

# Model of urban water management towards water sensitive city: a literature review

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**Abstract.** Nowadays, many cities are facing with complex issues such as climate change, social, economic, culture, and environmental problems, especially urban water. In other words, the city has to struggle with the challenge to make sure its sustainability in all aspects. This research focuses on how to ensure the city sustainability and resilience on urban water management. Many research were not only conducted in urban water management, but also in sustainability itself. Moreover, water sustainability shifts from urban water management into water sensitive city. This transition needs comprehensive aspects such as social, institutional dynamics, technical innovation, and local contents. Some literatures about model of urban water management and the transition towards water sensitivity had been reviewed in this study. This study proposed discussion about model of urban water management and the transition towards water sensitive city. Research findings suggest that there are many different models developed in urban water management, but they are not comprehensive yet and only few studies discuss about the transition towards water sensitive and resilience city. The drawbacks of previous research can identify and fulfill the gap of this study. Therefore, the paper contributes a general framework for the urban water management modelling studies.

## 1. Introduction

Water is one of abundant primary natural resources in which has many benefits on it. This natural resource has many impacts for whole aspects in human life. Today, water becomes the main aspect in the world, especially in cities. Moreover, maintaining its sustainability is very complicated and complex. Social, culture, climate change, and other environmental problem has influenced to the water management itself. By considering the water management in cities, instead of national scale, many stakeholders have key role to manage and ensure water supply and demand. These stakeholders are connected to each other. The water management on cities is often considered as Urban Water Management (UWM). The paradigm of urban water management recently concerns on developing infrastructure in response to urban development that shifts to implement more sustainable [1] and comprehensive urban water management [2]. Sustainable urban water management helps socio economic developments without compromising the current and future water supply and needs [3]. Some cities are still struggling with the supply of important services, such as water and sanitation. Meanwhile, others are struggling to cope with many vulnerabilities created by the existing system of water management. Cities throughout the world are facing complex problem related to the effect of climate



change, population growth, and hydrological variability, while ensuring sustainable water resources management and the protection of water environments [4]. Therefore, many countries especially developed and developing countries are trying to find guidance on solving the institutional challenges and the existing infrastructure to support a transition from urban water management into Water Sensitive City (WSC).

The concept of Water Sensitive City has developed as integrated vision of urban water management approach which meets not only the water needs, but also simultaneously give many benefits to increase the livability and resilience of a city [1]. This concept is also related to a new urban water governance paradigm regarding the use of decentralized water systems [5]. Water Sensitive City is based on the holistic point of view to manage the integrated water cycle in order to take care and increase the health of receiving waterways, mitigating flood risk, creating public spaces, as well as creating harvesting, cleaning and recycling water. It uses water management as a means of delivering better outcomes which are more broadly and able to deliver many critical objectives for the city liveability [6]. Eventually, water sensitive approach is developed with paradigms that water can contribute for connected, keen, and liveable communities. These paradigms of water management can be developed to make any decisions for stakeholders who have roles in water management system. It is important to breakdown all the key principles of water management in order to get resilient outcomes in all problems related to water. Modelling is one of approaches that can be a decisive tool to manage water management system considering systemic thinking of all relevant aspects in water management, especially urban water management and water sensitive city. Many research in modelling water management had been conducted. There are still few research that are mapping the literature review of modelling water management, including urban water system. Nevertheless, it is also hardly found research that are mapping the literature review in modelling water sensitive city. Therefore, this research reviews some research mapping not only in urban water system but also in water sensitive city, so that the research gap can be filled for scientific contributions.

## **2. Method proposed and literature review**

Some previous research had been conducted in water management system, including sustainable urban water management (SUWM) towards specifically in water sensitive city (WSC). This paper reviewed some research related to the transition of urban water management towards the water sensitive city. Selection of some research related to water management depends on some criteria. This research was developed into two criteria, such as the concept of water management and classification of modelling approaches of water management, including urban water management and water sensitive city. After gathering data from some previous research, the next step is to conduct literature review. In reviewing literature, the research classifies the previous papers based on the criteria explained before such as the concept and the modelling approach of water management. Hence, from the classification of previous research, it can be found the research gap to be fulfilled. At the end, the discussion and recommendation about further research in water sensitive city specifically are included in this research.

