A Workbench for Societal Transitions in Water Sensitive Cities

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ABSTRACT
Strategic planning for the future management of urban water systems, in the face of pressures such as climate change and increasing water demand, presents a significant challenge. This is exacerbated by the lack of adequate support tools, particularly computational tools, for assessing the *societal* water system and methods for exploring future scenarios and hypothetical policy experiments. Currently most computational tools and methods are limited to predictions based on an assessment of the biophysical component of water systems and associated decision support systems are often based upon engineering derived outcomes. While this is important, it is insufficient to fully capture the complexity of the socio-technical system and therefore this paper presents the first conceptualisation of a *Societal Transitions Workbench for Urban Water Systems* which is a computational tool for modelling the societal component of water systems. Such tools could help our decision makers to perform *rigorous thought experiments* of the implications of water policies in terms of societal change and hence more comprehensively inform strategic planning through complementing the existing engineering and biophysical based models.

KEYWORDS
Societal transitions; exploratory modelling; thought experiments; urban water system

INTRODUCTION
This paper presents the first conceptualisation of the *Societal Transitions Workbench for Urban Water Systems* (the Workbench) – computational tool designed for modelling the societal dimension of urban water systems and informing strategic planning. It draws upon the most contemporary and analytically rigorous understandings of transformative change, the recent innovation of the 'multi-pattern approach' (MPA), in societal systems from the field of transition studies (de Haan 2010; de Haan and Rotmans 2011). Past transitions models of societal change (such as multi-level and multi-phase) have been successfully applied to other societal systems including transport, energy and health care (see Grin, Rotmans et al. 2010, for a recent overview of the field) with some attempt at computational modelling. The MPA now provides the conceptual rigour and framing to enable such development of computational models. Therefore the focus of this paper is to apply the MPA in the conceptual development

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of a computational model (i.e. the Workbench) of the societal dynamics associated with urban water systems.

The workbench is designed for policy-makers, decision-makers and planners in the urban water sector to enable transitions towards *Water Sensitive Cities*, as conceptualised by Wong and Brown (2009). Its intended use is to enable hypothetical policy experiments and exploration of possibly unthought-of consequences of actions and external events, such as moving to a fully decentralised system or climatic extremes. This can be done interactively– as if it were a game – or automated, by supplying the workbench with an *ensemble* of plans and scenarios and get an overview of the *portfolio* of possible future developments. The workbench allows for these styles of use because it takes the unorthodox approach of *exploratory* modelling. Exploratory, as proposed by Bankes 1993 and Lempert et al 2003, in using quantitative (computer modelling) methods to gain qualitative insights (patterns of future developments). The agent-based model, while informed by previous transitions modelling approaches (de Haan 2007; Haxeltine, Whitmarsh et al. 2008; Schilperoord, Rotmans et al. 2008; Timmermans, de Haan et al. 2008), draws upon the distinct qualities of the recently developed MPA and therefore it is proposed to lead to a significant improvement on current modelling of societal dynamics.

THE MULTI-PATTERN APPROACH

Societal systems and constellations

The Workbench is based upon the idea that urban water servicing is a *societal* system, which here means that it is a system that has evolved to meet certain societal needs. In the case of an urban water system, these needs are obviously water-related in the broad sense. For example, the need for drinking water, flood protection, wastewater disposal, and so on. Therefore, water supply, sewage or drainage systems are technical manifestations of these societal needs.

The societal needs are the various 'services' society demands from an urban water system and vary from basic things like clean drinking water and stormwater drainage, to more higher level needs like individual influence over water resources. Societal needs can be thought of as a hierarchy based on individual needs, as proposed by Alderfer (1969), scaled up here to the societal system. This so-called E.R.G. theory presents a three tier hierarchy of 'existence', 'relatedness' and 'growth' needs. The extrapolation of these needs in relation to the urban water context is listed in Table 1.

