Conceptual Model To Measure The Sustainability Of Domestic Raw Water Supply From Mixed Sources

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CONCEPTUAL MODEL TO MEASURE THE SUSTAINABILITY OF DOMESTIC RAW WATER SUPPLY FROM MIXED SOURCES

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ABSTRACT: The domestic water mix is basically the use of renewable sources of raw water such as rain water and recycled gray water to be mixed with existing raw water sources, such as surface water, springs, and ground water, which are in critical condition. To find out the level of sustainability of raw water supply for drinking water using the Domestic Water Mix approach it is necessary to formulate a conceptual model to measure it. The main objective of the research is to formulate a conceptual model to measure the sustainability of raw water supply using the Domestic Water Mix approach. This research is exploratory in nature, more in the form of literature review relating to drinking water raw water, governance, and the process of its utilization and supporters. The result of this study shows that the conceptual model to measure the sustainability of water supply raw water using the Domestic Water Mix approach consists of 5 stages of measurement, namely: (1) problem identification; (2) assign key attributes; (3) WTP analysis; (4) formulating a model with a systems approach; and (5) mechanism of institutional cooperation. The method used in each stage is adjusted to the objectives of each stage, namely: (1) Multidimensional Scaling (MDS) & Monte Carlo; (2) Analytic Network Process (ANP); (3) Willingness To Pay (WTP); (4) Dynamic System; (5) Interpretative Structural Modeling (IMP).

Keywords: Domestic Raw Water, Mixed sources, Model, Sustainability

1. INTRODUCTION

The need for drinking water increases with the increase in population and development activities due to the development of a region's economy. As a basic need, water is part of the requirements for adequate living standards for the health and well-being of all humans so that water is positioned as a guarantee of the continuity of human life on earth.

Disruption to raw water supply is also caused by symptoms of river flow discharge extremities, namely the maximum discharges get higher and cause flooding in the rainy season, while the minimum discharges decrease in the dry season and cause drought. This condition is due to rain falling on the ground surface subject to the law of conservation of mass. Therefore, changes in land cover can cause changes in the rain fraction (fractions that seep into the ground/ infiltration and fractions that flow above the ground surface/ runoff). These changes can cause extreme flow rate. These extremes put pressure on water availability and threaten the sustainability of water resource infrastructure, such as reservoirs and drinking water supply systems [1-7].

The domestic water demand management approach especially for drinking water supply with the Domestic Water Mix concept has not been implemented optimally either at the local, regional or national level. The domestic water mix is basically the use of renewable sources of raw water such as rain water and recycled gray water to be mixed with existing raw water sources, such as surface water, springs, and ground water, which are in critical condition. To find out the level of sustainability of raw water supply for drinking water using the domestic mixed water approach, it is necessary to formulate a conceptual model to measure it. The main objective of the research is to formulate a conceptual model to measure the sustainability of raw water supply using the domestic mixed water approach.

2. RESEARCH METHODOLOGY

This research is exploratory in nature, more in the form of literature review relating to drinking water raw water, governance, and the process of its utilization and supporters.

Some important points to study are:

- Literature Review
- Regulations in force in Indonesia concerning water resources management
- Policies, programs and activities that apply in Indonesia

- Alternative ranking methods to support decision making

3. BASIC LITERATURE AND DISCUSSION

3.1 Integrated Water Resources Management Approach

The principle of Integrated Water Resources Management (IWRM) is defined as a process that emphasizes the coordination of the development and management of water resources, land and other related resources, to increase income and welfare evenly without compromising ecosystem sustainability [8].

The integration of human systems includes people's perceptions and understanding of water resources, inter-sector integration in national development policies, the influence of water resources development on the macroeconomic system, integration in policy making, integration of all stakeholders in planning and decision making, integration in management raw water and waste water, and integration of water management for various needs [9].