### *2.1. Urban water management*

Based on the information above, some concepts of urban water management, including sustainable urban water management had been widely researched in various aspects. The framework for cities transition through moving towards sustainable urban water conditions by considering ideological and technological contexts as a benchmarking tool and critical reassessment had been developed [1][7]. The complexity and solutions for eco-efficiency assessment of urban water systems are also explained [8]. Moreover, the interaction and understanding among governance were examined for sustainable urban water management [9][10]. In addition to that, some research reviewed the challenges and opportunities of transitioning to decentralized water management [11] and the transition scenarios to leapfrog for a sustainable urban water future [12]. Some research were also conducted in various aspects of urban water management, such as location aspect of urban storm water in tropics [13] and in coastal region [2] or city [14]. The sustainable utilization of urban water resources based on catastrophe theory was

comprehensively assessed [15]. Moreover, some literatures of the adaptation of climate change and water resource management were also been reviewed [16].

Meanwhile, there were many research on modelling urban water management. A model based on system dynamics and agent based model was constructed to integrate modelling platform for simulating changes to socio-economics, technical and natural systems and for examining the effects of variety of water demand strategies on urban water system [17]. Moreover, The Dynamic Urban Water Simulation Model (DUWSiM) incorporated urban water balance concepts with the land use dynamics model MOLAND and the climate model LARS-WG to provide long term planning of urban water supply and demand with the effects of urbanization scenarios and climatic changes in urban water cycle[3]. In addition, dynamic simulation-optimization model was developed to analyze the adaptive management of urban water distribution system contamination threats [18]. The model only focused on drinking water network, not any other water types, such as review of the assessment of water demand modelling and management [19][20]. Furthermore, the agriculture water savings and the strategy for agricultural water management were provided and to be quantified and the optimization model for agricultural water transfer was developed to analyze the economic value of irrigation water [21]. Yet, the model considered was only for agricultural aspects, no other aspects considered. The research of urban water management were developed in other field such suburban area by using Life Cycle Assessment (LCA) methods [22][23]. They developed modelling tool to perform LCA of urban water system environmental insights to stakeholder's issues related to forecasting scenarios influencing the system such as water demand, scarcity, and technologies. However, it did not focus on forecasting scenarios linked to changes in wastewater treatment and associated water quality impacts. LCA were also applied in sustainable urban water resources management to assess the impacts of water utilization under uncertainty [24]. In the other hand, the assessment of water resources and water ecological carrying capacity by using integrated system dynamics model had been reviewed [25] and water management system in a green building had been modeled [26]. Furthermore, potential of hydropower as a co-benefit in balancing urban water portfolio and flood risk management by using system dynamics modelling were conducted. This research only focus on how to dealing with the water infrastructure to its benefit in balanced urban water portfolio and flood mitigation [27].

## 2.2. *Water Sensitive City*

To ensure the sustainability and resilience of city and its water system, it requires comprehensive aspects of technological, planning, economic, cultural and institutional dimensions considered in developing leapfrogging strategies and investment plans. The transition change processes are not easy to conduct. Technical innovation is not enough to be considered. Therefore, it is needed to understand the social and institutional dynamics that have important roles in attempt to move deeply rooted water management systems into new directions water sensitivity and resilience [1]. Monash researchers had conducted research within the EU FP7 PREPARED to develop the prototype of socio-technical model of Urban Water System, DAnCE4Water (Dynamic Adaptation for eNabling City Evolution for Water), which combines a Social Transitions Module [28] and can assess the joint effect of socio-technical factors and transitions to more sustainable urban water infrastructure. This research also included the UrbanBEATS model (Urban Biophysical Environments and Technologies Simulator) which made important breakthroughs on how to manage water infrastructure within a virtually generated urban setting [29]. In addition to that, DanCE4Water developed module of water supply and drainage networks within an evolving city in Australia [30]. Meanwhile, a strategic program was constructed to provide operational guidance for planners, designers, and decision-makers in planning and managing initiatives to facilitate sustainability transitions to Water Sensitive City [31].

