School Case Study

Urban Sustainability Assessment

Group 6

Anderson Silva, Andreia Guerreiro, Antonis Georgantas, Athanasios Pliousis, Diogo Silva, Leydiana Pereira, Luis Dias, Marco Scherz and Thomas Xenos
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1. Problem Context
2. Approach
3. Results and Validation
4. Conclusions and Future Work
1. Problem Context
2. Approach
3. Results and Validation
4. Conclusions and Future Work
1- Describing the context

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)

- 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.**
Contents

1. Problem Context
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4. Conclusions and Future Work
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
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
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

<table>
<thead>
<tr>
<th>City</th>
<th>Air qualified days per year</th>
<th>Residential power consumption</th>
<th>Domestic waste treated</th>
<th>Employment share</th>
<th>Pension security coverage</th>
<th>Healthcare security coverage</th>
<th>Disposable income per urban capita</th>
<th>Energy consumption per unit GDP</th>
<th>Service share in GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beijing</td>
<td>0,876</td>
<td>0,699</td>
<td>0,982</td>
<td>0,53</td>
<td>0,54</td>
<td>0,59</td>
<td>32,903</td>
<td>4,59</td>
<td>0,761</td>
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<tr>
<td>Berlin</td>
<td>0,953</td>
<td>8,9</td>
<td>1</td>
<td>0,5</td>
<td>1</td>
<td>0,99</td>
<td>23,562</td>
<td>0,007</td>
<td>0,826</td>
</tr>
<tr>
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<td>0,91</td>
<td>5,95</td>
<td>1</td>
<td>0,52</td>
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<td>1</td>
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<td>1,594</td>
<td>0,5</td>
<td>0,502</td>
<td>0,85</td>
<td>1</td>
<td>29,288</td>
<td>0,159</td>
<td>0,919</td>
</tr>
<tr>
<td>London</td>
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<td>3,988</td>
<td>0,932</td>
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<td>1</td>
<td>33,052</td>
<td>0,035</td>
<td>0,89</td>
</tr>
<tr>
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<td>0,54</td>
<td>1</td>
<td>0,88</td>
<td>31,417</td>
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<td>0,647</td>
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<td>0,92</td>
<td>0,678</td>
<td>1</td>
<td>0,99</td>
<td>31,661</td>
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<td>0,737</td>
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<tr>
<td>Prague</td>
<td>0,965</td>
<td>1,153</td>
<td>0,865</td>
<td>0,515</td>
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<td>1</td>
<td>14,2</td>
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<td>Seoul</td>
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<td>1,283</td>
<td>1</td>
<td>0,623</td>
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<td>0,96</td>
<td>32,791</td>
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</tr>
<tr>
<td>Shanghai</td>
<td>0,923</td>
<td>0,757</td>
<td>0,61</td>
<td>0,47</td>
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<td>0,41</td>
<td>36,23</td>
<td>6,18</td>
<td>0,583</td>
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<tr>
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<td>0,89</td>
<td>6,75</td>
<td>1</td>
<td>0,52</td>
<td>1</td>
<td>1</td>
<td>30,5</td>
<td>0,041</td>
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<tr>
<td>Tokyo</td>
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<td>2,376</td>
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<td>0,501</td>
<td>1</td>
<td>1</td>
<td>51,097</td>
<td>0,014</td>
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</tbody>
</table>
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.
2- Preference modeling

- 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).

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

1. Problem Context
2. Approach
3. Results and Validation
4. Conclusions and Future Work
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

<table>
<thead>
<tr>
<th></th>
<th>ENVIRONMENTAL</th>
<th>SOCIAL</th>
<th>ECONOMIC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Air qualified days per year</td>
<td>Residential power consumption</td>
<td>Domestic waste treated</td>
</tr>
<tr>
<td>Copenhagen</td>
<td>0,91</td>
<td>5,95</td>
<td>1</td>
</tr>
<tr>
<td>New York</td>
<td>0,899</td>
<td>2,6</td>
<td>1</td>
</tr>
<tr>
<td>Shanghai</td>
<td>0,923</td>
<td>0,757</td>
<td>0,61</td>
</tr>
<tr>
<td>Pluton</td>
<td>0,99</td>
<td>0,5</td>
<td>0,99</td>
</tr>
<tr>
<td>Mars</td>
<td>0,795</td>
<td>4,75</td>
<td>0,72</td>
</tr>
<tr>
<td>Jupiter</td>
<td>0,6</td>
<td>9</td>
<td>0,45</td>
</tr>
<tr>
<td>Max</td>
<td>Max</td>
<td>Max</td>
<td>Max</td>
</tr>
</tbody>
</table>

