Development of a Decision Support Tool for Evaluation of Urban Water System Metabolism Efficiency

Vladimir Nikolic, Ph.D.
Post-doctoral Fellow
Ryerson University
nikolic.vladimir@ryerson.ca

Darko Joksimovic, Ph.D.
Associate Professor
Ryerson University
darkoj@ryerson.ca
1 | REVITALIZATION OF TORONTO’S WATERFRONT

Toronto Waterfront in 2038
Scooch over: Toronto has room for more density, study says

By TESS KALINOWSKI Real Estate Reporter

Wed., Jan. 9, 2018

Slow-moving roads, the subway squish and mushrooming skyscrapers might be the most obviously visible signs of Toronto’s growing population density.

But there’s still plenty of room for more people in The Six before it approaches the top of a list of 30 high-income, international cities, says a study by the Fraser Institute being released Tuesday.

Race is on to build the tallest Toronto highrise

By MAY WARREN StarMetro Toronto

Wed., July 18, 2018

As plans progress for a massive change at the waterfront, competition for the title of Toronto’s tallest building (after the CN tower) is heating up.

A 95-storey building is planned for the Pinnacle 1 Yonge site, which is marketed to be the tallest in the city. At 307 metres high, according to site plans submitted in June to the city’s development web portal, the proposed highrise would edge out First Canadian Place, which currently holds the honour.

Canada Census 2016: Toronto growth well above the already high national average

The census indicated that Toronto ranked No. 1 among the country’s 55 census metropolitan areas.
VERBAL GROWTH / INTENSIFICATION IN ONTARIO

Greenbelt Area, Ontario
Collaboration between Ryerson University and Waterfront Toronto
Concept of Urban Metabolism, after Abel Wolman
Centralized [Traditional] approach  

Decentralized [Hybrid] approach
Technologies used to balance urban water metabolic process
IWRET Workshop survey topics:

i. Decentralized technologies;
ii. Quantitative and qualitative indicators of sustainability;
iii. Graphic user interface (GUI).
### 9 | PREFERRED TECHNOLOGIES

#### Water Supply
- Fit-for-purpose only (e.g. dual plumbing): 3.5
- Social networks and apps: 2.7
- Integration of smart water and energy metering: 3.8
- Smart water meters: 3.9
- Smart water appliances: 3.2
- Water saving devices: 4

#### Stormwater
- Treatment systems (for reuse): 4.1
- Modular storage systems: 3.9
- Bioretention basins: 3.9
- Constructed wetlands: 3.8
- Vegetated filter strips: 3.9
- Soakaways, infiltration trenches...: 3.8
- Pervious surfaces and permeable...: 3.8
- Perforated pipe systems: 3.7
- Dry swales: 3.4
- Enhanced grass swales: 3.7
- Downspout disconnections: 4.2

#### Wastewater
- Vacuum toilets/sewers: 2.7
- Low pressure sewers: 2.8
- Living machines: 3
- Sand filters: 2.9
- Constructed wetlands: 3.5
- Packaged wastewater treatment plants: 3.8

#### Reuse/Recycle
- Nutrient recovery from packaged...: 3.7
- Energy recovery from packaged...: 3.5
- Street-level heat recovery from...: 3.2
- Building-level heat recovery from...: 3.4
- Unit-level heat recovery: 3.2
- Urine separation: 2.8
- Composting toilets: 2.6
- Dry toilets: 4
- Greywater systems: 4.3
- Rainwater harvesting: 4.3
PREFERRED INDICATORS OF SUSTAINABILITY

Environmental
- NO2 caused, avoided: 3.06
- CH4 caused, avoided: 3.12
- CO2 caused, avoided: 3.42
- Improvements in runoff quality: 4.28
- Reductions in rainfall runoff: 4.46
- Total rainfall runoff: 3.69
- Savings in wastewater generation: 4.23
- Savings in non-potable consumption: 3.37
- Savings in potable consumption: 5.87
- Water loss: 3.53
- Water usage: 4.96
- Reductions in energy use: 4.03
- Energy use: 4.38
- Chemical use: 3.48

Socio-cultural
- Social inclusion: 3.16
- Public awareness: 3.68
- Participation/responsibility: 3.72
- Public acceptability: 3.94
- Number of permanent jobs created: 3.06
- Percentage of land devoted to parks and open spaces: 3.09
- Area of land devoted to parks and open spaces: 3.29
- Number of trees / plantings planted on site: 3.03
- Potential risk to human health: 4.66

Economic
- Operational cost: 4.43
- Capital cost: 4.06
- Financial risk exposure: 3.75
- Affordability: 4.24
- Willingness to pay: 3.52
- Total cost of building materials used: 3.06
- Life cycle costs: 4.71

