UN environment

Spatial Microsimulation Urban Metabolism (SMUM)

Introduction

June 2018 | Paul Hoekman

Introduction

Cities are increasingly responsible for anthropocentric environmental pressures. These environmental pressures are often directly linked to the flows and stocks of resources, including the production, consumption, storage, and discharge of materials. Annual material use has increased from 24 billion metric tonnes in 1970 to 70 billion metric tonnes in 2010 (Fischer-Kowalski et al., 2016). These increases can largely be attributed to fast-growing cities in emerging and developing economies. Yet even more urban growth is expected in the coming decades, with the urban population expected to increase from 54% in 2014 to 66% by 2050 (UN, 2015b).

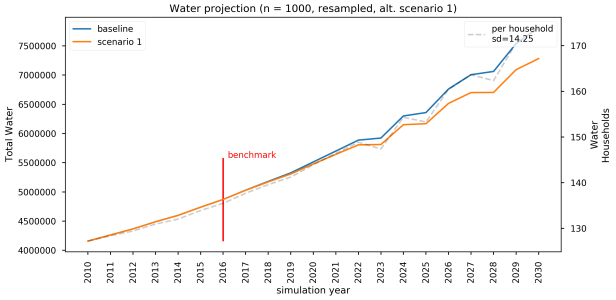
In order for cities to curb their environmental impact and address targets around climate change adaptation and mitigation, it is key to find better ways to manage urban resource flows. To facilitate this transition, UN Environment has developed a Spatial Microsimulation Urban Metabolism (SMUM) tool. This tool, released as open source software, provides cities with an instrument that can assess the impact of policies on resource flows and requirements. Unlike other tools that model policy impacts on a city-wide level, SMUM can provide insights on individual groups in the population, broken down for instance by income, education, age, or household size. This can be of great value for cities that want to make sure that their policies are fair and reach everyone in the population. SMUM can assist cities move forward on three of the commitments defined in the New Urban Agenda principle (UN, 2016) including 1) ensuring that no one is left behind; 2) strengthening resilience in cities; and 3) reducing greenhouse gas emissions. This also aligns strongly with several of the Sustainable Development Goals (UN, 2015a). SMUM allows cities to better understand resource use and the effectiveness in addressing resource needs at a very detailed level.

About SMUM

The Spatial Microsimulation Urban Metabolism (SMUM) tool combines two powerful approaches for the simulation of resource flows within cities. The first approach is Urban Metabolism (Kennedy, Cuddihy, & Engel-Yan, 2007; Kennedy, 2012). This approach describes the metabolic performance of cities by quantifying and balancing all resource inputs and outputs. The second component of the simulation tool is the Spatial Microsimulation model (Orcutt, 1957; Clarke, 1996; Tanton, Vidyattama, Nepal, & McNamara, 2011; Muñoz H., Dochev, Seller, & Peters, 2016). This component of the simulation library constructs a synthetic population for the specific city-system and allocates consumption values to the individual groups within the city.

SMUM can be used to model the impact of policy around any number of resources, including water, electricity, construction materials, food, waste and others. The system can be fully adapted to suit the local requirements and policy priorities. Simulations have already been carried out for a diverse set of cities including Recife (Brazil), Sorsogon (Philippines), Brussels (Belgium) and Cape Town (South Africa).

The tool is set up in a way that the different parts function as independent modules. This means that cities can decide to swap out certain modules for external data, if this is already available. It also accommodates the division of tasks by allowing different users to work on different parts of the system.



The process

There are three main steps defined in the tool:

1. **Constructing a synthetic population**
   SMUM creates a synthetic population by defining the distribution of demographic data (e.g. from a census), consumption values for each record are computed with a micro-level consumption model.

2. **Reweighting and calibrating**
   The model benchmarks the proxy sample to know demographic aggregates by reweighting the sample. The micro-level consumption values are calibrated to match aggregated city-level consumption values.

3. **Constructing scenarios**
   Policy makers can define different transition scenarios and the model will calculate and visualize the impact of these scenarios on different population groups.

The Spatial Microsimulation Urban Metabolism (SMUM) tool is developed as a collaborative instrument in which scientists work together with policy makers. The scientific community provides support to execute the first part of the process (step 1 and 2). Together with policy makers,

they: 1) define base scenarios that use urban metabolism approaches to model the resource inputs and outputs for the city; 2) define a demographic development projection for the city; and 3) construct micro-level consumption models describing the drivers of consumption and consumption intensities.

The tool is very flexible and can be adjusted to suit the available data and output requirements for individual cities. The input requirements can be relatively few, although SMUM is able to accommodate detailed data inputs. The minimal data inputs include: 1) the projected aggregated drivers of consumption; 2) aggregated consumption values; and 3) a micro-level consumption model (which can be defined within SMUM, provided directly from local sources or from academic literature).

