

Exploring the concept of sustainable urban water management: Key influencing factors and principles of SUWM in Bandung metropolitan area

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Abstract. Urban water conditions are under pressure due to rapid urbanization, population growth, climate change and economic development. The current urban water management approach is not enough to cope with these changes and pressures. Many literatures have been mentioned the need to shift from the conventional approach into more sustainable way which integrate environmental, social and economic objectives. This article discusses the current conditions of urban water management in Bandung Metropolitan Area (BMA) emphasizing on key influencing factors at policy, organizational and operational level. It also examines the key principles of Sustainable Urban Water Management (SUWM) based on the literature reviews. Data and information gathered from primary sources through questionnaire and in-depth interviews and secondary sources from literature reviews. The outputs are key influential factors of current urban water management and the key principles of SUWM in BMA that can be adopted as guiding framework for future urban water management.

Keywords: *urban water, sustainable urban water management, principles of SUWM, metropolitan area*

1. Introduction

In an increasing urbanized world, urban water conditions are stressed by constant changing contexts and impacting external factors such as rapid urbanization, population growth, climate change, economic development [1], environmental pollution, resource limitations and ageing infrastructure [2]. These stresses threaten water security for human needs, increased water related hazard and lead to deterioration of ecosystem in cities [3]. It is also expected that climate change provided significant consequences for urban water systems. Therefore, the current urban water management approaches and methods are not enough to cope with on-going and future changes and pressures in dealing with the stresses, future changes and uncertainties.

Urban water system consists of a series of activities within water cycles starting from: i) water extraction from its sources (ground water and surface water), ii) water purification into drinking water, iii) distribution of water to users, iv) collecting and storage of wastewater and v) wastewater treatment [4]. As urban population increases, water demand continues to increase. Meanwhile, the ability of the city government to meet the needs is still limited and many obstacles encountered [5].



Many literatures clearly stated that governance failures are the origin of many resource management problems including urban water management [6]. The issues of water scarcity and future uncertainty pushed the governments to rethink urban water management system. The concept of sustainable urban water management (SUWM) has been discussed since 2000 along with the implementation of Local Agenda 21. SUWM is an alternative to the traditional way of urban water management to cope with the challenges facing our urban water systems [7].

The implementation of sustainable urban water management is facing numerous systemic and interrelated socio-institutional barriers. These barriers are among others: institutional fragmentation, poor political leadership, unproductive intergovernmental relations, limited long-term strategic planning, and inadequate community participation [7]. Urban water infrastructure system was heavily developed in large scale and lock-in to the long terms changes, huge investment and rigid to change.

This article aims to explore the concept of sustainable urban water management for Bandung Metropolitan Area (BMA) emphasizing the key influential factors of current urban water management in the perspective of policy process. It also examines key principles of SUWM that can be adopted as guiding framework for future urban water management. We emphasize to analyse the current urban water management in BMA by identifying key factors influencing at policy hierarchy processes consists of policy, organizational and operational level [8]. Policy level is the first level where the ideal condition of urban water management is formulated through legislation and national policies represented by the actors coming from legislative and judiciary bodies. Organizational level is the second level of policy process which formulating institutional arrangements and technical regulations to implement policies and regulations. Operational level is the third level to implement policies and regulations by the operators such as: government agencies, firms and community. This analysis provides a baseline of urban water management condition as basis for future urban water governance. BMA was chosen as case study representing the fast urban growing area in Indonesia with the complex urban governance system.

In the following section we provide a short profile of BMA and method are provided. Section 3 provides result and discussions. The final section outlines the conclusions.

2. Material and method

2.1 A profile of Bandung Metropolitan Area (BMA)

Bandung Metropolitan Area (BMA) or widely known as *Kawasan Perkotaan Cekungan Bandung* is one of national strategic areas as stipulated in National Spatial Plan (RTRWN). BMA has total area of ± 348.261 Ha [9]. Administratively, BMA consist of five administrative cities/districts including: Bandung City (16,767 ha), Cimahi City (3,927 ha), Bandung District (176,812 ha), West Bandung District (130,577 ha) and five sub-districts in Sumedang District (Cimanggung, Tanjungsari, Sukasari, Jatinangor, Rancakalong and Pamulihan) with total area of 20,198 ha [10]. In this study, Sumedang District is not included as case study area. The delineation of BMA follows the functional urban areas, which characterized by the growing urban areas. In term of population, BMA has 8.6 million in 2015 [9]. It is accounted for 2.9% of the Indonesian population.

