Analysis of the sustainability of water supply in Balikpapan City using multi-dimensional scaling

M M Harfadli\(^1\) and M Ulimaz\(^2\)

\(^1\) Environment Engineering Department, Institut Teknologi Kalimantan, Balikpapan, East Kalimantan, Indonesia
\(^2\) Urban dan Regional Planning Department, Institut Teknologi Kalimantan, Balikpapan, East Kalimantan, Indonesia

Email: maarijharfadli@lecturer.itk.ac.id

Abstract. One of the issues of environmental priority in Balikpapan City is the limited availability of raw water. Based on the problem, it is necessary to carry out a sustainability analysis to determine the status sustainability of clean water supply for Balikpapan city. The purpose of this research is to analyze the sustainability of clean water supply in Balikpapan City based on environmental, economic, social, infrastructure and technology dimensions, legal and institutional dimensions. The research location was in The Balikpapan City with a research time of six months. This research uses primary data and secondary data obtained through literature studies, stakeholder interviews, and field surveys. The technique of determining respondents used a propulsive sampling technique. Sustainability analysis using the Rapid Appraisal of the Status (RAP) technique that consists of Multi-Dimensional Scaling (MDS) analysis, Monte Carlo analysis, and Leverage analysis. The results showed that the provision of clean water in the city of Balikpapan is relatively sustainable in environmental dimensions (51.48), economic dimensions (63.49), infrastructure and technology dimensions (50.57), and legal and institutional dimensions (56.14). but relatively unsustainable on the social dimension (47.69). Besides that, it is known five attributes that are most sensitive or influence the sustainability of water supply in Balikpapan city. They are water conservation areas, availability of paying for water usage, community participation in reforestation programs, water treatment plant conditions, cooperation between stakeholders

1. Introduction

Clean water is water that can be used properly every day by humans, free from the dangers of disease, and not endangering life. The availability and fulfillment of water for residents is part of the community's rights as stipulated in statutory regulations. Clean water is the essence of life. The need for clean water for human life as well as need oxygen.

The need for clean water continues to increase in direct proportion to the population growth rate in a City. The Balikpapan City is no exception, which has a population growth rate of around 1.4% per year. However, cannot be matched by the availability of raw water which is limited in quantity in Balikpapan city. This problem is stated in the 2016 Regional Environmental Management Performance Information Document for the Balikpapan city, that the issue of environmental priorities for Balikpapan city is one of the limited availability of raw water.

Therefore, the availability of water resources in Balikpapan City need to be managed in a sustainable way. The concept of sustainability is a concept that optimizes the benefits of natural and human resources by harmonizing social, economic and environmental goals. In this study, the
approach used to determine the sustainability of clean water supply in Balikpapan city uses five dimensions. This is by considering various aspects that affect the process of providing clean water in Balikpapan city. The five dimensions used are the environmental dimension, the economic dimension, the social dimension, the infrastructure and technology dimension as well as the legal and institutional dimensions [1,2].

There are several studies that have been conducted regarding the sustainability status of both water supply and other natural resources. The Multi Dimensional Scaling (MDS) method has been used to assess the sustainability status by previous researchers. The MDS method used to see the status of the sustainability of raw water supply in the Ciliman watershed. The results of his research show that social dimension and institutional legal are less sustainable with index values of 46.76% and 46.13%, respectively [3].

The MDS method also use to find the sustainability of water management across regions in Jakarta. The results of his research explained that of the four dimensions used only the ecological dimension with a score of 48.75%. The most influential or sensitive attributes are drought, flood and green open space [1]. The sustainability of the development of Baubau City using the MDS method. The results showed that the City of Baubau was relatively sustainable in the technological infrastructure dimension and the legal institutional dimension, but it was relatively unsustainable in the ecological dimension and the economic dimension and not sustainable in the social dimension [4].

Furthermore, research conducted by Azmanajaya regarding the factors that affect the sustainability of clean water supply in Tarakan City shows that there are 13 attributes that are sensitive to the sustainability of water supply. Three attributes of the economic dimension. Two attributes of the social dimension. Three attributes of the infrastructure and technology dimensions. Two attributes to the legal and institutional dimensions [5].