The Global Water Partnership offers an attractive integration concept for integrated water resources management. According to GWP (2000) in Kodoatie & Sjarief (2008) important elements in integrated water resources management can be grouped into 3 main elements, i.e: [10]:

1) The enabling environment is a general framework of national policies, legislation, regulations, finance for the management of natural resources by stakeholders, their function is to arrange and make policies, regulations and finances, so that they can be referred to as rules of the games.
2) Institutional roles are functions of various levels of administration and stakeholders, their roles define actors.
3) Management instruments are operational instruments for effective regulation, monitoring and law enforcement that enable decision makers to make informative choices among alternative actions.

3.2 Urban Water Management Approaches

The concept of a water management approach for urban areas is part of integrated water resources management. This approach has developed into several concept approaches, including the Integrated Urban Water Management approach, Water Sensitive Urban Design, Water Sensitive City, Water Metabolism City and Water Smart City.

According to World Bank, the Integrated Urban Water Management is a flexible, participatory, and repeatable process that combines elements of the urban water cycle (water supply, sanitation, rainwater management, and waste management) with city development and watershed management to maximize economic, social and environmental benefits in a fair way. Water Sensitive Urban Design is one part of the concept of a green infrastructure approach. In this concept, the integration between the management of water cycle sustainability and urban design is carried out by adopting water-sensitive urban design techniques [11].

Water Sensitive City is a concept that considers a city as a water reservoir. All water is collected both rainwater and wastewater, i.e. domestic and non-domestic waste, and industrial waste [12]. Considering that Water Sensitive City is a concept, and then to implement it requires another method, Water Metabolism City.

City Water Metabolism is a model in the management of a region's water. Regional water metabolic systems can be urban or rural play an important role in sustainable development, because they are directly related to basic human needs, such as access to drinking water, sanitation, water quality and health [12].

Water Smart City is a method in which water sources are maintained to be sustainable so that future generations of urban communities can have access to manage water in urban areas with supporting infrastructure so that they can survive and function despite pressures from more extreme climates [13]

Related to national water security, the Government of Indonesia issued a national policy that is in line with the concept of the urban water management approach above, i.e the Domestic Mixed Water approach. This approach is a holistic approach in meeting domestic water needs through the utilization of all water sources, natural and non-natural such as recycled water from domestic wastewater, optimally by integrating drinking water supply systems, wastewater management, and rainwater management in the urban region in such a way that natural water sources are maintained in a sustainable way [14-15]. This approach will contribute to water security which is important for food and energy security.

3.3 Domestic Water Mix Conceptual Model

The forms of water cycle sustainability management are management of drinking water, water flow caused by rain, water quality, wastewater management and water cycle (water conservation) [11].

The urban hydrological cycle consists of a drinking water supply-management wastewater system, and a hydraulic system, which forms the

overall urban water system. Because in the developed regions of Indonesia the interactions between the two systems occur at more points, the water cycle in the developed regions in Indonesia which will be described below is slightly different [16].

Sudrajat (2015) explained that the hydrological system includes natural and non-natural processes. Natural processes are part of the hydrological cycle on land such as surface runoff and soil and surface and soil storage. Non-natural processes include processes resulting from human activities such as infiltration and ex-filtration due to leakage of water supply systems and wastewater management, wastewater disposal through percolation to groundwater, addition of rainwater runoff due to changes in land use and land cover, ground water supplementation, surface and ground water uptake, and waste water disposal to surface water bodies. The source of water for the hydrological system comes from rain and the water supply and waste water management system [14].

Domestic wastewater from housing in Indonesia is mainly not disposed of through the piping system. Therefore, water recycling can be done for used water that has entered the receiving water body. Wastewater of industrial activity is also can be utilized after being discharged into the river [17].

