EURO PhD Summer School on MCDA/MCDM
Chania, Greece
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School Case Study

Urban Sustainability Assessment

Group 6

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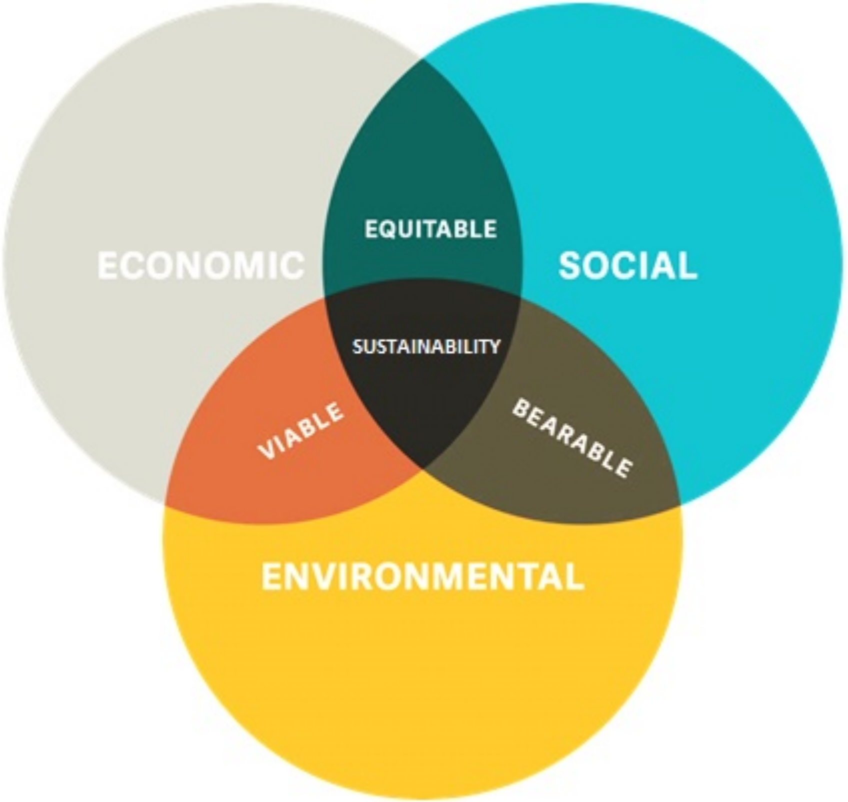


Sustainability is defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (World Commission on Environment and Development 1987).

More than 54% of world population is urban (Phillis et al. 2017).

1- Describing the context (2)

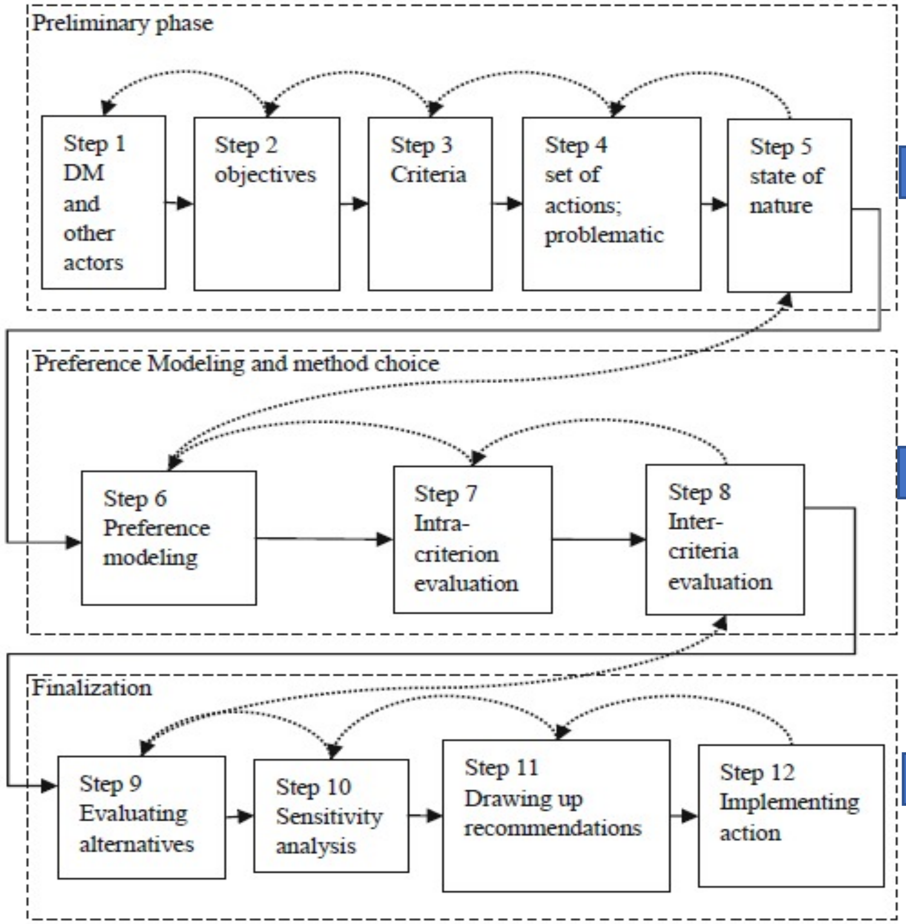
INTERNATIONAL INSTITUTE OF URBAN SUSTAINABILITY
(IIUS)