Based on the aggregated demographic data and the consumption model, SMUM will create a proxy sample and calculate calibrated consumption values for the city's population. The software will be able to provide results of the impact of the whole population, or any subset, based on the variables that were used. The user can break down the results based on one or more variables (for instance income or age). SMUM uses Markov Chain Monte Carlo (MCMC) algorithms to create this sample, which will then be reweighted , implementing a GREGWT algorithm, to provide a forecast for the simulated time-frame. The results of this sample will be validated against available aggregated data to ensure representativeness of the model.

After this work is done, policy makers will have a tool at their disposal that can be used to define and visualize the transition scenarios (step 3). This is done by tweaking three different parameters: 1) population sampling rules; 2) efficiency growth rates; and 3) technology penetration rates.

Outputs

SMUM will generate a number of data tables and visualizations that demonstrate the impact of the different transitions. The visualizations provide policy makers with powerful tools to grasp the impact of their policy on selected groups.

The outputs provide policy makers with a tool to assess their policy proposals. Depending on the outcome, SMUM can also provide insights into the impacts of these policies on the identified groups in the population and it can illustrate shortcomings in resource distribution of the target transition. By changing the parameters and creating multiple scenarios, policy makers can furthermore get a better understanding of the required technology adoption rates or the minimum efficiency increases that must happen for resource transitions to materialize.

Benefits

SMUM provides policy makers with the following benefits:

- **Allows for assessment of policies** which enable cities to validate the impact on resource flows their policies may have.
- **Supports policies that leave no one behind** by simulating the impact at a micro level within the city rather than on a city-wide level.
- **Encourages collaboration between policy makers and the scientific community** by developing academically-supported base scenarios.
- **Requires relatively little data** to perform a detailed simulation by running advanced statistical models.
- **Offers great flexibility** and can model a large number of resource flows for different population groups.
- **Can be used for a variety of different cities** by tweaking the configuration of the tool to suit the data availability and parameters of individual cities.

Getting started

If you would like to start using the Spatial Microsimulation Urban Metabolism (SMUM) tool, please take stock of the existing datasets on resource flows for your city, and identify which policies and resource flows are of your primary interest to be assessed.

As an open source project, this software tool is available free of charge. There is online documentation available which provides detailed examples of how to run this software and what the results will look like. Instructions on how the software can be installed and run are also available online.

If your city is interested in using SMUM, feel free to get in touch with the Global Initiative for Resource Efficient Cities (GI-REC) at UN Environment. Read more about GI-REC at: https://resourceefficientcities.org/.

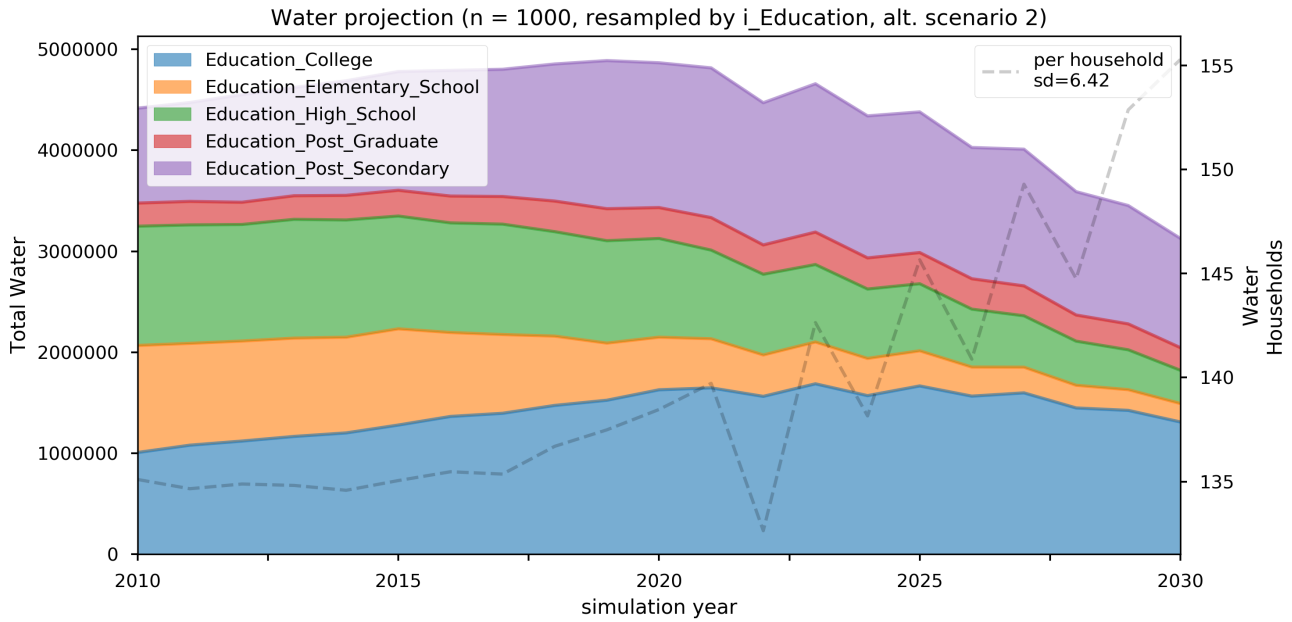


Figure 1: Sample output: projection of water consumption broken down by education level between 2010-2030

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