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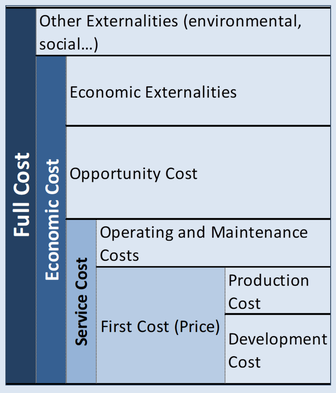
Green Storm-Water Infrastructure (GSI) Strategy Generation & Assessment Tool

For Urban & Regional Comprehensive Planning

Why?

To remove barriers impeding design and adoption of GSI

Remove Planning Barriers	Remove Decision Barriers
. Assist in developing the plan (performed by the Planner) . Generate GSI Strategies . Assess their hydrology, costs & benefits.	. Assist in adopting the plan (by the community and stakeholders) . Meet the planning objectives . Minimize costs & maximize benefits . Evaluate outcome variability



Benefit Category	Impact
Hydrology	Improve water quality: Nutrien, Sediments & TSS, Dissolved solids, Bacterial & Other Toxins
	Fresh water availability
	Reduce flood risks
	Increase ground recharge
Trees And Green space	Reduce aquatic thermal impacts
	Reduce Energy demand
	Carbon sequestration
	Air purification
	Noise Reduction
	Reduce runoff Water
	Preserve natural habitat
Investment	Employment opportunities, Tax Revenues

GSI Elements hydrologic functions

Structural BMPs	GSI Elements	Hydrologic Functions				
		Infiltration	Detention	Reuse	Conveyance	Evapotranspiration
Pervious Pavement	Alley, Parking, Walkway	●	●			
Swales	Grass, Bio.		●		●	●
Bioretention	With or without underdrain	●	●			●
Green Roofs	Intensive, Extensive		●			●
Infiltration Strategies	Wells, Trenches, Chambers, Basins	●				
Rainwater Harvesting	Rain Barrels, Cisterns			●		
Planter Box	Planter Box					●
Vegetated Filter Strip	Vegetated Filter Strip				●	●

The Tool Architecture

Hydrology Module

Planning Unit:
Neighborhood and Watershed

Hydrologic Formulation:
. Runoff volume
. Peak rate discharge
. Runoff water quality
. Infiltrated volume
. Evapo-transpired volume

Economic Module

Full cost formulation:
Generates full cost formulae for each Green Storm-water infrastructure element.

Benefits quantifying and monetizing:
Generates Formulae quantifying benefits and monetizing them.

Economic multiplier formulation:
Generate Formulae for economic impact on the economy using Economic Input/ Output (EIO) method

Optimization Module

Optimization:
Maximize the net benefit of GSI
Subject to:
. Runoff volume control
. Peak rate control
. Runoff quality control
. Budget
. GSI design constraints

MCDM:
Maximize the weighted sum of different objectives each pertaining to the following impact categories:

Total Cost | Hydrology | Green Space | Economic Multiplier

User Interface

User Inputs:
. Study area:
  . Geographic location.
  . Boundaries.
. Hydrologic performance objectives
. Potential budget

Tool Outputs:
. Green Storm Water Infrastructure elements selection and
. sizing.
. Study area expected hydrology
. Costs and benefits values
. Sensitivity and confidence intervals

Risk Assessment

Uses Monte Carlo Simulation to generate confidence intervals.

Data-base Module

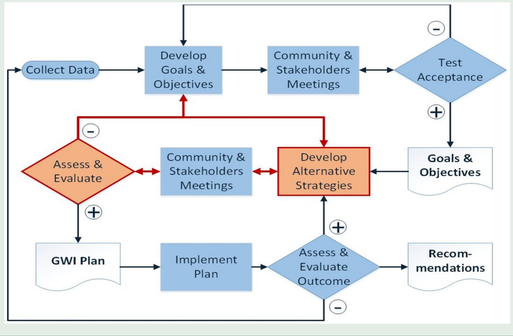
Green Storm-water Infrastructure Elements Database

Hourly Meteorological Database

Geographic Database (land cover, soil types, areas, planning boundaries…)

Costs and Benefits Database

Tool Impact on planning process



The tool will help reducing the repetition of same tasks over & over.

The planning process consists mainly of **<u>two repeating series of tasks</u>**:
. **<u>The first</u>** leads to develop planning goals and objectives and a strategy to achieve them.
. **<u>The second</u>** consist of implementing the plan, assessing the outcome that leads to revise the strategy.

Multi-Criteria Model

Objective function:

$$Max\ Z_M = \sum_j (\omega_j Z_j) \qquad X_i \in \mathbb{R}^+$$

Where:

Z_j is the decision criterion formulation quantifying cost or benefit j where j pertains to economic multiplier, water saving and green space benefits and the negative value of the total cost. Z_j is a function of X_i.

ω_j is an assigned weight of value between 0 and 1 and the sum of all ω_j is equal to 1.

The constraints remain the same as in the optimization model.

This model will generate sets of non-dominated solutions.

Optimization Formulation

Optimization:
Objective function:

$$Min\ Z = \sum_i (C_{T_i} - B_i) X_i \qquad X_i \in \mathbb{R}^+$$

Where:
X_i is the amount of GWI element (i) to be implemented (in functional unit)
C_{Ti} is the Annualized Total cost of GWI element (i) per functional unit (includes service, opportunity and externality costs)
B_i is the Annualized Net total benefits of GWI element (i) per functional unit

Subject to:

Budget constraint: $g_1 = \sum_i (C_{Si} X_i) \le T_B$

Where:
C_{Si} is the annualized Service cost of GWI element (i) per functional unit
T_B is the Annual total budget.

Runoff Volume Control: $g_2 = Q_{Pre} - \sum_i ((R_i + D_i) X_i) \le Q_0$

Where:
Q_{Pre} is the Total Pre-GWI plan implementation runoff volume.
Q_0 is the Total Pre-development runoff volume.
R_i is the Average retention depth of GWI element (i)
D_i is the Average detention depth of GWI element (i)

Peak Rate Control: $g_3 = \Psi_{Pre} - \sum_i (\Psi_i X_i) \le \Psi_0$

Where:
Ψ_{Pre} is Pre-GWI plan implementation runoff Peak rate flow.
Ψ_0 is the Pre-development runoff Peak rate flow.
Ψ_i is the Runoff peak rate reduction of GWI element (i) per functional unit

Water Quality constraints: $g_{j_4} = \frac{(Q_{Pre} - \sum_i (R_i X_i))\varphi_{0_j} + \sum_i \left(D_i X_i \varphi_{d_{ij}}\right)}{Q_{Pre} - \sum_i ((R_i - D_i) X_i)} \le \varphi_j$

Where:
Contaminant (j) refer to TSS, NOx and P
φ_j = Allowable concentration of contaminant (j)
φ_{0_j} = Concentration of contaminant (j) in pre-implementation runoff
$\varphi_{d_{ij}}$ = Concentration of contaminant (j) in detained water runoff from GWI element (i).

GWIEs Specific design constraints:
like minimum, maximum and/or intervals of design parameters that need to be met.

In this formulation the Net Total Benefits (B_i) is the estimated economic value of benefits: where each benefit is represented by a dollar value and the objective function will consist of minimizing the net total cost.

This method will generate specific values for the decision variables.

However, the drawback from solving this type of problem is that the environmental and social benefits are under estimated and misrepresented in the objective function. In addition the economic multiplier cannot be part of the benefit formulation.