In the Water Sensitive City, a hybrid mix of water systems and sources will operate at an interval of scales providing sustainable water services that will protect environmental quality and diversity, generation fairness (equity), and landscape amenity [32]. The implementation of water systems have to be in line with governance arrangements including strategies to enhance believe among stakeholders

and to facilitate knowledge sharing for making decision. The collaboration and leadership are also essential for transitioning to Water Sensitive City [33].

The existing models were based on different objectives or have different methods/approaches. After reviewing literature from some previous research presented in table 1, it can be found that there are still few papers which considering high level planning and decision support tools to analyze the effects and the sustainability urban water management as well as water sensitive city. Moreover, it is hardly found some research in modelling the framework of Water Sensitive City comprehensively.

**Table 1.** Previous research on water management

No	Author	Year	Methodological Properties		Topics			Aspects		
			Analytical Approach	Model Approach	Urban Water Management	Sustainable Urban Water Management	Water Sensitive City	Water Infrastructure	Water Quality	Water Supply and Demand
1	Brown et al [1]	2009	x		x		x	x	x	x
2	Diaz et al. [2]	2016	x		x			x	x	x
3	Willuweit and Oullivan [3]	2013		Simulation		x		x		x
4	Wong and Brown [4]	2009	x				x			
5	Brown et al. [6]	2008	x				x	x	x	x
6	Marlow et al. [7]	2013	x			x		x		
7	Stanchev and Ribarova [8]	2016	x		x			x		x
8	van de Meene et al.	2011	x			x		x		
9	Furlong et al. [10]	2016	x		x			x		
10	Chelleri et al. [11]	2015	x		x					
11	Poustie et al. [12]	2016	x		x					
12	Limand Lu [13]	2016	x			x		x	x	x
13	Li et al. [14]	2016		Non-linear regression model	x				x	
14	Chen et al. [15]	2016		Catastrophe assessment model	x					x
15	Olmstead [16]	2014	x		x					x
16	Baki et al [17]	2012		Simulation (System Dynamics and Agent-based Modelling)	x					x
17	Rasekh and Brumbelow [18]	2015		Dynamic simulation optimization model	x				x	
18	Cominola et al. [19]	2015		Multivariate analysis and behavioral modeling	x					x