The water supply-management system of wastewater includes components that supply water to the built area and manage wastewater from the area. The water source for the system is water imported from outside the built area to meet the water needs in the area through the piping system and which are local in nature such as springs, wells, rivers and rainwater. Domestic wastewater can be reused for domestic purposes after going through the necessary treatment. The importation of water into the built-up areas in the coast and islands can also include water produced from seawater treatment [14].

3.4 Environmental Sustainability

The term sustainable development first appeared in 1980 in the World Conservation Strategy of the International Union for the Conservation of Nature (IUCN), then in 1981 it was used by Lester R. Brown in the book Building a Sustainable Society. According to the Brundtland Report from the United Nations in 1987, sustainable development is a development process that is based on the principle of "meeting current needs without compromising the needs of future generations".

Sustainable development is a form of policy that is quite complex. This is due in the process of sustainable development trying to combine the economic and environmental sides. The paradigm of sustainable development must be understood as the political ethics of development, which is a moral commitment on how development should be organized and implemented to achieve goals [18].

In the process of sustainable development there are three important aspects in it. These three aspects are related to form a balance between human needs and natural needs. These three aspects are economic, social and environmental.

Economic sustainability can be understood as a form of preservation of existing natural resources. This aspect must also be understood as meeting the vital needs of humans, not a kind of trade competition that ends in a materialistic and hedonistic form.

Social sustainability is a form of simplicity of development that is rich in the meaning of life. In social sustainability here is very influential on the sustainability of life. It aims to achieve social equality, social services in the fields of health, education, politics and others.

Environmental sustainability is a control tool in a sustainable development. The government tries to provide stability for the use of natural resources and the actual function of nature. In this concept there must also be respect for biodiversity (biodiversity), see the value in nature (intrinsic value), and still see that humans are part of nature.

The concept of sustainable development has a close relationship with ethical and political issues. This is because there is a conflict of interest between humans and nature. Humans want to be able to survive by using existing natural resources, while nature also wants to stay alive as a valuable entity in itself. In politics there is a decision taken by the government as a form of concern for the environment. This decision must refer to principles that keep in mind both aspects, both natural and human.

In terms of environmental ethics, sustainable development is more in line with views or deep ecology and not anthropocentrism views. The view of environmental ethics, eco-centrism, is made the basis for making a policy by the government. As for some eco-centrism views that are used as the basis of policies made by the government are:

1) Respect for nature (respect for nature).
2) The principle of moral responsibility for nature.
3) The principle of no harm.
4) The principle of democracy.
5) The principle of life is simple and in harmony with nature.
6) The principle of justice.
7) The principle of moral integrity.

Development orientation no longer emphasizes aspects of economic growth (economic growth) but rather ecological sustainability. This is what

distinguishes patterns of development based on economic aspects from development that promotes ecological unity as a form of development.

The problem is, can anthropocentric socioeconomic views and eco-centric ecological views be combined. That is, sustainable development not only emphasizes improving human quality, but also the quality of the environment and the preservation of the supply of natural resources as a life support system and a driver for improving welfare.

4. ANALYSIS OF MIXED WATER SOURCES DETERMINATION METHODS

4.1 Framework of Thinking

The targets strategy in relation to water resources management is contained in Presidential Decree No. 2 of 2015 concerning the 2015-2019 National Middle Term Plan, namely by the application of raw water management for drinking water which is called the Domestic Mixed Water approach.

The domestic mixed sources of raw approach is a new paradigm of integrated water resource management, specifically for the supply of raw water for drinking water, and is part of the operation of a drinking water supply system that supports sustainable development. However, the application of this approach has not been tested in the field, so that it has the potential to cause problems when implemented. Therefore, a conceptual model is needed to measure the sustainability of this approach as an integrated raw water source for the implementation of a sustainable drinking water supply system from various aspects. The conceptual model of sustainability measurement will be the basis for developing a policy model for implementing domestic mixed water so that it can become an operational foundation in integrated urban water resource management in supporting sustainable drinking water supply.