- IIUS is an independent, multicultural, non party political, nonprofit, global organization that uses creative analyses to shows global environmental problems;
- The Institute conducts annuals study sessions for consolidation of the world sustainability parameters in its report, based in data from the previous year.

In this year, the event occurs in Chania from July 23 to August 3. In the last day, IIUS will be presented with the "*XVIII Sustainable World City*" award.

1- Modeling the problem

The framework proposed by Almeida et al. (2016) was used in this study.



Identify the aspects and factors that have impact on the problem.

The most flexible moment, and is responsible for modeling the DM's preferences and choose the multicriteria method.

Apply the multicriteria method, analyse the results and make changes in the parameters for robustness concern.

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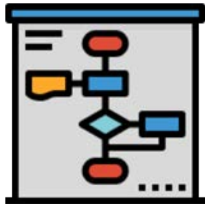
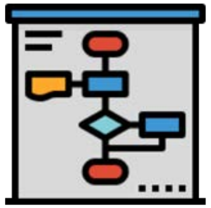


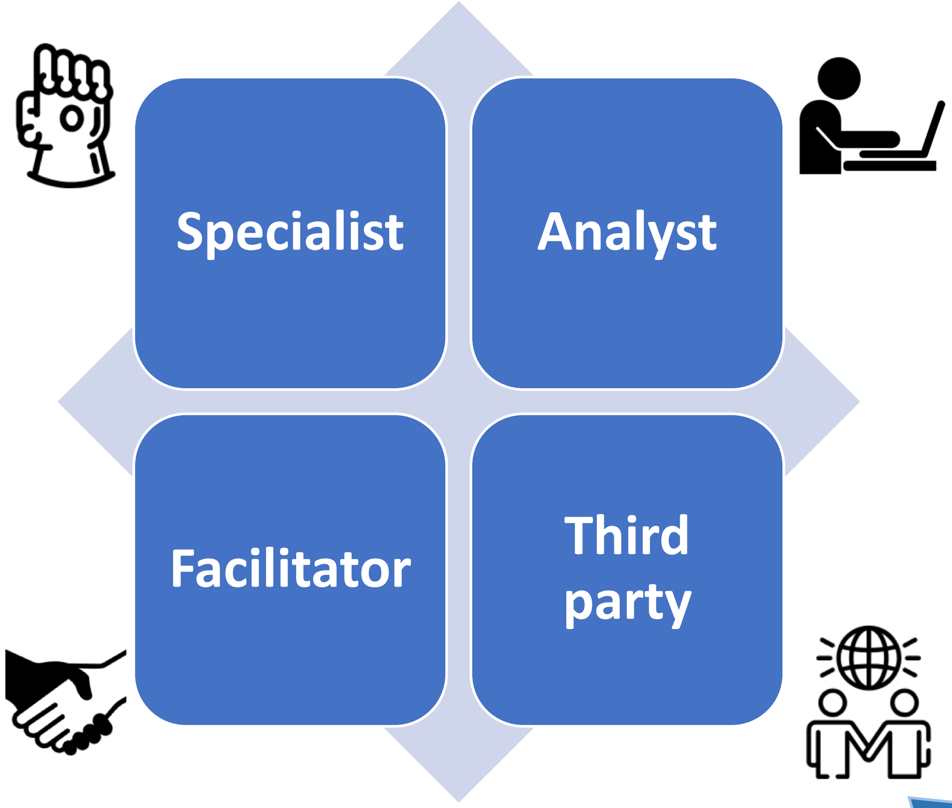


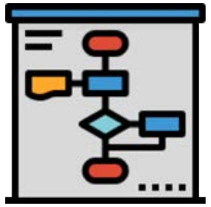
2- DM and other actors

Decision-Maker (DM) input your preferences about the evaluation of alternatives. The DM is the only actor responsible for consequences of the decisions.