Physically, BMA or *Kawasan Perkotaan Cekungan Bandung* has an elongated ellipse-shaped basin extending east-northwest direction, ranging from Nagreg area to the east to Padalarang in the west with a horizontal distance of up to 60 km. Meanwhile, the north-south distance has a width of about 40 km [11]. BMA is surrounded by ranks of quarternary volcanoes. The elevated area ranged from ± 650 m to $\pm 2,000$ m above sea level.

The current urban water management in BMA consists of two main systems: piped system and non-piped system. Piped water systems are provided by local water companies in each respective cities/districts among other are: PDAM Tirta Wening in Bandung City, PDAM Kerta Raharja in Bandung District, PT PMGS is West Bandung District and UPT *Air Minum* in Cimahi City. The coverage of water services delivered by those four operators reached 48.2% of total population in BMA. The rests are using non-piped system for water services using individual deep wells, water

hydrants and other source of water. Some challenges on water provision in BMA are related to water shortage due to limited water availability, unequal access to water services and service quality.

2.2 Method

A mixed method research approach was used to analyse key influencing factors and the applicable concept of sustainable urban water management for Bandung Metropolitan Area. A quantitative analysis by using the Structural Equation Model (SEM) was conducted to identify key factors influencing at policy, organizational and operational levels and to understand the relationship among variables both exogenous and endogenous variables. The data set was collected from primary survey mainly from questionnaires, which have been filled by 154 respondents coming from actors/stakeholders at national, province and local. Respondents are represented individuals from various institutions such as: members of parliament, officers from water-related ministries (public works, environment, health, planning authority), provincial parliament, city/district parliament, officers from water-related agencies at province and city/district level (public works, environment, planning, health), non government organizations, practitioners and experts.

A qualitative analysis by using the results from in-depth interviews with key informants was conducted to further elaborate key influencing factors on the current urban water management conditions and to identify the principles of sustainable urban water management for Bandung Metropolitan Area (BMA). Key informants are individuals who are represented as actors/stakeholder in water resource, water supply and wastewater sectors from legislatives, national ministries, provincial agencies, cities/districts agencies, non government organizations, association, water operator, etc. There are 24 key informants who were interviewed to discuss on current water management conditions.

3. Result and discussions

3.1 Model Fit Testing for Measurement and Structural Model

The Structural Equation Model (SEM) is used to measure key factors influencing the current urban water management at policy, organizational and operational levels. The statistic modeling is illustrated in Figure 1.

Based on the output of SEM analysis using LISREL software obtained values that can be used as reference in testing the whole model both structural and measurement model. The model fit testing is carried out in order to evaluate the degree of fit or Goodness of Fit (GOF) between data and the prediction model. The absolute fit measure was used to measure model fit testing by using these following indicators: RMSEA (Root Mean Square Error Approximation), NFI (Normed Fit Index), GFI (Goodness of Fit Index) and AGFI (Adjusted Goodness of Fit Index). The results shown that the five indicators used as parameters in testing model fit meet the requirements. It can be concluded that the model has a good fit and statistical predictive power.

