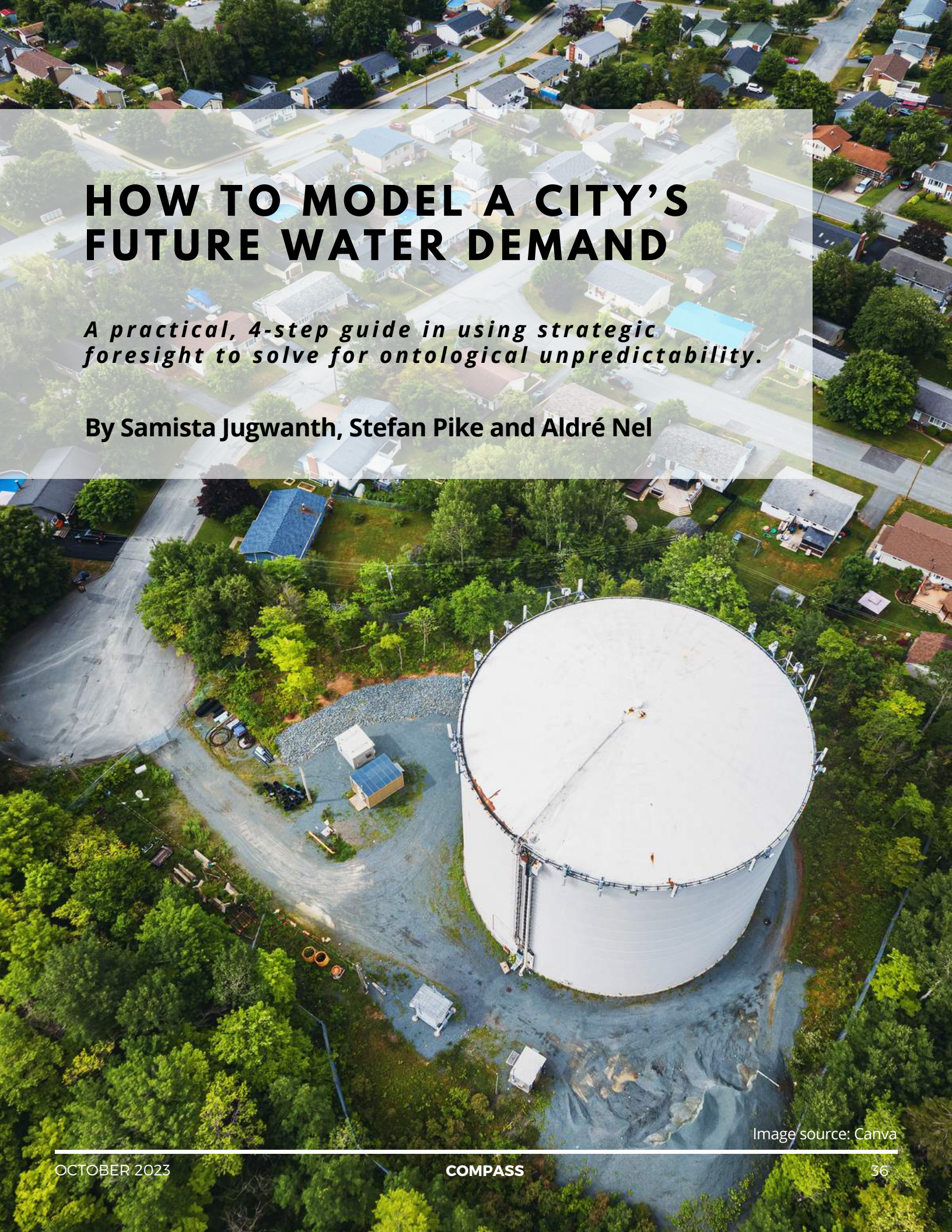


An aerial photograph of a suburban neighborhood. In the foreground, a large, white, cylindrical water storage tank stands prominently. To its left is a gravel area with some small buildings and equipment. The background shows a dense residential area with houses, streets, and trees. A semi-transparent white box is overlaid on the top half of the image, containing the title and subtitle.

HOW TO MODEL A CITY'S FUTURE WATER DEMAND

A practical, 4-step guide in using strategic foresight to solve for ontological unpredictability.