The president of IIUS is the DM

Other actors presented in this application:





2- Objectives

The goals of the project are supporting the DM by:

1. Identifying the most important criteria (indicators) for sustainability.

2. Identifying cities, which implement already the best practices.

2- Criteria

Economic

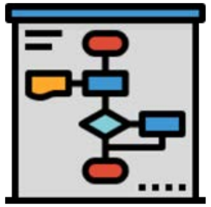
- Energy consumption per unit GDP
- Service share in GDP
- Disposable income per urban capita

Social

- Air qualified days per year
- Residential power consumption
- Domestic waste treated

Environmental

- Energy consumption per unit GDP
- Service share in GDP
- Disposable income per urban capita



2- Criteria

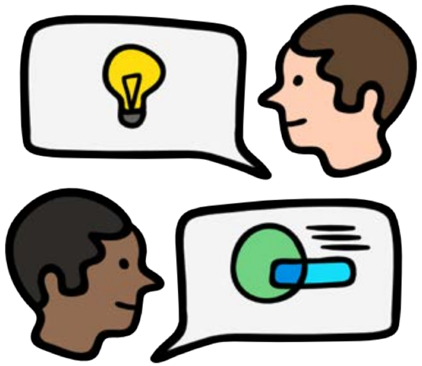
Main reasons why the other indicators were discarded:

Redundant information:

- *Concentration of NO_2, SO_2 and PM_{10} and industrial air pollution SO_2*

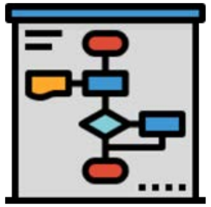
Highly related to more than one pillar:

- *Urban population density*
- *Total water consumption (liters per unit of GDP)*



Doubtful relevance:

- *Middle school students share*
- *Passengers using public transit*
- ...



2- Set of actions, problematic

- As IIUS makes every year, it is necessary to have a ranking of the cities with the best one in the first position and the worst of all in the last.

Ranking problematic involves problems which alternatives are compared each other based on their properties and grouped into classes that can be ordered, resulting in a complete or partial order (Roy 1996).

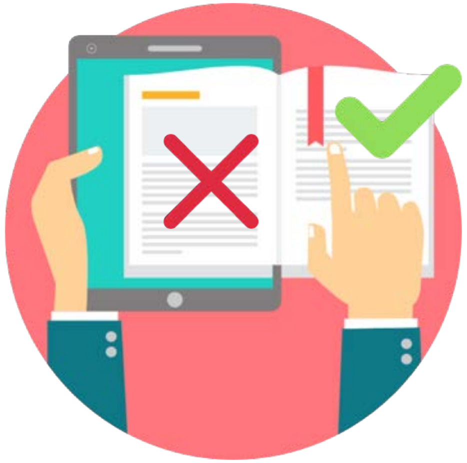
2- Set of actions, problematic

Consequence Matrix

	ENVIRONMENTAL			SOCIAL			ECONOMIC		
	Air qualified days per year	Residential power consumption	Domestic waste treated	Employment share	Pension security coverage	Healthcare security coverage	Disposable income per urban capita	Energy consumption per unit GDP	Service share in GDP
Beijing	0,876	0,699	0,982	0,53	0,54	0,59	32,903	4,59	0,761
Berlin	0,953	8,9	1	0,5	1	0,99	23,562	0,007	0,826
Copenhagen	0,91	5,95	1	0,52	1	1	26,969	0,015	0,8
Hong Kong	0,88	1,594	0,5	0,502	0,85	1	29,288	0,159	0,919
London	0,953	3,988	0,932	0,514	1	1	33,052	0,035	0,89
New York	0,899	2,6	1	0,54	1	0,88	31,417	0,06	0,81
Paris	0,647	11,2	0,92	0,678	1	0,99	31,661	0,021	0,737
Prague	0,965	1,153	0,865	0,515	1	1	14,2	0,201	0,837
Seoul	0,927	1,283	1	0,623	0,56	0,96	32,791	0,086	0,91
Shanghai	0,923	0,757	0,61	0,47	0,39	0,41	36,23	6,18	0,583
Stockholm	0,89	6,75	1	0,52	1	1	30,5	0,041	0,58
Tokyo	0,953	2,376	1	0,501	1	1	51,097	0,014	0,9

