Ensuring water availability with complete urban water modelling

Climate, water and health
HS7.3/CL3.7/NP1.4

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Urban Water Optioneering Tool (UWOT)
- Introduction
- Implementation
- Assessment
- Optimization

UWOT applications
- Water recycling in different climatic conditions
- Natural hydrosystem flow-pattern restoration
- Water scarcity in a small island
- Assessing health risk from water storage with RTI

Beyond the state-of-art
- Integration with other models
Description of UWOT (introduction)

UWOT simulates the urban water cycle by modelling individual water uses and technologies and aggregates their combined effects at development scale.
Description of UWOT (introduction)

**Appliances**
1. Washing Machine
2. Toilet
3. Treatment
4. Shower
5. Bath
6. Hand-basin
7. Kitchen Sink
8. Dish Washer
9. Garden
10. Outside use
11. SUDS local
   ...

**Central technologies**
- Central treatment units
- Central SUDS

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**Technology library**

<table>
<thead>
<tr>
<th>Resources Utilisation</th>
<th>Specification</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Usage</td>
<td></td>
<td>(l/use)</td>
</tr>
<tr>
<td>Water Loss</td>
<td></td>
<td>(%)</td>
</tr>
<tr>
<td>Energy Use</td>
<td></td>
<td>(kWh/use)</td>
</tr>
<tr>
<td>Chemical Use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land Use</td>
<td></td>
<td>(m²)</td>
</tr>
</tbody>
</table>

| Economic parameters                  |                |          |
| Willingness to pay                   |                | (£)      |
| Capital Cost                          |                | (£)      |
| Operational Cost                     |                | (£/use)  |

| Social parameters                    |                |          |
| Risks to human health                |                |          |
| Acceptability                        |                |          |
| Public Awareness                     |                |          |
| Social Inclusion                     |                |          |

| Technical parameters                 |                |          |
| Reliability                          |                |          |
| Durability                           |                |          |

| Operational Parameters               |                |          |
| Frequency of use                     | (uses/p/d)     |          |
| Input Quality (Worst)                |                |          |
| Output Quality                       |                |          |
Description of UWOT (implementation)

Current version

- MS Excel
- UWOT engine (dll)

New academic version

- UWOT mex
- MATLAB
- Database
- Design application

Future commercial version

- GUI
- Database
- Execute
- UWOT engine (dll)
UWOT assesses the sustainability of a development water cycle through the use of sustainability indicators.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Type</th>
<th>Aggregation method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potable</td>
<td>Quantitative</td>
<td>Summation</td>
</tr>
<tr>
<td>Runoff</td>
<td>Quantitative</td>
<td>Summation</td>
</tr>
<tr>
<td>WW disch.</td>
<td>Quantitative</td>
<td>Summation</td>
</tr>
<tr>
<td>Energy</td>
<td>Quantitative</td>
<td>Summation</td>
</tr>
<tr>
<td>Landuse</td>
<td>Quantitative</td>
<td>Summation</td>
</tr>
<tr>
<td>Cap. cost</td>
<td>Quantitative</td>
<td>Summation</td>
</tr>
<tr>
<td>Op. cost</td>
<td>Quantitative</td>
<td>Summation</td>
</tr>
<tr>
<td>WW qual.</td>
<td>Qualitative</td>
<td>Mix</td>
</tr>
<tr>
<td>Chemical</td>
<td>Qualitative</td>
<td>Summation</td>
</tr>
<tr>
<td>RTI</td>
<td>Qualitative</td>
<td>-</td>
</tr>
<tr>
<td>Will. To pay</td>
<td>Qualitative</td>
<td>Summation</td>
</tr>
<tr>
<td>Acceptabl.</td>
<td>Qualitative</td>
<td>Summation</td>
</tr>
<tr>
<td>Publ. awarn.</td>
<td>Qualitative</td>
<td>Summation</td>
</tr>
<tr>
<td>Social incl.</td>
<td>Qualitative</td>
<td>Summation</td>
</tr>
<tr>
<td>Reliability</td>
<td>Qualitative</td>
<td>Summation</td>
</tr>
<tr>
<td>Durability</td>
<td>Qualitative</td>
<td>Summation</td>
</tr>
<tr>
<td>Flexibility</td>
<td>Qualitative</td>
<td>Summation</td>
</tr>
</tbody>
</table>
Description of UWOT (optimization)

**Single objective optimization (SOGA)**

\[
\text{min } \sum w_i O_i(x)
\]

Where: \(x\) is the decision variables vector, \(w=(w_1, w_2, \ldots, w_n)\) is the preference vector and \(O_i\) is the standardized value of the \(i^{th}\) indicator.