Real values

Fictional values
3- Criteria evaluation

Economic pillar

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

Environmental pillar

- Air qualified days per year
- Domestic waste treated
3- Criteria evaluation

Social Pillar

We had to eliminate the indicator “Pension security coverage” since it had a weight equal to 0.
We used the **ROC** procedure to estimate the **weights** for the global score.

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

Ranking sensitivity analysis

Cities

Number of iterations performed

Beijing
Berlin
Copenhagen
Hong Kong
London
New York
Paris
Prague
Seoul
Shanghai
Stockholm
Tokyo

Number of iterations performed
3- Drawing up recommendations

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

<table>
<thead>
<tr>
<th>City</th>
<th>Social</th>
<th>City</th>
<th>Environmental</th>
<th>City</th>
<th>Economic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paris</td>
<td>0,94</td>
<td>Prague</td>
<td>0,94</td>
<td>Tokyo</td>
<td>0,89</td>
</tr>
<tr>
<td>Seoul</td>
<td>0,81</td>
<td>Seoul</td>
<td>0,9</td>
<td>Hong Kong</td>
<td>0,31</td>
</tr>
<tr>
<td>Copenhagen</td>
<td>0,68</td>
<td>Beijing</td>
<td>0,89</td>
<td>Seoul</td>
<td>0,3</td>
</tr>
<tr>
<td>London</td>
<td>0,68</td>
<td>Tokyo</td>
<td>0,87</td>
<td>London</td>
<td>0,28</td>
</tr>
<tr>
<td>Prague</td>
<td>0,68</td>
<td>New York</td>
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<td>0,23</td>
</tr>
<tr>
<td>Stockholm</td>
<td>0,68</td>
<td>London</td>
<td>0,79</td>
<td>Berlin</td>
<td>0,22</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>0,67</td>
<td>Shanghai</td>
<td>0,7</td>
<td>New York</td>
<td>0,2</td>
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<tr>
<td>Tokyo</td>
<td>0,67</td>
<td>Berlin</td>
<td>0,68</td>
<td>Copenhagen</td>
<td>0,19</td>
</tr>
<tr>
<td>Berlin</td>
<td>0,66</td>
<td>Copenhagen</td>
<td>0,65</td>
<td>Copenhagen</td>
<td>0,19</td>
</tr>
<tr>
<td>New York</td>
<td>0,58</td>
<td>Stockholm</td>
<td>0,62</td>
<td>Paris</td>
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<td>Paris</td>
<td>0,54</td>
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<td>0,12</td>
</tr>
<tr>
<td>Shanghai</td>
<td>0,1</td>
<td>Hong Kong</td>
<td>0,41</td>
<td>Shanghai</td>
<td>0,09</td>
</tr>
</tbody>
</table>
3- Implementing action

Final ranking:

<table>
<thead>
<tr>
<th>City</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seoul</td>
<td>0,778</td>
</tr>
<tr>
<td>Tokyo</td>
<td>0,750</td>
</tr>
<tr>
<td>Paris</td>
<td>0,739</td>
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<tr>
<td>Prague</td>
<td>0,702</td>
</tr>
<tr>
<td>London</td>
<td>0,666</td>
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<td>Copenhagen</td>
<td>0,617</td>
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<tr>
<td>Berlin</td>
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<tr>
<td>Stockholm</td>
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<td>Beijing</td>
<td>0,444</td>
</tr>
<tr>
<td>Shanghai</td>
<td>0,265</td>
</tr>
</tbody>
</table>
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!

Group 6

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