**Table 1.** Previous research on water management (Continued)

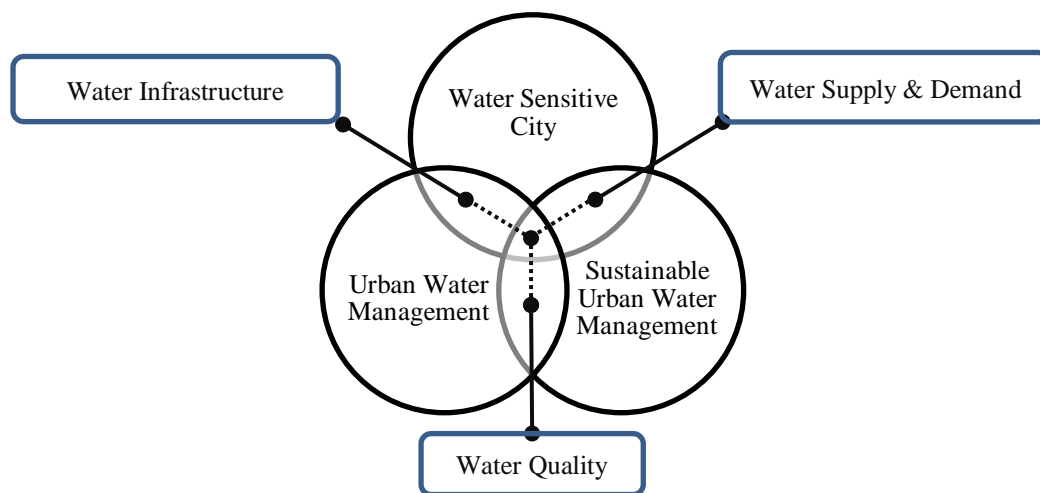
No	Author	Year	Methodological Properties		Topics			Aspects		
			Analytical Approach	Model Approach	Urban Water Management	Sustainable Urban Water Management	Water Sensitive City	Water Infrastructure	Water Quality	Water Supply and Demand
19	Bosmann and Eser [20]	2016	x		x					x
20	Loubet et al [22]	2014	x		x			x		x
21	Loubet et al [23]	2016		Simulation and Life Cycle Assessment	x			x		x
22	Cai et al. [24]	2016		Optimization model and Life Cycle Assessment		x		x		x
23	Wang et al [25]	2014		System Dynamics Cellular Automata-Markov Model	x				x	x
24	Kalantzis et al. [26]	2016		Mental Model	x			x		
25	Sahinet et al. [27]	2016		System Dynamics Model	x			x		
26	de Haan et al [28]	2013		Socio Technical model	x			x		x
27	Bachet et al [29]	2015	x			x		x		x
28	Urich et al [30]	2013		Simulation-Model(DAN CE4Water)	x			x		
29	Ferguson et al [31]	2013	x				x	x		x
30	Dobbie et al [32]	2016	x				x	x		
31	Floyd et al [33]	2014	x				x	x		

### 3. Solution model framework

Based on the previous research review, model framework of water management considering the transition urban water management towards water sensitive city was developed for constructing the conceptual model. The following Figure 1 represents the model framework of researched topic. The following framework is constructed by concluding variables from previous research and classified with the intersection between the concept of water management. Each parts of water framework have its intersection. According to the research so far, water infrastructure was developed within urban water management and water sensitive city. This aspect is considered due to the importance indicator to leapfrog from urban water management towards water sensitive city. Furthermore, water supply and

demand was developed within sustainable urban water management. Many research found were conducted in the related aspect. Meanwhile, many research about water quality were developed within urban water management and sustainable urban water management.

The framework above is the first input data for modelling the urban water management towards water sensitive city. The next step is to construct the conceptual model by using causal loops diagram. Causal loop diagram is designed to model the logic of existing system based on the research framework before proceeding to the simulation model using simulation software. It represents causal relationship and loops between variables in the system. By using causal loop diagram, the expected model can be viewed comprehensively and it is known for simulating system dynamics. In other words, conceptualization of the model begins with first by identifying the variables that interact in the system related to urban water management as well as water sensitive city concept. Causal loops diagram is made to show the main variables that will be described in the model. With the existence of causal loops, it is able to understand the relationship among variables, and how far the influence of variables on system behavior and how the impacts of each variable to the others are.



**Figure 1.** Integrated Research Framework.

#### 4. Conclusions

Based on the data analysis, it can be concluded that there are many complex problems related to water management, including sustainable urban water system and water sensitive city. Besides that, there are few research conducted to identify and solve the problem as an integrated system in the city. All research so far about Water Management is still partial in specific aspect, such as the quality of water as well as water supply and demand separately. Furthermore, few research about water supply and demand in city related to transition in Water Sensitive City are hardly found. Although there was a research that developing integrated model of sustainable urban water system using system dynamics, yet the model did not involve how to leapfrog and to make transition into Water Sensitive City. Moreover, there is no research using modelling approach in the field of Water Sensitive City with comprehensive aspects. The conceptual model had been constructed and aimed to become important inputs for the future simulation model. This conceptual model will become an input in modelling stage to view the logic of the real system and the relationship among variables in urban water management and water sensitive city.

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