Urban Water Reuse

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4th Delft - Girona Workshop on Robustness of Complex Network – July 7th 2021
Decision making in water reuse

Challenges

Criteria and Indicators

Technologies

Distribution and potential uses
Feasible water reuse projects

Experts, literature, case studies

Water Reclamation Plants

Reclaimed water distribution network

Decision Support Systems

CLEaN-TOUR DSS
CLEaN-TOUR project: objective

Circular Economy to facilitate urban water reuse in a touristic city

- Goal is to develop a tool to support planning of water reuse networks in cities, including collection of waste/greywater, treatment and re-distribution to the final users

Centralised or decentralised approach?
CLEaN-TOUR DSS

**INPUTS**

- Target **city**
- **Automatic** (cloud) and **default** data collection
- Additional user information (uses or city districts to be considered or not, etc.)

**OUTPUTS**

- Administration
- Urban planners
- Eng./consulting companies
- etc.
### CLEaN-TOUR DSS: Data collection

#### Automatic data from the cloud

<table>
<thead>
<tr>
<th>Land use</th>
<th>Street graphs</th>
<th>Land elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="House" /></td>
<td><img src="image2" alt="Map" /></td>
<td><img src="image3" alt="Map" /></td>
</tr>
</tbody>
</table>

#### Default (customizable) values

<table>
<thead>
<tr>
<th>Water origins (generation)</th>
<th>Water destination (consumption)</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image4" alt="Shower" /></td>
<td><img src="image5" alt="Sink" /></td>
<td><img src="image6" alt="Screwdriver" /></td>
</tr>
</tbody>
</table>

- Literature, case studies, previous research & real data
- SewerLCA
**CLEaN-TOUR DSS: Data collection**

<table>
<thead>
<tr>
<th>Canonada (mm)</th>
<th>Cost de material (€)</th>
<th>Cost de mà d’obra (€)</th>
<th>Cost total (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>63</td>
<td>1.71</td>
<td>69.13</td>
<td>74.83</td>
</tr>
<tr>
<td>75</td>
<td>2.43</td>
<td>71.33</td>
<td>73.75</td>
</tr>
<tr>
<td>90</td>
<td>3.49</td>
<td>72.97</td>
<td>80.46</td>
</tr>
<tr>
<td>110</td>
<td>4.94</td>
<td>74.62</td>
<td>83.54</td>
</tr>
<tr>
<td>125</td>
<td>6.29</td>
<td>76.82</td>
<td>87.11</td>
</tr>
<tr>
<td>140</td>
<td>7.92</td>
<td>79.02</td>
<td>86.94</td>
</tr>
<tr>
<td>160</td>
<td>10.31</td>
<td>81.77</td>
<td>92.08</td>
</tr>
<tr>
<td>180</td>
<td>13.05</td>
<td>98.27</td>
<td>111.32</td>
</tr>
<tr>
<td>200</td>
<td>16.11</td>
<td>112.01</td>
<td>128.12</td>
</tr>
<tr>
<td>225</td>
<td>20.43</td>
<td>125.76</td>
<td>146.19</td>
</tr>
<tr>
<td>250</td>
<td>25.04</td>
<td>139.50</td>
<td>164.54</td>
</tr>
</tbody>
</table>

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<th>Cost de mà d’obra (€)</th>
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</tr>
</thead>
<tbody>
<tr>
<td>315</td>
<td>39.83</td>
<td>167.00</td>
<td>206.83</td>
</tr>
<tr>
<td>400</td>
<td>64.07</td>
<td>194.49</td>
<td>258.56</td>
</tr>
<tr>
<td>450</td>
<td>112.95</td>
<td>205.77</td>
<td>318.72</td>
</tr>
<tr>
<td>560</td>
<td>173.57</td>
<td>230.55</td>
<td>404.12</td>
</tr>
<tr>
<td>630</td>
<td>223.13</td>
<td>242.95</td>
<td>466.08</td>
</tr>
<tr>
<td>710</td>
<td>-</td>
<td>-</td>
<td>525.28 *</td>
</tr>
<tr>
<td>800</td>
<td>-</td>
<td>-</td>
<td>592.28 *</td>
</tr>
<tr>
<td>900</td>
<td>-</td>
<td>-</td>
<td>666.72 *</td>
</tr>
<tr>
<td>1000</td>
<td>-</td>
<td>-</td>
<td>741.15 *</td>
</tr>
<tr>
<td>1200</td>
<td>-</td>
<td>-</td>
<td>890.03 *</td>
</tr>
<tr>
<td>1400</td>
<td>-</td>
<td>-</td>
<td>1038.91 *</td>
</tr>
</tbody>
</table>