Engineering
- Flexibility/adaptability: 4.00
- Durability: 4.21
- Reliability: 4.71
- Ease of demonstration: 3.27
- Maturity: 3.27
- Performance: 4.86
Main Elements of System Dynamics (SD) Simulation Model
ARCHITECTURE OF HYBRID WATER SYSTEMS

Centralized System

- Integrating all elements of urban water cycle;
- Including all four groups of decentralized solutions to allow flexible representation of hybrid water systems;
- Integrating of sustainability performance indicators recognized by the potential users;
- Use open-source technology, publicly available for use, modification and distribution; and,
- Incorporating low data requirements typically used for master planning;
Three spatial scales represented in IWRET
Visualization of the water supply component
Visualization of the waste and stormwater component
CHANGING MORPHOLOGY OF WATER SYSTEMS

Visualization of decentralized options

Porous Pavement and Permeable Patio
Bioretention and Rain Garden
Bioswale
Living Machine
Smart Water Appliances
Membrane Bioreactor

Greywater Reuse
Green Roof
Rainwater Harvesting

Water Flow
Energy Flux
GHG Flux
Chemical Flux
Financial Flux
# List of Major Model Outputs

<table>
<thead>
<tr>
<th>Description</th>
<th>Presentation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Neighborhood</strong></td>
<td></td>
</tr>
<tr>
<td>Single family units over time</td>
<td>Continuous graph - line</td>
</tr>
<tr>
<td>Multi-family units over time</td>
<td>Continuous graph - line</td>
</tr>
<tr>
<td><strong>Water and Wastewater Balance</strong></td>
<td></td>
</tr>
<tr>
<td>Water demand for irrigation</td>
<td>Continuous graph - line</td>
</tr>
<tr>
<td>Water demand for domestic use</td>
<td>Continuous graph - line</td>
</tr>
<tr>
<td>Water demand for commercial and institutional activities</td>
<td>Continuous graph - line</td>
</tr>
<tr>
<td>Water demand for industrial activities</td>
<td>Continuous graph - line</td>
</tr>
<tr>
<td>Total daily demand of potable water</td>
<td>Continuous graph - line</td>
</tr>
<tr>
<td>Total water loss due to leakage in water supply system</td>
<td>Number</td>
</tr>
<tr>
<td>Treated Wastewater in WWTW</td>
<td>Continuous graph - line</td>
</tr>
<tr>
<td><strong>Stormwater</strong></td>
<td></td>
</tr>
<tr>
<td>Daily precipitation</td>
<td>Histogram, bars</td>
</tr>
<tr>
<td>Daily stormwater runoff</td>
<td>Continuous graph - line</td>
</tr>
<tr>
<td>Runoff from impervious areas</td>
<td>Continuous graph - line</td>
</tr>
<tr>
<td><strong>Reuse and Recycle</strong></td>
<td></td>
</tr>
<tr>
<td>Rainwater harvested daily</td>
<td>Continuous graph - line</td>
</tr>
<tr>
<td>Total volume of harvested rainwater</td>
<td>Number</td>
</tr>
<tr>
<td>Greywater collected daily</td>
<td>Continuous graph - line</td>
</tr>
<tr>
<td>Blackwater collected daily</td>
<td>Continuous graph - line</td>
</tr>
<tr>
<td>Total volume of treated blackwater</td>
<td>Number</td>
</tr>
<tr>
<td><strong>Financial</strong></td>
<td></td>
</tr>
<tr>
<td>Capital investments required for system extension</td>
<td>Number</td>
</tr>
<tr>
<td>Installation and construction costs of new system elements</td>
<td>Number</td>
</tr>
<tr>
<td>Costs of operation</td>
<td>Number</td>
</tr>
<tr>
<td>Costs required for system maintenance</td>
<td>Number</td>
</tr>
<tr>
<td>Sum of all system costs</td>
<td>Number</td>
</tr>
<tr>
<td><strong>Energy and Greenhouse Gas Emissions</strong></td>
<td></td>
</tr>
<tr>
<td>Energy required for system operation</td>
<td>Number</td>
</tr>
<tr>
<td>Embodied energy required for system for system construction</td>
<td>Number</td>
</tr>
<tr>
<td>Embodied GHG required for system for system construction</td>
<td>Number</td>
</tr>
<tr>
<td>GHG emissions during system operation</td>
<td>Number</td>
</tr>
</tbody>
</table>
19 | TYPES OF QUESTIONS

• Quantify the metabolic performance of UWS across the urban water cycle.

• What would be the impact of different configurations of the UWS on the long-term sustainability performance?

• What particular environmental categories would have positive, and what categories would have negative impacts?

• What would be consumed, recovered, caused and avoided environmental impacts of different technologies?

• Would there be reductions in rainfall runoff?

• Would there be savings in potable water consumption?
THANK YOU FOR YOUR EFFORT AND ASSISTANCE