By Samista Jugwanth, Stefan Pike and Aldré Nel

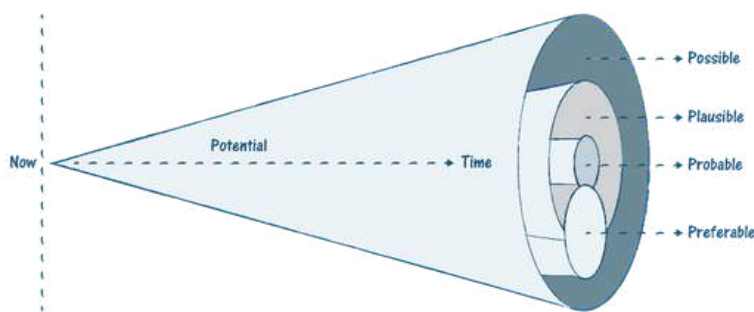
Image source: Canva

For a city to achieve its desired level of water security, effective planning with regards to its bulk water infrastructure is critical. Key to planning for effective infrastructure, is understanding and quantifying a city's future water demand/consumption patterns. Inadequate planning results in water restrictions, higher water tariffs and reduced food security. Indirectly, these limitations also restrict a city's economic growth and urban development.

Traditionally, water demands are predicted (as a single-value outcome) using population counts, historical consumption data (if available), planned Levels of Service, and land usage. However, these four variables do not capture the complexity of the system, especially with the future being increasingly more volatile, uncertain, complex, and ambiguous (VUCA).

APPLYING STRATEGIC FORESIGHT METHODS TO TRADITIONAL WATER DEMAND MODELLING

Water demand is not a single value prediction, but like the futures cone, an envelope of possibilities that diverge as time proceeds. Ontological unpredictability refers to this potential of various realities. Strategic foresight allows one to examine the current drivers and signals that affect water consumption, in order to extrapolate possible outcomes in varying degrees of probability. The intention of identifying possible outcomes is to allow a city (or a larger regional area) to identify potential risks and to have the chance to plan corresponding mitigation strategies. It also allows a city's leaders to anticipate potential opportunities that could be used to enhance growth, innovation, efficiencies, and value.



In this article, we propose a methodology that can be used to model this envelope of water demand projections over time. Step 2 and Step 3 are best completed as a facilitated workshop. Workshop participants should include government officials, design engineers, operations and maintenance staff as well as users (commercial, industrial and residential). Demographic diversity in terms of age, gender and socio-economic level also will lead to more comprehensive results.

STEP 1: DEFINE THE MODEL BOUNDARIES (SPACE AND TIME)

The first step in any model development is to determine the scale of the model. Cities are variable in how different areas behave and react to events and drivers.

As a result, a single model should not be used for a whole city -- rather smaller zones, that account for grouping of socio-economic levels and land use, should be defined. Low-income residential (mainly apartments and lower water needs) areas, high-income residential areas (irrigated gardens and pools), industrial and commercial areas will all have varying requirements and will react differently to changing conditions.

Like the futures cone, the shape of the envelope is time dependant – and therefore, at the outset of the project, it is important to define and communicate the project’s timesteps. As a start, three time-steps, set at five years apart, is recommended.

STEP 2: IDENTIFY AND CATEGORISE DRIVERS USING THE STEEP FRAMEWORK

To start of the workshop, participants must be introduced to the intention of the project, as well as the requirement for divergent thinking. They must also be introduced to the 10 water use categories that make up the city-wide water demand. With this in place, the group will be required to brainstorm the

drivers that they believe will affect water use in their city. Drivers are defined as current trends or variables that may have a significant impact on the future. Demographic shifts, urbanization, and climate change are examples of drivers identified that could impact future water demands significantly.

These drivers are listed using the STEEP-V categorization, with which many professional futurists are familiar. STEEP-V is an acronym for social, technological, economic, environmental, political aspects, and values. It is a useful framework to assist in brainstorming and categorizing data for further analysis. In a water demand context, factors for each driver include:



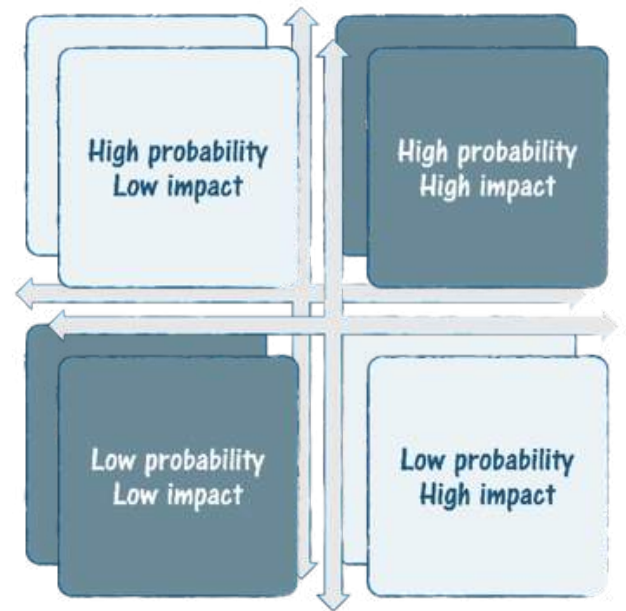


Image source: Canva

- Social factors: Demographic data and other societal issues such as water awareness, illegal water connections, inviting consumers to use recycled water, etc.
- Technological factors: Technological advancements in water-use efficiency (water recycling systems), water storage systems, rainwater harvesting, and developing new technologies to harvest water, such as desalinization plants and off-shore water mining.
- Environmental factors: Ecological and environmental aspects such as weather, climate, pollution, and climate change.
- Economic factors: Gross domestic product per capita, affordability (raising/lowering the cost of water for users), socio-economic levels, infrastructure age, proposed future developments etc.
- Political factors: States of unrest, level of governance and service delivery, and regulatory factors pertaining to water consumption and demand.
- Values factors: Moral obligation to treat all water users equally and equitably, the right for all people to clean drinking water (safety), treating water as sacred, creating water systems that will benefit future generations, etc.

In previous workshops, this exercise has resulted in over 100+ drivers or variables as opposed to the traditional four.

STEP 3: RELATE DRIVERS TO CONSEQUENCES AND PRIORITIZE



The drivers identified in Step 2 are extrapolated into consequences on water demand.

For example, an economic upturn would result in higher salaries and consumption which result in greater household water demand. It is important to note that consequences can be combined or extended from each other creating degrees of consequences.

Another example, higher salaries and production results in greater taxation, which can lead to an increase in public infrastructure (such as parks, stadiums, etc.) and its associated water demand. Because the combinations of drivers and consequences may be too expansive to model – it's important to prioritize those that are highly likely versus those that are not likely or not relevant to a particular city.

To solve for this, the consequences are categorized in the four quadrants of the probability-impact chart. The intersection between probability and impact provides an indication of the significance. Using the probability-impact matrix, the position of consequences on the quad chart, can be translated into a significance level, allowing the modeler to prioritize consequences with a high or very-high rankings. This forms a sensitivity analysis, as the drivers (variables) that contributed the derivation of the highly and very-high significant consequences are used in the water demand model.

STEP 4: CONFIRM SCENARIOS TO MODEL

The set of variables to model has now been refined. The next step is to confirm the scenarios that will be modeled to form the water demand envelope.



IMPACT		Negligible	Minor	Moderate	Major	Significant
PROBABILITY	Very Likely	Medium	Medium	High	Very High	Very High
	Likely	Medium	Medium	High	High	Very High
	Possible	Low	Medium	Medium	High	Very High
	Unlikely	Low	Low	Medium	Medium	High
	Very Unlikely	Low	Low	Medium	Medium	High

In this respect the Four Future Archetypes (Growth, Constraint, Collapse and Transformation) have been modified. The ability to constrain and transform water demand has been interpreted as the potential to dramatically curtail water consumption in the event of a water shortage.

This Curtailment scenario assumes that there is an increase in desired water behavior (through awareness programs) that leads to lower water use, such as people watering their lawns/gardens less, taking shorter showers, installing water-saving appliances (low-flush toilets), etc., as well as using alternative water sources

(such as grey water and rainwater harvesting systems). Therefore, although only three main scenarios are identified (Growth, Conventional and Collapse), there are a further three corresponding

Curtailment sub-scenarios. Using this, a city is able to understand the varying requirements of the system, as well as to identify just how much they can restrict water consumption based on the path that they are on.

The significant consequences from Step 3 are distributed into the scenarios in order illustrate to the modeller how the selected variables are affected. The table below is an example based on previous projects:



Image source: Canva

Scenario	Description
Scenario 1: Growth 	The urban capacity for growth and densification is on the rise and the city is under tremendous stress to supply the most basic need to its inhabitants – water. This includes a high population growth rate, improvement in the Level of Service required, increase in economic activity, urban greenery and urban/indoor farming. It also is representative of high bulk water losses caused by ageing infrastructure.
Scenario 1C: Curtailed Growth	Growth + Curtailment measures: Intentional reduction in water use, increased use of water saving devices, initiatives, and increase use of alternative water sources.
Scenario 2: Conventional 	Water is consumed in the manner that it is currently. An average growth rate is assumed with negligible change in land use or Level of Services.
Scenario 2C: Curtailed Conventional	Conventional + Curtailment measures as described in 1C
Scenario 3: Collapse 	Changes in policy and technology, combined with socio-economic factors influenced by world events, drive people away from the city to smaller urban and rural areas. This is evident by low population growth rates, no change in Level of Service, decrease in economic activity, no improvement in urban greenery and urban/indoor farming. Due to infrastructure upgrades, bulk water losses are reduced, and there is some privatization (including off-grid systems) of water supply.
Scenario 3C: Curtailed Collapse	Collapse + Curtailment measures as described in 1C

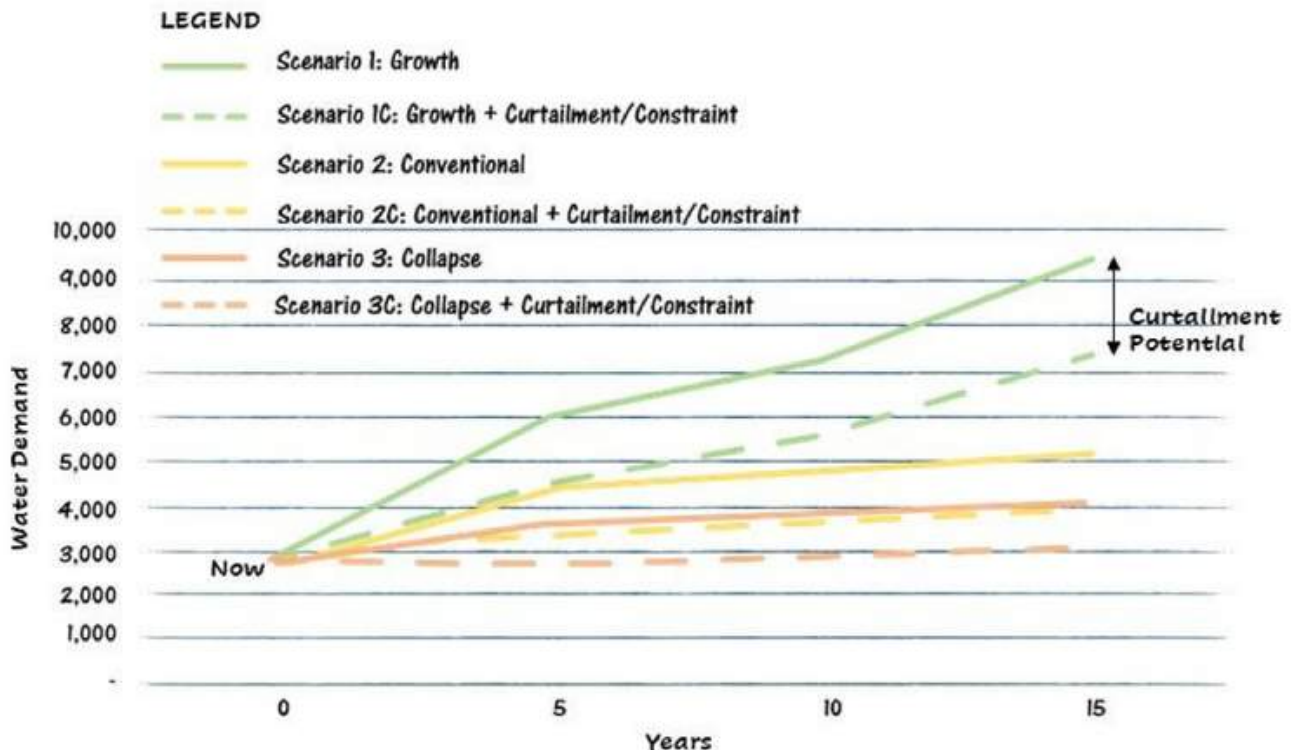
This methodology allows one to identify the variables that are critical to each city investigated. It further produces the scenarios that need to be modelled in order to forecast the possible water demand scenarios that could exist over time – creating an envelope of water demands that mimic a futures cone.

It is interesting to note that some of these scenarios have different effects on the water demand relative to the time interval being examined. This method also allows a city to understand how it can reduce or curtail its water demand in the event of shortages or an emergency, as well as to quantify this.

Once again, the extent of curtailment changes across scenarios and time intervals. With this level of information, a city can design its bulk water infrastructure to be adaptable and resilient in the face of our volatile and unpredictable future.

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