2- State of Nature

This problem is considered deterministic since there is no uncertainty or risk related to the data used.

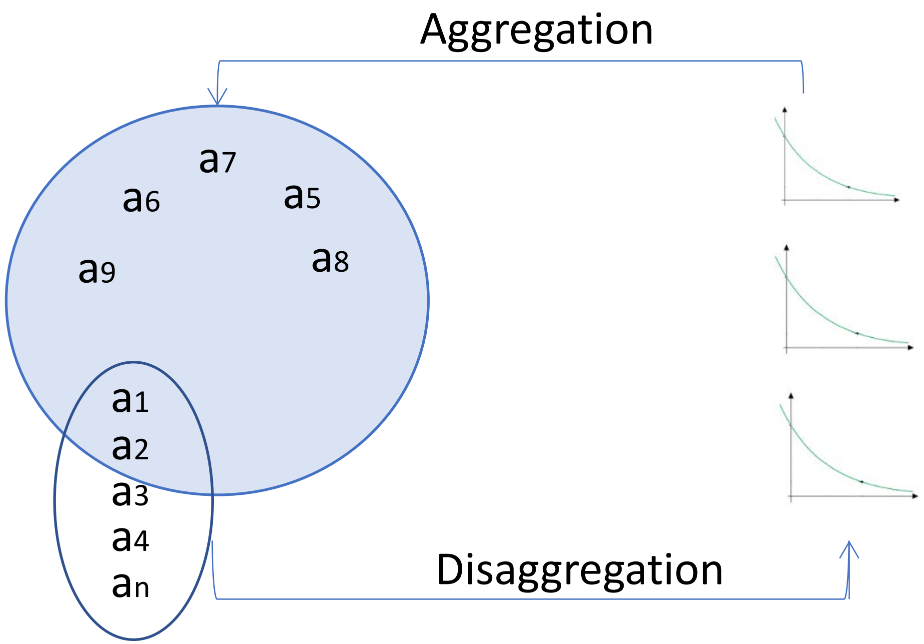


Methods as the Multi-attribute Utility Theory (MAUT) were disregarded, reducing the set of options and approaches to construct a model for the problem.

- According to the DM, good performances in some specific criteria can compensate lower performances in others ones.

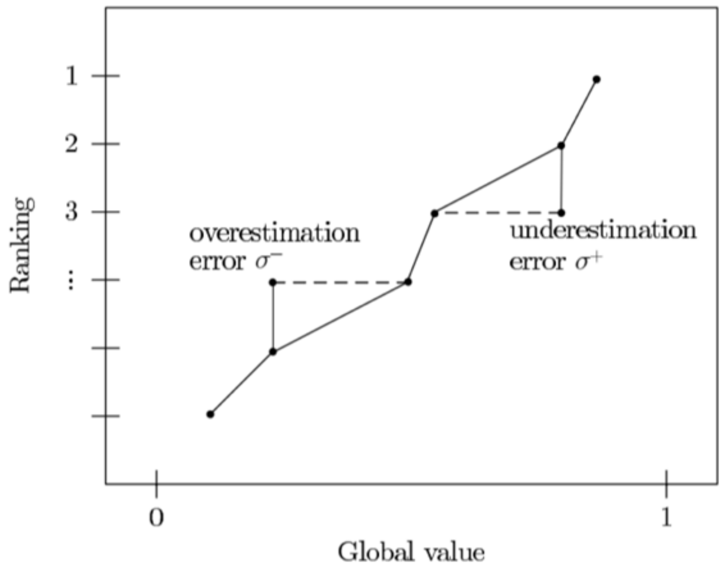
Thus, **compensation** between the criteria are important for a reasonable evaluation.

UTASTAR method was used.