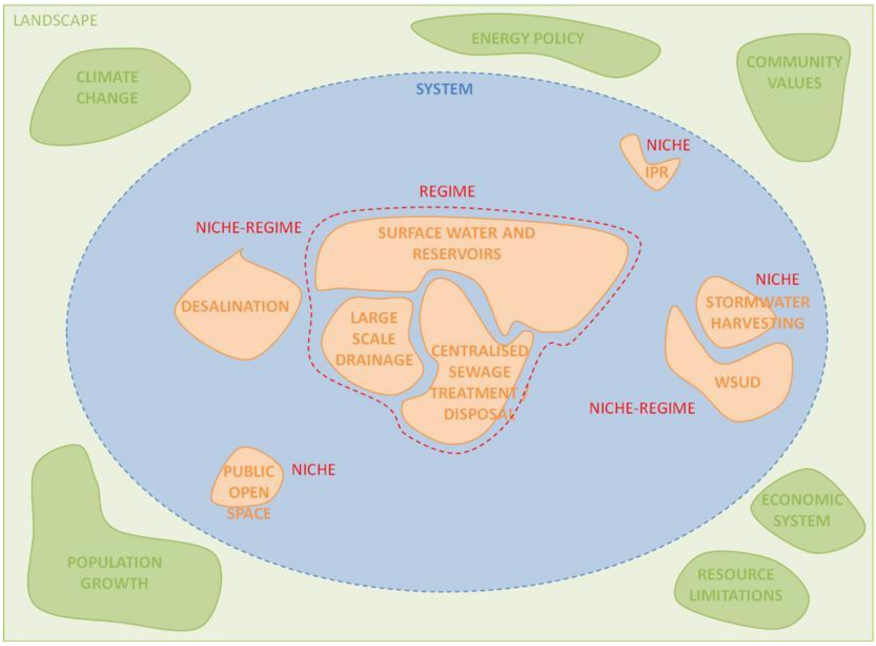
Table 1. Societal needs in urban water systems.

Need category	*Urban-water related need*	*Description*
Existence	Drinking Water	Safe, secure and accessible supply of drinking water available
	Non-drinking Water	Safe, secure and accessible supply of water available for uses other than drinking
	Public Health	Safe and hygienic disposal of wastewater
	Public Safety	Protection of people from water, e.g. during floods or storm events
	Property Protection	Protection of property and infrastructure from water, e.g. during floods or storm events
Relatedness	Comfort	A pleasant micro-climate and landscape for human thermal comfort

	Social Cohesion	Space for social interaction and human connectedness with people and places
	Beauty	Aesthetic urban environments
	Recreation	Space for play, sport and leisure
	Ecological health	Clean and healthy ecosystems with no negative impact on other ecosystems
Growth	Independence	Independence and self-sufficiency for one's water needs
	Control	Influence on decision-making about water infrastructure
	Social justice	Equal opportunity to access the benefits of the urban water system
	Identity	Harmony with culture and tradition, to feel belonging.
	Intergenerational equity	Preserve the ability of future generations to meet their water-related needs

The societal system is composed of different constellations meeting different water-related needs. A constellation is a subsystem representing a specific functioning of the societal system to fulfil a certain need. For example, a drinking water constellation, a flood protection constellation, a constellation around waste water disposal, etc. Each constellation has a share in the functioning of the entire urban water system, and the larger its share, the greater its *power* (de Haan 2010; de Haan and Rotmans 2011). The most powerful constellation, or a closely related group of powerful constellations, is usually called the *regime*. Less powerful constellations are often referred to as *niches*. See Figure 1.

Figure 1. Depiction of an urban water system with constellations



Constellations can be represented with a range of properties, referred to as *facets*. Facets describe the way and extent a certain societal need is met by a constellation. A facet can be an infrastructure (e.g. stormwater treatment technologies) or a more social property like a value (e.g. public health protection). Constellations can, but need not, share a range of facets. Table 2 comprises a list of potential facets for constellations in the urban water system that directly meet the societal needs listed in Table 1.

Table 2. Facets of urban water constellations.

Category	*Facet*	*Category*	*Facet*
Infrastructures	Water network	Institutions	Restrictions
	Sewerage network		Subsidies
	Drainage network		Private business
	Surface water technology		Public service
	Seawater technology		Communal service
	Groundwater technology		Personal use
	Rainwater technology	Values	Wellbeing
	Stormwater technology		Aesthetics
	Greywater technology		Profit
	Blackwater technology		Heritage
	Green infrastructure		Social justice
	Levees		Future wellbeing
	Managed flood plains		Environment
	Floating infrastructure	Legitimacy	Transparency
			Democratic influence
			Community engagement

For example, a societal need for adequate stormwater drainage could be met in part by the constellation ‘Water Sensitive Urban Design’ with a certain facet ‘Wetland’, and in part by the constellation ‘Centralised Drainage’ with another facet. The two constellations together might meet the associated societal need completely, or there may be a need deficit, which would prompt constellations to increase the weight of the corresponding facet, thus increasing the power of the constellation. However, this also depends on the landscape. Just as the physical urban water system is enveloped in a landscape, the societal system is enveloped in a societal *landscape*. From this landscape it experiences external influences, such as demographic shifts, (inter)national economic developments, climatic extremes and the like

Evolution and transition, conditions and patterns

In normal circumstances the urban water system evolves to continue meeting the societal needs. A gradual growth in drinking water demand will normally result in enlarging the capacity of the drinking water infrastructure, reinforcing the power of the drinking water supply constellation. This regular evolution of the constellations is obviously constrained by the landscape since, for example, the placement of the infrastructure will depend on the demographics, or the amount of investment will depend on the economic climate.