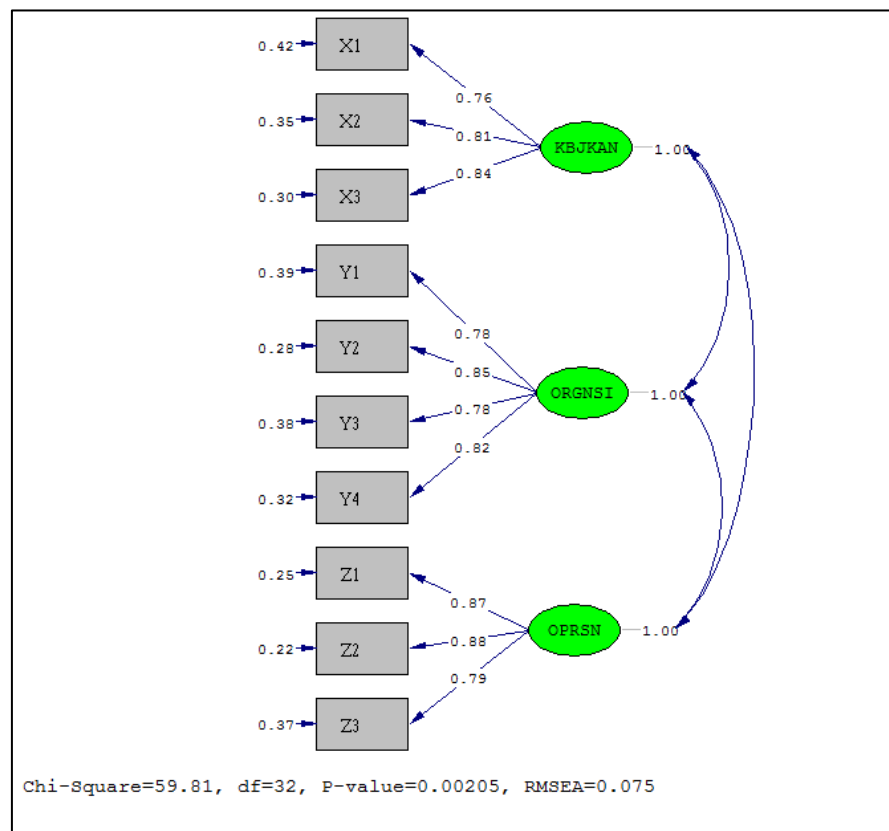


Figure 1. Statistic modeling for key factors influencing urban water management

Table 1. Model Fit Testing Using Goodness of Fit Index

Goodness of Fit Index	Cut off value	Result
Degree of freedom (dof)	Positive	32
P-value	$\geq 0,05$	0,081
RMSEA	$\leq 0,05$	0,075
NFI	$\geq 0,80$	0,97
GFI	$\geq 0,80$	0,91
AGFI	$\geq 0,80$	0,84

Furthermore, the measurement for the construct of each latent variable can be seen in Table 2. All manifest variables have significant validity based on T-Value value greater than T-Table required is 1.96 and loading value for each manifest variable is above 0.5. The correlation coefficients of each manifest variable are as follows: i) the most influential variables at policy level are policy coherence with loading value is 0.4, political commitment (0.81) and long-term vision and objective (0.76); ii) the most influential variables at organizational level are financing with loading value is 0.85, learning (0.82), institutional (0.78) and information (0.78), iii) the most influential variables at operational level are capacity with loading value is 0.88, awareness (0.87) and participation (0.79).

Table 2. Summary of T-Value and Standardized Solution

Latent Variable	Manifest Variable	T-Value	Loading	T-Table
Policy	Long term vision and objective	10.30	0.76	1.96
	Political commitment	13.90	0.81	1.96

Latent Variable	Manifest Variable	T-Value	Loading	T-Table
Organizational	Policy coherence	15.25	0.84	1.96
	Institutional	15.37	0.78	1.96
	Financing	14.89	0.85	1.96
	Information	15.07	0.78	1.96
Operational	Learning	15.72	0.82	1.96
	Awareness	14.80	0.87	1.96
	Capacity	16.81	0.88	1.96
	Participation	13.26	0.79	1.96

After knowing that all paths in the measurement model have met the criteria, the next step is to observe the testing results of structural model consisting of two groups: i) the relationship between exogenous variable and endogenous variable (Gamma), represented by the direct effect between policy with organizational and policy with operational; ii) the relationship between endogenous variables (Beta), represented by the relationship between organizational and operational. Based on the calculation in Table 3, it can be seen that the variable of policy provides significant influence to the variable of organizational and the variable of operational where the T-Value is 20.01 and 7.14. These values are greater than the T-Table, which is 1.96. The correlation coefficient between policy and organizational is 0.87 and the correlation coefficient between policy and operational is 0.58. The relationship between organizational with operational provides significant influence where the T-value is 19.05 greater than T-table which is 1.96. The correlation coefficient between organizational and operational is 0.82.

