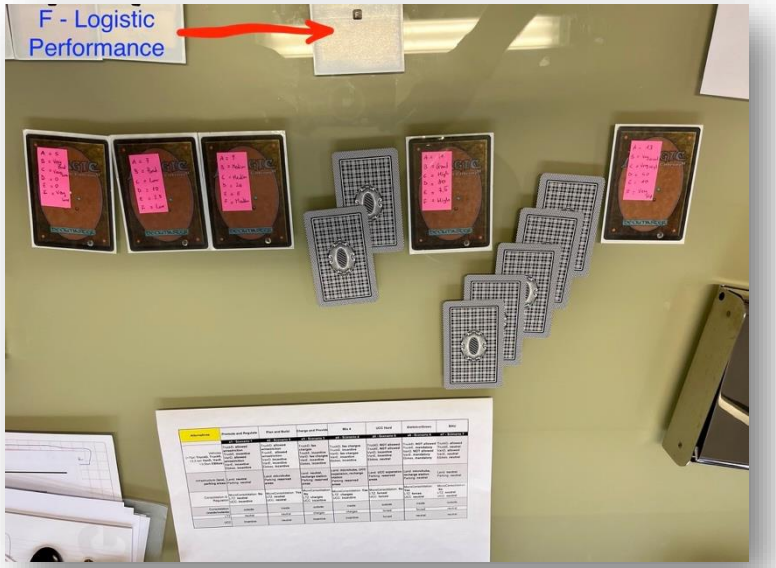


Levels	L1	L2	L3	L4	L5
Level 1		0			
Level 2			1		
Level 3				2	
Level 4					3
Level 5					

DCM implementation - criteria







Levels	L1	L2	L3	L4	L5	L6
Level 1		1				
Level 2			0			
Level 3				0		
Level 4					2	
Level 5						1
Level 6						

Levels	L1	L2	L3	L4	L5
Level 1		0			
Level 2			1		
Level 3				1	
Level 4					2
Level 5					

Levels	L1	L2	L3	L4	L5
Level 1		0			
Level 2			0		
Level 3				2	
Level 4					5
Level 5					

DCM Implementation - Performance table

#	Alternatives Scenarios	C1 (Cost)	C2 (Busin. Clima)	C3 (Infrast. Use)	C4 (Env. Emis)	C5 (Safety)	C6 (Log. Perfor.)
1	**Promote and Regulate**	10,86€	Very Good	Medium	26.000€	300€	Low
2	**Plan and Build**	10,32€	Good	Good	34.999€	7.400€	Medium
3	**Charge and Provide**	11,72€	Bad	Medium	31.000€	900€	Low
4	**Mix 4**	11,18€	Medium	Good	32.000€	8.800€	Good
5	**UCC hard**	9,14€	Bad	Very Good	33.000€	3.000€	Very Good
6	**Electric Fleet**	13,83€	Bad	Medium	42.000€	600€	Low
7	**BAU**	10,75€	Medium	Very Bad	0	0	Very Low

$g_j(a_i)$ is the performance of each alternative a_i on each criterion g_j

Results: Ranking of alternatives

Weights

3%
6%
10%
20%
27%
34%
100%

Values

$v6(l6,1)$	**0,00**
$v6(l6,2)$	**9,09**
$v6(l6,3)$	**18,18**
$v6(l6,4)$	**45,45**
$v6(l6,5)$	**100,00**

#	Alternatives Scenarios	C1 (Cost)	C2 (Busin. Clima)	C3 (Infrast. Use)	C4 (Env. Emis)	C5 (Safety)	C6 (Log. Perfor.)
1	Promote and Regulate	10,86€	Very Good	Medium	26.000€	300€	Low
2	Plan and Build	10,32€	Good	Good	34.999€	7.400€	Medium
3	Charge and Provide	11,72€	Bad	Medium	31.000€	900€	Low
4	Mix 4	11,18€	Medium	Good	32.000€	8.800€	Good
5	UCC hard	9,14€	Bad	Very Good	33.000€	3.000€	Very Good
6	Electric Fleet	13,83€	Bad	Medium	42.000€	600€	Low
7	BAU	10,75€	Medium	Very Bad	0	0	Very Low

	g1 - Transportation Cost	g2 - Business Climate	g3 - Infrastructures Use	g4 - Environmental Emissions	g5 - Safety	g6 - Logistics Performance	
Performance DCM	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	**Ranking**
Promote and Regulate	10,39	33,67	0,92	10,75	0,10	0,90	56,73
Plan and Build	11,74	24,05	1,84	16,42	3,97	1,79	59,82
Charge and Provide	11,64	4,81	0,92	12,84	0,29	0,90	31,40
Mix 4	12,69	24,05	1,84	12,54	5,30	9,86	66,29
UCC Hard	13,95	14,43	3,06	14,63	1,13	4,48	51,69
Elettrico/Green	2,95	4,81	0,92	22,09	0,19	0,90	31,86
BAU	10,66	14,43	-	-	-	-	25,09

u_j is the generic value function and $u_j(g_j(a_i))$ is the value of the performance $g_j(a_i)$

Results and comments

1. In the DM's perception, the most important criterion was **“Logistics performance”** which was intended to be the quality of the service.

2. The second criterion, **“Cost of transportation”,** required some clarification: some costs are revenues for other stakeholders in the logistics sector. However, the DM defined the cost as each operator's price to provide or access logistics services.

3. No scenarios reached an outstanding position in the ranking because they represented different strategies with radically different performances in various aspects. The ranking tool could encourage policymakers to reason about which feasible scenarios would be the best, depending on the preferences expressed by the DMs.

4. The DM's active interest in refining criteria, whether by adding new ones or modifying from qualitative to quantitative and vice versa, underscores their commitment to the process. In case of modifications to the criteria selected case, the tool has to be adjusted to accommodate these changes.

Findings and contribution

a) Limited research has been performed on ranking urban freight transport scenarios from an MCDA perspective.

b) This study uses a variant of the DCM as an MCDA tool to solve a ranking problem comprising a set of criteria, criteria weights, and results obtained by the different scenarios.

c) Conceived initially to establish criteria weights, the DCM is used here **to build a complete MCDA model** (Corrente et al., 2021).

d) This method has been tested in other sectors (Bottero et al., 2015, Dinis et al., 2023), and **its application in urban logistics planning represents a novel contribution** provided by this study.

e) Qualitative judgments are translated into numbers, and the distance between judgments is measured through card placement in an intuitive way for the DM.

f) This method is easily customizable, can be adapted to different problems, and updated if new elements arise. It also works for many alternatives, especially if they are added in the evaluation process or when other stakeholders are involved in logistics planning activities.

Thanks for your attention

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