Under unusual circumstances, however, a societal system might change more radically; it might go through *transitional* change. Transitional change implies a shift in power relations, for instance by a niche constellation suddenly gaining power or by a regime constellation changing the way it meets societal needs. Compare this to the political equivalent, an election outcome that gives power to a previously small political party, shifting the power relations, or a powerful political party changing its politics. Three patterns of transitional change are distinguished: *Empowerment,* where a constellation gains power on its own; *Reconstellation*, where a constellation gains power by outside influences; and *Adaptation*, where a constellation radically changes its functioning (de Haan 2010; de Haan and Rotmans 2011). These patterns are described in Table 3.

Table 3. Patterns of transitional change with some examples and their effect in the model.

Pattern	*Real-world example*	*Effect in the model*
Empowerment	*– Bottom-up constellation change*	
	Large-scale adoption of rainwater tanks in Australian cities, making the rainwater harvesting constellation more powerful.	An existing constellation acquires new facets, or its facets' values increase.
Reconstellation	*– Top-down constellation change*	
	Design and construction of separated sewerage systems in Australian cities, creating a powerful centralised wastewater constellation.	A new constellation emerges with a selection of facets to meet certain societal needs, possibly subsuming an existing constellation.
Adaptation	*– Internally induced constellation change*	
	Dutch flood protection constellation implementing ecologically sensitive levee systems, *de facto* absorbing the ecological water management niche.	A constellation acquires new facets and discards some, if the new facets correspond with an existing constellation it is absorbed.

The unusual circumstances that trigger transitional change are called *conditions* for transitional change. And they might have their origins in landscape influences, in which case the condition is called *tension*. Another possibility is that a constellation itself is not able to meet societal needs properly, which is referred to as *stress*. A last possibility is that the presence of an alternative way to meet a societal need challenges the way a constellation currently does so, which is called *pressure*. A condition – tension, stress or pressure – can be thought of as driving transitional change, which here means invoking a transition *pattern*. Thus, stress in the current urban drainage constellation might invoke a pattern of reconstellation whereby an alternative, for example decentralised stormwater treatment solutions, becomes more powerful, thus shifting the power balance (de Haan 2010; de Haan and Rotmans 2011). The conditions are tabularised in Table 4Table 1.

Table 4. Conditions for transitional change, examples and manifestations in the model.

Condition	*Real-world example*	*Manifestation in the model*
Tension	*– with the landscape.* Adverse functioning of a constellation in relation to its environment, the landscape.	
	Climate change creating tension for current approaches to flood mitigation.	Landscape factors present for certain facets
Stress	*– within.* Internally adverse functioning.	
	Centralised water supply suffering from stress in that it uses water restrictions for demand control but depends on water consumption for funding.	Not able to meet needs with current facets, regardless of their values.
Pressure	*– from other constellation(s).* Adverse functioning of a constellation with respect to another constellation.	

	The stormwater quality management constellation around biofilters, wetlands and other decentralised technologies putting pressure on the centralised drainage constellation	A constellation having some facets that meet societal needs also met by another constellation through the same, or other, facets.

MODEL OUTLINE

To work with the Workbench, see Figure 2, it needs to be provided with two main inputs:

1. The initial system state, which entails:
    a. What constellations make up the societal system
    b. What facets and their values describe these constellations
    c. What are the societal needs
2. The scenarios that provide the boundary conditions for the evolution of the system, which entails:
    a. How the societal needs develop over time
    b. How the landscape develops over time