UTASTAR is an improved version of the original UTA method (Jacquet-Lagreze and Siskos, 1982).

- The introduction of the meaning of double error to deal with underestimations as well as overestimations of the marginal functions.



- Transformation of the partial values for each criterion scale of the reference actions through equidistant spaces w_{ij} to facilitate the resolution of the LP (Siskos, 2008).

$$w_{ij} = u_i(g_i^{j+1}) - u_i(g_i^j) \geq 0 \ \forall \ i = 1, 2, \ldots, n \text{ and } j = 1, 2, \ldots, \alpha_i - 1$$

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3- Methodology applied

Sustainability assignment

- **Economic**
  - Energy consumption per unit GDP
  - Service share in GDP
  - Disposable income per urban capita
- **Social**
  - Air qualified days per year
  - Residential power consumption
  - Domestic waste treated
- **Environmental**
  - Energy consumption per unit GDP
  - Service share in GDP
  - Disposable income per urban capita

3- Training set

Real values

New York

Shanghai

Copenhagen

Fictional values

Pluton

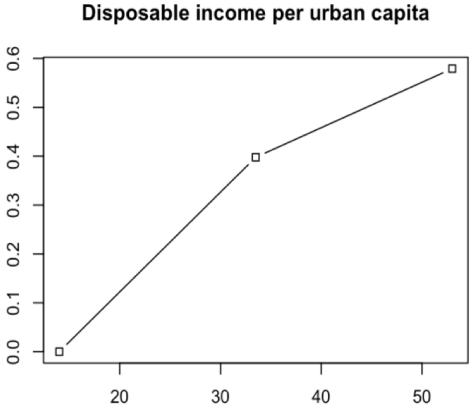
Mars

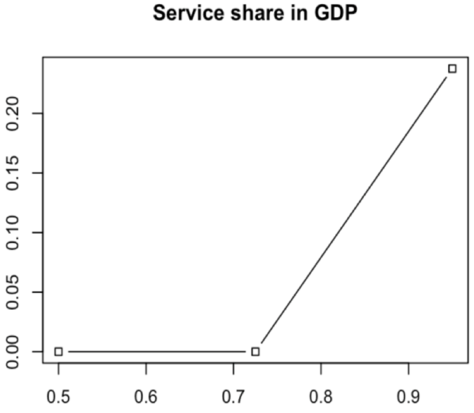
Jupiter

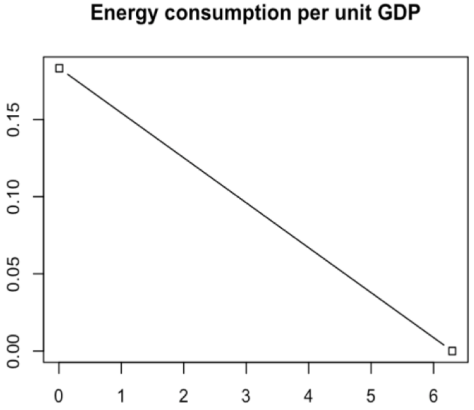
3- Indicators gains/losses

	ENVIRONMENTAL			SOCIAL			ECONOMIC		
	Air qualified days per year	Residential power consumption	Domestic waste treated	Employment share	Pension security coverage	Healthcare security coverage	Disposable income per urban capita	Energy consumption per unit GDP	Service share in GDP
Real values									
Copenhagen	0,91	5,95	1	0,52	1	1	26,969	0,015	0,8
New York	0,899	2,6	1	0,54	1	0,88	31,417	0,06	0,81
Shanghai	0,923	0,757	0,61	0,47	0,39	0,41	36,23	6,18	0,583
Fictional values									
Pluton	0,99	0,5	0,99	0,7	1	1	53	0,001	0,95
Mars	0,795	4,75	0,72	0,55	0,675	0,75	37,5	3,15	0,725
Jupiter	0,6	9	0,45	0,4	0,39	0,5	22	6,3	0,55
	Max	Min	Max	Max	Max	Max	Max	Min	Max