Table 3. Effects Among Variables

Latent Variable	T-Value	Path Coefficient
Policy with Organizational	20.01	0.87
Organizational with Operational	19.05	0.82
Policy with Operational	7.14	0.58

The above testing results of SEM model are confirming the policy hierarchical process in literature review which starting from policy, organizational and operational level [8]. The relationship started from policy formulation done by legislative at policy level, continues to institutional arrangement by executive at organizational level and implements by operator operational level.

3.2 Qualitative analysis of factors influencing the current urban water conditions

The results of qualitative analysis are shown in Table 4 including quotes from interviewees with regard to key factors, which have been identified by quantitative analysis. The table represents key factors of current urban water management in BMA at policy, organizational and operational level.

Policy level is a critical step in policy process whereas legislative actors at national level formulate the ideal condition of future urban water. Water sector involves many interrelated sectors and affecting each others [12]. Unclear roles and responsibilities of each institution at different levels of government contribute to poor water management. Each agency translates policies based on the interests and their tasks. The effective urban water management could possibly achieve if there is policy coherence between water-related sectors at all levels of government. Policy coherence defines as the systematic promotion of mutually reinforcing policy actions across government departments and agencies creating synergies towards achieving the agreed objectives [12]. With regard to water availability, the interviewees emphasized need for policy coherence across government agencies to regulate and utilize

adequate water sources for variety of water uses. It is also pointed out the importance of policy coordination for integrating all water sector including raw water, water supply and wastewater. Urban water policy should also link with the spatial and land use planning in order to ensure the quality of water resources.

At organizational level, financing is a key factor undermining effective urban water management. The financing issues consist of insufficient local government budget to deliver better water services and lack of investment in urban water infrastructure in cities. Revenues in water sector mainly coming from tariffs (revenues from the water bill) which are still limited to recover the ongoing operation and maintenance cost as well as to cover the costs of services expansion now and in the future. Tariff structures and management models may need adjusting to secure stable revenues in the face of declining water consumption patterns [12]. Most local government has low fiscal capacity [13], which will make difficult for cities/districts to invest more on public services. It is also related to the limited borrowing capacity of local government. The interviewees emphasized one of factors hindering regional water provision in BMA is related to tariffs setting. Furthermore, financing becomes barriers for effective urban water management due to the lack of local budget availability to support local water company (PDAM) in expanding water services and underinvestment in water sector by other parties (private, international agency and community).

At the operational level, key factor influencing the current urban water management is related to the capacity of actors/stakeholders at different levels of government. The capacity issues consist of the technical, managerial and responsiveness of local actors in the implementation of urban water policies. The actors involved at operational level are local water companies (PDAM's), local-own companies, state owned companies such, private companies and community-based water operators. Most cities/districts in BMA are likely to face the lack of capacity to manage urban water properly, especially for the newly established cities/districts such as Cimahi and West Bandung. The interviewees emphasized some challenges with regard to capacity among others are: the understanding of community on the importance of water quality, lack of community knowledge and awareness pushed the bad government to deal with water issue and the awareness of community that using ground water is not sustainable.

Table 4. Summary of the Qualitative Analysis of Key Influencing Factors of current Urban Water Management in BMA

Level	Qualitative Examples
Policy Coherence	<ul style="list-style-type: none"> • "... with regard to water availability, each ministries has their own authorities based on their interest such as MoEF manages water bodies, while MoEMR responsible for ground water, the challenge is how they can regulate and utilize adequate water sources for variety of water uses but not in silo perspective, that is still blank area " (Water Association) • ... there should be a backbone to integrate raw water, water supply and wastewater both in term of policy coordination and at the operational level (MoEF) • ...there should be paradigm change that water provision is not rely on raw water, but it should use grey water (run off) as water source, it need strong policy in urban land use control for hotel and apartment (WJEPA) • ... in fact spatial plan and water resource is is iterative, spatial plan should consider the need for water (KAI)
Financing	<ul style="list-style-type: none"> • ...factor that hindering regional water provision is the lack of regulation to distribute the authorities (only based on memorandum of understanding and cooperation agreement), institutional and tariffs setting (WJWRA) • ... the barrier is on the investment, although water mix is a different with water coverage (MoPWH) • ...the platform of sustainable water are: demand creation, infrastructure development and management, cost recovery, asset management and collaboration (NDPB)