4.2 Analysis and Discussion

Based on the above framework, a hypothesis can be formulated as follows:

- Raw water sources for drinking water are increasingly limited so more efficient management of raw water needs is needed.
- The management of raw water needs using the domestic mixed water approach is a new paradigm that can be an alternative in conserving raw water.
- There are potencies of unused water sources to overcome the scarcity of raw water problems.

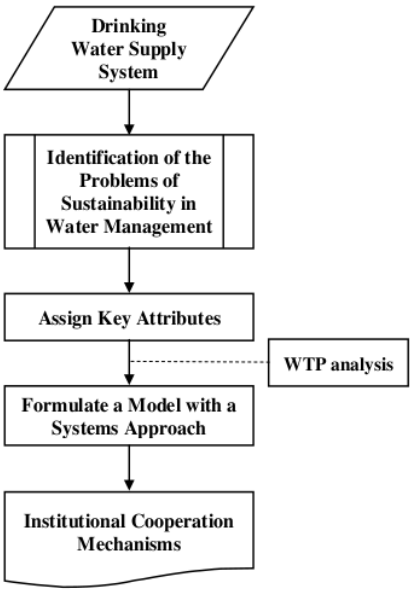

Fig. 1 Framework for drinking water raw water management model with Domestic Water Mix approach

Management performance in the implementation of the management of raw water sources using the domestic mixed water approach is a key factor used as a benchmark for the success of the management of raw water sources for sustainable water supply system. Fig 1 shows the framework for raw water management model with domestic mixed water approach.

5. DESIGN A CONCEPTUAL MODEL TO MEASURE THE SUSTAINABILITY OF THE DOMESTIC WATER MIX

The study was conducted with a system approach in order to formulate a conceptual model of drinking water management based on domestic water mix and institutional cooperation mechanisms related institutions in managing raw water sources of drinking water, so that the sustainability of drinking water raw water is maintained. Systematically the research approach can be seen in Table 1.

Table 1. Systems approach to drinking water raw water management model based on domestic water mix

No	Specific Purposes	Data Type	Data Form	Data Source	Analysis Method	Expected Output
1.	Determine critical attributes	Primary	Interview results and dissemination questionnaire	• Related Service / Agency. • Expert opinion	• *Multi-dimensional Scaling (MDS)* • *Monte Carlo*	Generate critical attributes from 5 aspects of the sustainability dimension
		Secondary	Research results and related reports from various sources			
2.	Determine the key attributes	Primary Secondary	Interview results and dissemination Questionnaire	Expert opinion	• *Analytical Network Process* (ANP) • *Software Super Decision*	Generate key attributes that represent 5 aspects of the sustainability dimension
3.	Model of management of raw water sources for drinking water based on domestic water mix	Secondary	Literature search results from the results of studies, Law and Regulation related to drinking water supply systems		Dynamic system with PowerSim or Stella software	Formulated a model raw water management based on domestic water mix
4.	Institutional cooperation mechanism	Primary	Interview results and dissemination Questionnaire	Expert opinion	*Interpretive Structural Modeling* (ISM)	The stakeholder structure model for managing domestic water mixes as a source of drinking water is formulated

5.1 Measurement Method in the Conceptual Model

Measurement of sustainability can be conducted by using data and information. The collection of data and information from various sources is done by using the following methods:

a) Literature Study and Secondary Data Collection
b) Collection of primary data
c) Sampling Techniques

Willingness to pay consumers for drinking water tariffs based on domestic water mix based raw water will be illustrated from the answers of respondents who were randomly selected for discussion and filled out the WTP questionnaire. This approach is intended so that the water supply company can play a role in maintaining the sustainability of raw water. Public appreciation for the willingness to pay for drinking water tariffs in order to help maintain the sustainability of raw water sources will be used as input during the formulation of the model. Respondents for ISM analysis are experts dealing with the management of raw water sources for drinking water based on domestic mixed water. The basis for consideration in determining experts to serve as respondents using the following criteria:

- The existence of respondents and willingness to be respondents.
- Has a reputation, position or position and has shown its credibility as an expert in the field under study.
- Have experience in the field.