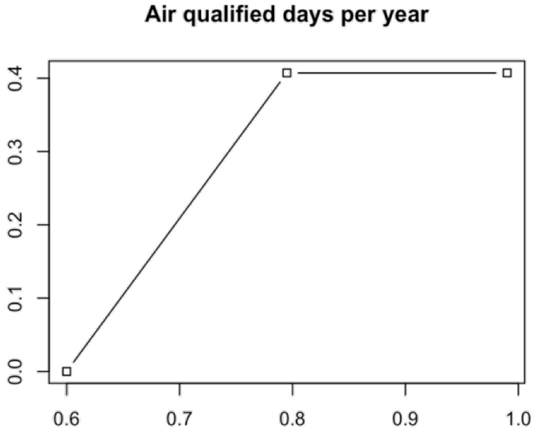
3- Criteria evaluation

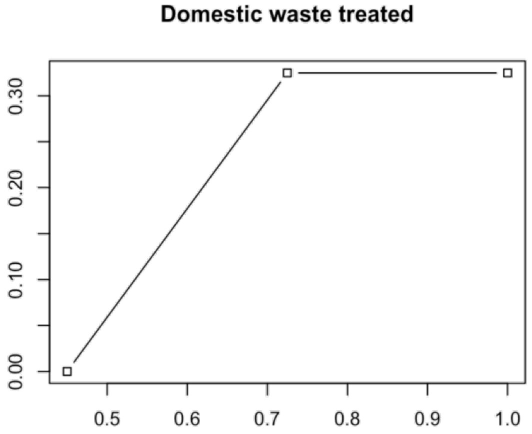


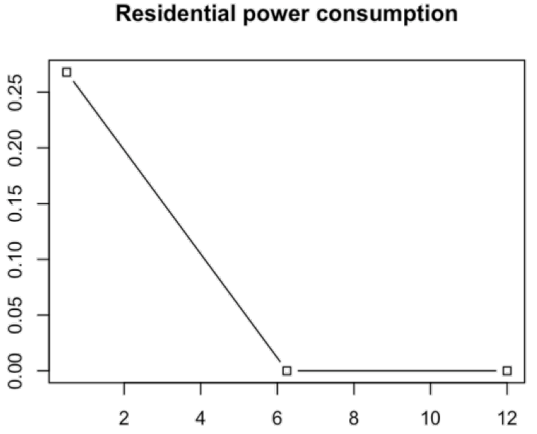




Economic pillar



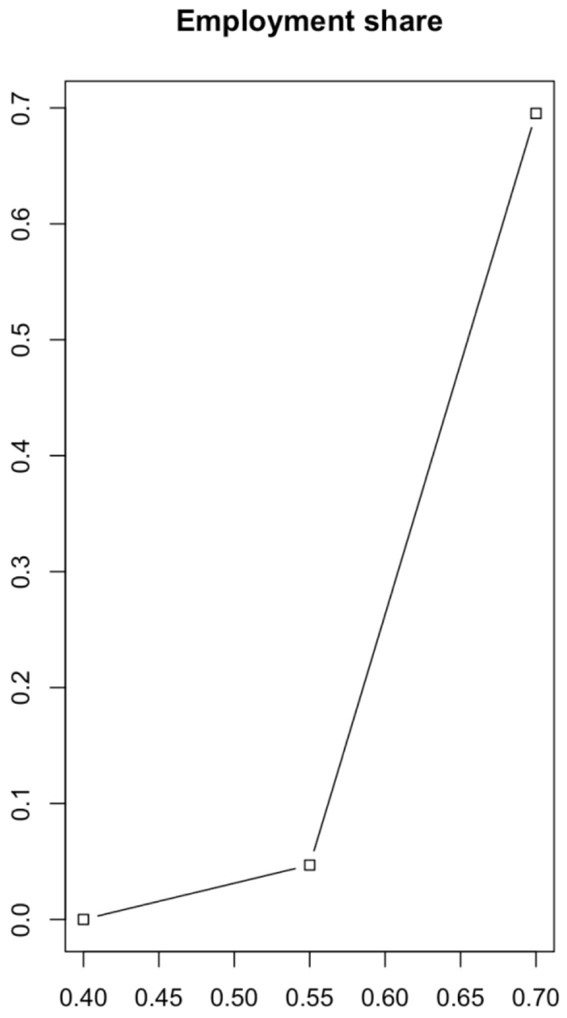


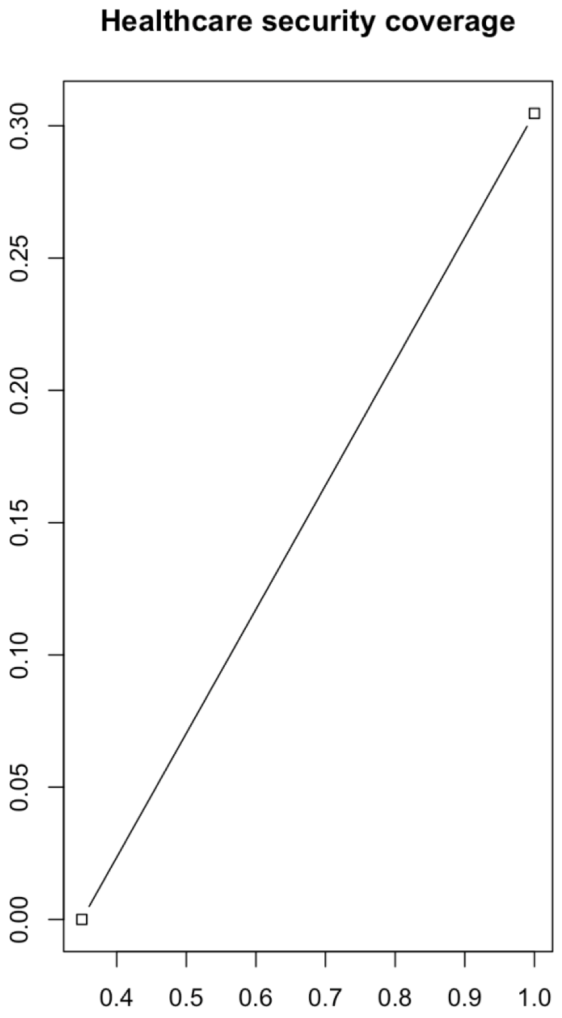


Environmental pillar

3- Criteria evaluation

Social Pillar





We had to eliminate the indicator "Pension security coverage" since it had a weight equal to 0