Cost de material (€) – inclou el preu de la canonada, Cost de mà d’obra (€) – inclou els preus dels treballadors i el d’obrir i tancar la rasa (57.04€), Cost total (€) – especifica el cost total de construcció per metre inclouent els costos de material, de mà d’obra i un 5% addicional per costos indirectes.
CLEaN-TOUR DSS: the logics

User inputs
- City name
- City's cadastral data files

CleanTour tool
- City street graph
- City terrain usage, location and inhabitants

Resulting data
- Graph results on map and GraphML
- EPANET optimized file
- EPANET

OpenStreetMap API
- City name
- City's cadastral data files

Elevation API
- City topography
- Elevation added to street graph
- Origins and destinations added to street graph
- Routing from origins and to destinations
- Pipe diameter optimization iterations
CLEaN-TOUR DSS

**INPUTS**

- Target city
- **Automatic** (cloud) and **default** data collection
- Additional information (carwash, firemen, etc.)

**OUTPUTS**

- Proposal of optimal water reuse network (on a map)
- **Water savings** quantification
- Km. of network
- **Investment** costs (pipes, pumps, treatment systems...)
- Operation & maintenance costs
- Validation and optimisation of pipe diameters with **EPANET**
<table>
<thead>
<tr>
<th>WATER USES</th>
<th>Modelled consumption (m3/y)</th>
<th>Real consumption (m3/y)</th>
<th>ERROR (%)</th>
<th>Correction factor (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private economic activities</td>
<td>534.680</td>
<td>540.802</td>
<td>1.15</td>
<td>-</td>
</tr>
<tr>
<td>Public use (municipal buildings + public gardening)</td>
<td>213.558</td>
<td>171.557</td>
<td>24.48</td>
<td>-</td>
</tr>
<tr>
<td>Domestic</td>
<td>9.112.783</td>
<td>1.594.749</td>
<td>471.42</td>
<td>18</td>
</tr>
</tbody>
</table>
CLEaN-TOUR DSS: Results

- Automatic network generation/routing
- Automatic clustering of elevated areas (or for potential decentralisation)
- Optimization of network generation/routing

- First satisfactory results in Girona and Lloret de Mar
- (comparison between centralised and decentralised solutions)
Routing: Steiner tree problem

- Design of a water network from WWTP to a set of points of use
- Should include all points of use
- As shortest/cheaper as possible
Example: Girona

Definition of points of use (destinations)

Pipe diameter and valves
Example: Girona

First algorithm: 61,3 km, 8873 m³/d, 7.1M€

Second algorithm: 49,5 km, 8873 m³/d, 5.8M€
Spectral Clustering

- Results of the spectral clustering of the Street graphs of Lloret de Mar with 3 clusters
Optimization: Steiner tree

• For each cluster, finding Steiner tree
• Tree of minimum cost connecting all terminals of a graph, using other nodes (Steiner vertices)
• Kou algorithm
• Takahashi algorithm
• Ant Colony Optimization
• Melhorn algorithm (best results)
Example: Girona, total costs
Drinking vs regenerated water
Next Steps

- Optimizing network generation based on a fixed budget.
- Automatic clustering for potential decentralisation.
- Comparison between centralised and decentralised solutions.
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Thanks a lot for your attention

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