5.2 Determination of Critical Attributes

Analysis of the sustainability of raw water management based on domestic mixed water includes five main aspects, namely: (1) environmental aspects, (2) economic aspects, and (3) social aspects, (4) infrastructure and technology aspects, and (5) aspects legal and institutional.

In the next stage, a sensitivity analysis is carried out to see what attributes are most sensitive contributing to the sustainability index of domestic mixed water management as a source of raw water for drinking water. The effect of each attribute is seen in the form of a change in "root mean square" (RMS) ordination [19]. The greater the value of RMS changes due to the loss of a particular

attribute, the greater the role of these attributes in the formation of the index value of the sustainability of domestic mixed water management as a source of raw water for drinking water on a sustainability scale.

To evaluate the effect of random errors in the process of estimating the ordination value of domestic mixed water management as a source of drinking water raw sources, Monte Carlo analysis can be used. Monte Carlo analysis is also useful for studying the several aspects [20].

As feedback and follow-up from the study of managing the domestic mixed water, it is followed by the formulation of a development strategy to prepare strategic actions and see whether changes are needed in the future and alternative strategic scenarios based on existing conditions, using analysis ANP. Comparisons are made based on the judgment of the decision maker by assessing the level of importance of an element. Using AHP, the relative importance value is determined by a scale of Saaty 1 to 9 which will be shown in Table 2 [21,22].

Table 2. Definition of Rating Scale and Numerical Scale [21,22]

Score	Definition	Description
1	Equally important	Both elements are equally important
3	A little more important	One element is slightly more important than the other elements
5	More important	One element is more important than the others
7	Very more important	One element is clearly more absolutely important than the other elements
9	Absolute more important	One absolute important element
2,4,6,8	Adjacent considerations	Values between two values are close together
The opposite	If for activity *i* gets one number when compared to activity *j*, then *j* has the opposite value when compared to activity *i*.	For one value of the comparison of element *a* with element *b*, then element *b* has a value that is the opposite of the value of element *a* when compared with element *a*

In general the steps that must be taken in using ANP are as follows [23]:

1. Defining the problem
2. Determine the weighting of components
3. Create a pair wise comparison matrix
4. Determine the priority weight or eigenvector
5. Check consistency ratio
6. Formulate Supermatrix

6. SYSTEM APPROACH AND MODELING

The components in a system are theoretically interconnected and have interdependencies between components. The system must be seen as a whole (holistic) and will be as a goal chaser so that there is a balance to achieve goals. A system has an intake (input) that will proceed to produce output. In a system there is feedback that functions as a regulator of system components that interact with each other to achieve goals, and larger systems can consist of several small systems (sub-systems) that will form a hierarchy. Thus, the system can function as one approach to solve a complex problem or formulate policies and strategies to achieve a certain goal [24].

The system approach is defined as a method of solving problems that begins with a tentative way of defining or formulating goals and the result is an operating system that can effectively be used to solve problems. These problems can be in the form of conflict of interest or limited resources [25].

According to Aminullah (2003), there are several stages that need to be done in a systems approach to solving complex problems, namely: (1) needs analysis, which aims to identify the needs of all stakeholders in the system; (2) problem formulation, which is a combination of all the problems that exist in the system; (3) system identification, aims to determine the system variables in order to meet the needs of all stakeholders in the system; (4) abstract modeling, which includes an interactive process between system analysts and decision makers, which uses the model to explore the impact of various alternatives and decision variables on various system criteria; (5) implementation, the main objective is to provide the physical form of the desired system; and (6) operation, at this stage the system is validated and often at this stage additional modifications occur because of the rapid changes in the environment in which the system is functioning [26].