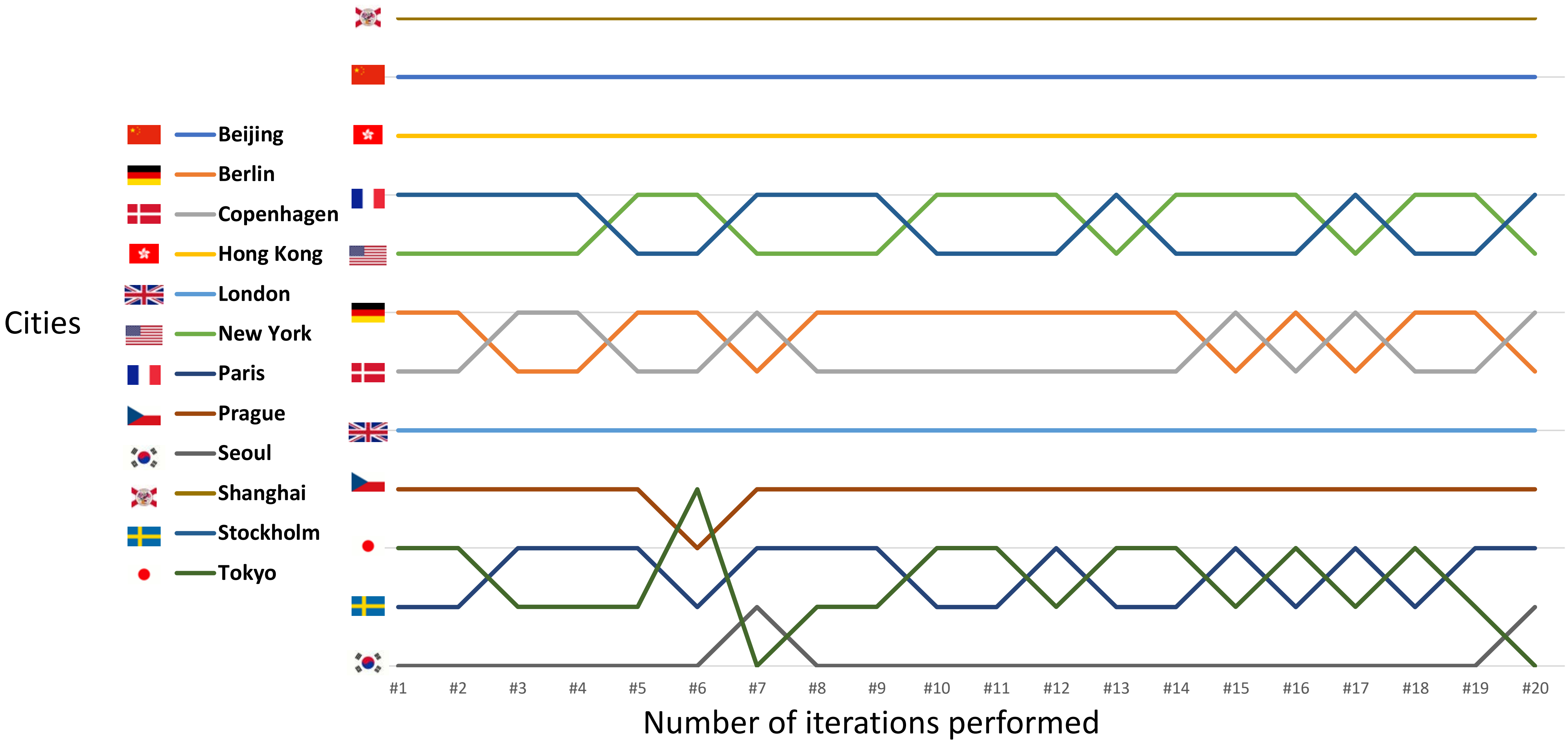
3 - Evaluating alternatives

We used the ROC procedure to estimate the weights for the global score

City	Social	Environment	Economic	Final
Beijing	0,31	0,89	0,07	0,444
Berlin	0,66	0,68	0,22	0,617
Copenhagen	0,68	0,65	0,19	0,617
Hong Kong	0,67	0,41	0,31	0,558
London	0,68	0,79	0,28	0,666
New York	0,58	0,81	0,20	0,602
Paris	0,94	0,54	0,13	0,738
Prague	0,68	0,94	0,23	0,702
Seoul	0,81	0,9	0,30	0,778
Shanghai	0,1	0,7	0,09	0,265
Stockholm	0,68	0,62	0,12	0,601
Tokyo	0,67	0,87	0,89	0,750
WEIGHTS	**0,611**	**0,278**	**0,111**	

3- Sensitivity analysis

Ranking sensitivity analysis



3- Drawing up recommendations

- We used the ROC method to estimate the weights for the global score

City	Social
Paris	0,94
Seoul	0,81
Copenhagen	0,68
London	0,68
Prague	0,68
Stockholm	0,68
Hong Kong	0,67
Tokyo	0,67
Berlin	0,66
New York	0,58
Beijing	0,31
Shanghai	0,1

City	Environmental
Prague	0,94
Seoul	0,9
Beijing	0,89
Tokyo	0,87
New York	0,81
London	0,79
Shanghai	0,7
Berlin	0,68
Copenhagen	0,65
Stockholm	0,62
Paris	0,54
Hong Kong	0,41

City	Economic
Tokyo	0,89
Hong Kong	0,31
Seoul	0,3
London	0,28
Prague	0,23
Berlin	0,22
New York	0,2
Copenhagen	0,19
Paris	0,13
Stockholm	0,12
Shanghai	0,09
Beijing	0,07

3- Implementing action

Final ranking:

City	Final
Seoul	0,778
Tokyo	0,750
Paris	0,739
Prague	0,702
London	0,666
Copenhagen	0,617
Berlin	0,616
New York	0,602
Stockholm	0,601
Hong Kong	0,557
Beijing	0,444
Shanghai	0,265

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4- Final remarks

- ✓ The term "Sustainability" is a subjective term
  - 👍 Satisfaction of sustainability depends on stakeholder preferences
  - 👎 Interactions among sustainability indicators lead to synergies and trade-offs

- ✓ Good communication between analysts and DM facilitates the elicitation process
  - 👍 Ranking was an appropriate result for the DM
  - 👎 The model lacks a strong stability

- ✓ MCDA R package has some limitations
  - 👍 It is user friendly
  - 👎 The post-optimality analysis did not work in the package

4- Future works

- The ranking can be improved with another set of representative criteria
- MCDA R package can be improved with additional features
- We should do robustness analyses in future works → Post optimality analysis
- Implementation of tracking applications (IoT) to extract more precise, personalised indicators

Thank you!

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