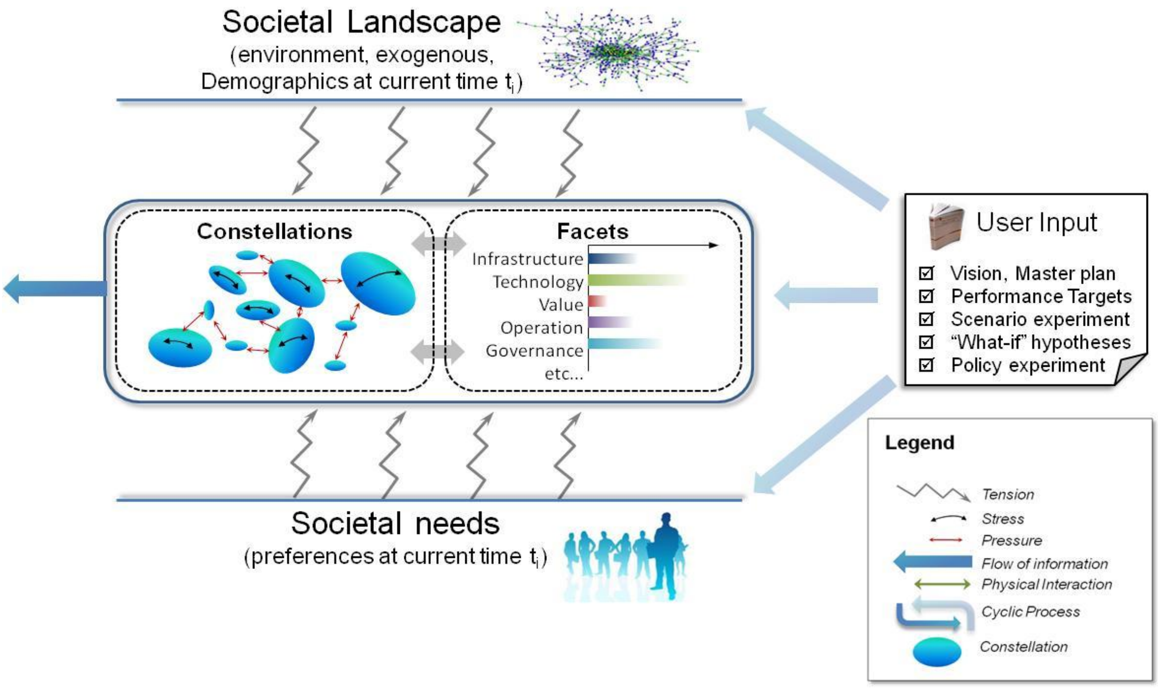
In the Workbench, the names are entered of the constellations that together represent the urban water system under consideration. For each constellation, facets are chosen from the list (see Table 2). They are provided with a weight, measuring to what extent that facet in that constellation meets the associated need. Before dynamics can be considered, the Workbench needs to be provided with two additional matters: the landscape and the societal needs. They can be regarded as a kind of boundary conditions to the model. Like one expects with boundary conditions, both the societal needs and the landscape are to be supplied for the time period to be modelled. In other words the Workbench is supplied with *scenarios* for the societal needs and landscape. These scenarios are provided as a time series and allow users to conduct policy experiments.

Which constellations are necessary to take into account in setting up the Workbench, and which facets they should have, obviously comes with many uncertainties and *will remain disputable*. However, this is fundamental to the modelling approach rather than a weakness because the exploratory nature of the Workbench lies in exploiting uncertainties and uses *several* hypotheses to explore the portfolio of *possible futures*, rather than minimising uncertainties and using the best-tested hypotheses to predict the most probable future. In other words, it is a ‘scenarios in - scenarios out’ model. The transitional dynamics provide straightforward ways to make the model exploratory, since they give rise to a number of parameters that can be explored. These are: (1) the thresholds at which conditions for transitional change are invoked; (2) the patterns that respond to each condition; and (3) which constellations are affected by the patterns.

Dynamics

The Workbench has dynamics on two levels: the normal evolution of the constellations and that of transitional change. Normal evolution leads to changes in the weights of the facets under the influence of (changing) societal needs and possibly constrained by the landscape. Normal evolution tends to make constellations meet societal needs better, but they retain their basic character and no dramatic changes in power are to be expected.

Figure 2. Model outline of the Workbench



However, as mentioned before, when sufficient conditions – tension, stress or pressure – are present, transitional change can occur. Transitional change is considered to be more radical which is reflected in the model dynamics in the following way. When conditions (Table 4) exceed a threshold, a transition pattern is invoked (see Table 3). Such a pattern not only changes the values of a facet in a constellation but it also acquires or discards facets; it changes *qualitatively*. A pattern also has a more abrupt effect, which is what one expects of transitional change.

Note that when a constellation becomes more powerful as a consequence of a transition pattern, and it does not meet a previously unmet societal need, *the gain in power goes at the expense of other constellations* except when it is a *growth* need. Although this power trade-off, what could be called a partial conservation of power, is contestable in many areas of social research, it is in line with transition theorising on power (Avelino and Rotmans 2009; de Haan 2010) and, moreover, appropriate for conceptual and technical reasons.

CONCLUSION AND DISCUSSION

This paper outlined the theoretical frame for understanding transitions in societal systems and the way it is being implemented into a Societal Transitions Workbench. The workbench is intended for planners and policy-makers to assist them in conducting rigorous thought experiments. The workbench has neither the ability nor the intention to predict the future state of any urban water system in any exact or quantitative way. Rather, the workbench uses current state-of-the-art in transition theorising, and the inherent, inevitable uncertainties in a system's potential developments to produce a portfolio of possible futures.

The workbench departs from a qualitative description of the urban water system, namely, in terms of its subsystems, or constellations. Although semi-quantified in terms of facets, the system description is still flexible. This is essential since it is intended that the workbench will be used in a participatory way, with different stakeholders coming to a shared understanding of what 'their' urban water system entails.

The workbench can be verified to a certain extent by using it to reproduce historic development paths. Although this will make the modelling dynamics more plausible, it still gives relatively little grip on future developments of such a system. Validation is this context is dependent on the effectiveness of the process that the Workbench is aimed to support: participatory decision making and strategic planning.

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