**Multi-objective optimization (MOGA)**

\[
\text{min } [O_1(x), O_2(x), \ldots, O_n(x)]
\]

The solution to the above problem is a set of Pareto points.
Description of UWOT (GUI-current ver.)

- Preferred water type per appliance
- Central reservoirs and public areas
- At most 6 different household types
- Appliance id
- Central technologies id
- Properties of the household types
- Recycling scheme
- Consumed water volume per water type
- Observed-simulated runoff
- Household tanks capacities
- GUI
- GANetXL optimization add-in
Description of UWOT (GUI-new ver.)

UWOT is a function

Globals: a structure with everything UWOT needs to run

Simulation results into a structure
Two water recycling schemes are optimized under three different climatic conditions: humid (Cfb), Mediterranean (Csa) and arid (BWh).
UWOT application 1 (recycling schemes)
UWOT application 1 (Results)

Pareto front of scheme 1

Graph showing the relationship between potable demand reduction (%) and capital cost increase (%) for three different schemes: Cfb, Csa, and BWh.
Scheme 2 solutions with min potable demand

Scheme 2, 20% reduction of rainfall
The runoff from two hypothetical developments, one with high (H) and one with low (L) urban density is investigated with UWOT.

The households of these developments implement a rainwater harvesting scheme (like scheme 1 presented previously).

The aim is to restore the rainfall-response to the pre-urbanization form and to minimize the potable water demand.
**UWOT application 2 (Results)**

<table>
<thead>
<tr>
<th></th>
<th>Conventional development H</th>
<th>Optimized development H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum runoff (m³/s)</td>
<td>3.26</td>
<td>1.12</td>
</tr>
<tr>
<td>Potable water demand (m³/d)</td>
<td>1116</td>
<td>834</td>
</tr>
</tbody>
</table>

![Graph showing runoff and water demand comparison](chart.png)
UWOT application 2 (Results)

<table>
<thead>
<tr>
<th></th>
<th>Conventional development L</th>
<th>Optimized development L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum runoff (m³/s)</td>
<td>2.38</td>
<td>1.09</td>
</tr>
<tr>
<td>Potable water demand (m³/d)</td>
<td>563</td>
<td>413</td>
</tr>
</tbody>
</table>

Graph showing:
- Undisturbed Obs. Runoff
- L Dev. Sim. Runoff - Optimised
- L Dev. Sim. Runoff - Conventional
Retro-fit solutions for potable water demand reduction in a small, water scarce island in Greece (Agkistri) was examined.

UWOT assessed the benefits of replacing conventional water appliances with low consumption ones (scenario 1) as well as the benefits of implementing greywater recycling (scenario 2).
Demand of Agkistri’s developments

Potable water demand reduced by 42% in scenario 2.
The probability of the Residence Time (RT) to be less than 2 days may be used as a hazard index for the water quality degradation due to prolonged storage. The RT changes continuously along with the water level fluctuation. For this reason a probabilistic approach is recommended.

The RT Index (RTI) is estimated numerically in UWOT with the formula:

\[
RTI = \frac{\text{Number of days with } RT < 2}{\text{Number of days of simulation}}
\]
The Residence Time (RT) of the central reservoir is $(60-3)/60=0.95$. 
Beyond the state-of-art (integration)

UWOT will be linked with a hydrological model to provide.

Sustainable (green) urban growth. UWOT will be integrated with a land-use model based on cellular automata to study the interactions between urbanization and the urban water infrastructure.
References


• Rozos, E., and C. Makropoulos, Assessing the combined benefits of water recycling technologies by modelling the total urban water cycle, International Precipitation Conference (IPC10), Coimbra, Portugal, 2010.