Level	Qualitative Examples
Capacity	<ul style="list-style-type: none"> • ... community understanding on the water quality is important, because access to non piped system is still huge covering 70 per cent (Bandung District Government) • ...lack of community knowledge and awareness pushed the bad government to deal with water issue (NGO) • ...the first thing is demand creation to make community aware that using ground water is not sustainable (NDPB) •community based system in water supply is not yet regulated and there is no secure mechanism for water quality coming from non-piped system (WJEPA) • ...in the future, monitoring water quality accessed by community should be done by the government (MoH)

3.3 Exploring Key Principles of SUWM

Many literatures have been discussed the need to change the current approach of urban water management to be a more sustainable ways which integrates the aspects of environmental, social and economic. Sustainable urban water management has various definitions in accordance to its emphasis and use, for example: Integrated Water Resources Management, Sustainable Water Resource Management and Water Sensitive Urban Design [14].

Integrated Urban Water Management (IUWM) is part of Integrated Water Resource Management (IWRM). Unlike the conventional hydrological management, the IUWM includes urban area as a critical element for the catchment areas and provide opportunities to integrate with non-urban sectors. IUWM is a new approach where water supply, sanitation, storm water and wastewater are managed in integrated manner with land use planning and economic development. Some principles of IUWM among others are: i) encompass alternative water sources, ii) match water quality with water use, iii) integrate water storage, distribution, treatment, recycling and disposal, iv) protect, conserve and exploit water resources at their source, v) account for non urban users, vi) recognize and seek to align formal and informal institutions, vii) recognize relationships among water, land use and energy, viii) pursue efficiency, equity and sustainability, and ix) encourage participation by all stakeholders [15].

The concept of SUWM has been further elaborated by the concept of water sensitive urban design (WSUD). This concept was developed as integrated approach to urban water management and land use planning in some cities in Australia. The main characteristic of WSUD is the integration of drainage and urban storm water components of urban water management. There are some common SUWM principles, which address the integration of the infrastructure and biophysical systems: provision for multiple uses, consideration of local context, incorporation of stakeholders and a long-term approach [7].

Based on the above principles of IUWM and WSUD, we have specified more precisely the applicable principles for sustainable urban water management into the following three principles

1. The long-term policy making and strategic planning of urban water management is taken into account the balance of environmental, social and economic, as well as the integration among sectors, actors and region in order to mitigate future risks and uncertainties;
2. All urban water systems, both natural and built-up are managed holistically and integrated, both in designing and functioning the integration of raw water, water supply and wastewater infrastructures and its management in order to protect public health and the environment;
3. Urban water management system should prioritize broader public interests through inclusive and participatory operations in order to ensure equitable access for all communities.

4. Conclusions

The shift from conventional urban water management system toward more sustainable way of urban water management is urgently needed in order to cope with changes and future uncertainties. As fast growing metropolitan region, BMA is facing serious challenges to cope with rapid urban population

growth, increased water demand, shortage water availability and improved access to water. These challenges are also influencing by the series of activities undertaken in policy process on water sector that involve all sectors, actors and different levels of government. A lot of factors contribute to shape the current urban water management in BMA. Key factors that influencing the current urban water management at policy process namely policy coherence at policy level, financing at organizational level and technical and managerial capacities at operational level. Based on the exploration to the concept of SUWM that already applied in developed countries, this research has identified key principles of SUWM for BMA among others are: long-term policy making and strategic planning, the integrated urban water systems and inclusive and participatory approach. These three principles can be used as guiding framework for the future urban water management in in BMA.

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