The model is an abstract depiction of a real world system, which will act like the real world for certain aspects [27]. The models are grouped into three types namely quantitative, qualitative, and *econic* models [25]. A good model will provide a description of real world behavior according to the problem and will minimize the insignificant behavior of the system being modeled.

The first step in developing a dynamic system

model is to determine the structure of the model. The structure of the model will give shape to the system and at the same time give characteristics that influence the behavior of the system. All model behaviors, however complex, can be simplified into a basic structure, i.e. the mechanism of intake, process, output, and feedback. According to Muhammadi, et al. (2001) the mechanism will work according to time changes or are dynamic in nature which can be observed in the form of performance (level) of a dynamic system model [28].

7. CONCEPTUAL MODEL

The whole conceptual method to measure the sustainability of the system of mixed water resources for drinking water purposes is shown in Figure 2. The model is developed based on the thorough analysis of important aspects considering each model stage.

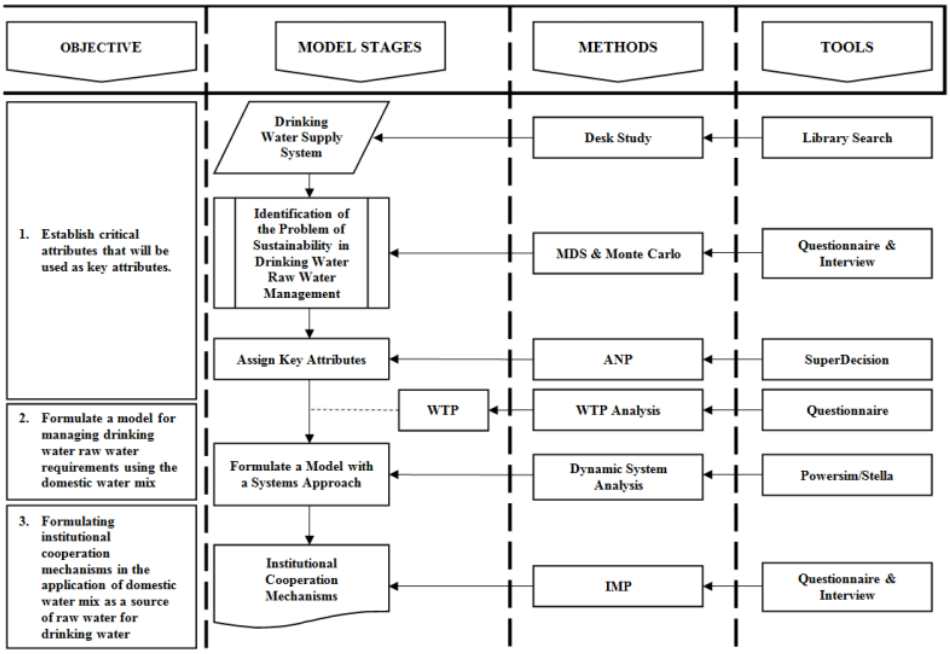

Fig. 2 Proposed diagram of conceptual method to measure the sustainability of domestic raw water suppy from mixed sources.

Measurement of the sustainability is conducted in the system approach formulation which is supported by completed attributes. This proposed conceptual model can be utilized each step to finally formulate the institutional cooperation mechanisms to be applied in providing drinking water from the mixed raw water resources.

8. CONCLUSION

Conceptual model to measure the sustainability of water supply raw water using the domestic mixed water approach consists of 5 stages of measurement, i.e: (1) problem identification; (2) assign key attributes; (3) WTP analysis; (4) formulating a model with a systems approach; and (5) mechanism of institutional cooperation.

The method used in each stage is adjusted to the objectives of each stage, i.e: (1) Multidimensional Scaling (MDS) & Monte Carlo; (2) Analytic Network Process (ANP); (3) Willingness to Pay (WTP); (4) Dynamic System; (5) Interpretative Structural Modeling (IMP).

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