Although there have been many studies on the status of water supply sustainability. However, the study of the sustainability status of water supply in Balikpapan City has not been published so far, so the data obtained as information is very lacking. Therefore it is necessary to have a study related to this problem. The purpose of this study are determine the status of the sustainability of clean water supply in Balikpapan city and to analyze sensitive influencing factors. The conclusions from this study are expected to be used in the formulation of strategies to improve the sustainability of clean water in Balikpapan city.

2. Method

2.1 Location and Times of Research
In this study, the research location was in The Balikpapan City with a research time of six months. The research method used is direct observation or measurement in the field and interviews using a questionnaire.

2.2 Population and Sampling
The technique of determining respondents used a propusive sampling technique, in which respondents were selected from government stakeholders and selected experts. The selection of experts is done deliberately who meet criteria such as the field of work related to clean water, understanding of the provision of clean water, etc. In this study, 14 respondents who fit the criteria were found.

2.3 Data Collection
Meanwhile, the primary data collection technique in this study is observation. Based on the involvement of the researcher, the observation is in the form of non-participant observation, where the researcher is not involved and only acts as an independent observer. Based on the process, the observation carried out is structured observation, where the observations are carried out systematically and the researcher already knows what aspects are relevant to the problem and the research objectives. The interviews conducted in this study were free-guided interviews.
Secondary data collection method is a method of collecting data and information from a number of agencies and related literature. Secondary data collection consists of an agency survey which is carried out to collect secondary data. In this study, the survey was conducted on an institutional basis which has relevance to the discussion.

2.4 Data Analysis
In this study, the analysis method for the sustainability of clean water supply uses the Rapid Appraisal of the Status (RAP-Balikpapan) analysis consisting of Multi-Dimensional Scaling (MDS) analysis, Monte Carlo analysis and Leverage analysis. Determination of the sustainability index on the five dimensions of sustainability, namely the dimensions of the environment, economy, social, infrastructure and technology, as well as legal and institutions with the attributes and scores of expert opinion scores.

3. Results and Discussion
The study of water supply in Balikpapan city was based on the sustainability dimensional index from the dimensions of sustainability such as environmental, economic, social, infrastructure and technology dimensions, as well as legal and institutions. The attributes of sustainability dimensional will be scored by an expert.

The results of scoring will be analyzed using the RAP-Balikpapan and obtained an environmental dimension index of 51.48% with a relatively sustainable status, an index of economic dimensions of 63.49% with relatively sustainable, the social dimension index was 47.69% with a relatively unsustainable status, the infrastructure and technology dimension index was 50.57% with a relatively sustainable status, and the legal and institutional dimension index was 56.14% with a relatively sustainable status. The dimensional value index for the sustainability of the RAP- Balikpapan analysis is presented in Figure 1.

![Figure 1. Kite diagram of relationship between dimension](image)

The kite diagram shows the results of the inter-dimensional sustainability analysis. The system sustainability scale has an interval of 0-100%. If the index value is more than 50%, then the dimension can be categorized as sustainable and if the index is <50%, the dimension is categorized as relatively unsustainable or less continuous. This index must be continuously increased until the desired sustainable conditions. Therefore, improvements should be made to the most sensitive attributes in each dimension. Attributes that are considered sensitive are based on regional conditions.

3.1. Environmental Dimension Status
The results of analysis using RAP-Balikpapan on 7 attributes obtained a sustainability index value for the environmental dimension of 51.48 which means relatively sustainable (the index is between the values of 50.01 - 75.00) (Figure 2). This sustainability index value shows that environmental conditions are sufficient to support the continuity of water supply in Balikpapan City.
Based on the leverage analysis on environmental attributes (Figure 3), it was found 3 (three) attributes that were considered the most sensitive to the level of sustainability from the environmental dimension, namely water conservation areas (RMS = 1.97), drought frequency (RMS = 1.02), development of raw water sources (RMS = 0.95). Any change in the leverage attribute will quickly affect the sustainability index value in the environmental dimension. This means that to increase the sustainability value of the environmental dimension there must be specific policies, plans, and strategies to be able to provide water conservation areas, overcome dryness problems, and develop raw water sources.

![Figure 2. Index and sustainability status of environmental dimension](image)

![Figure 3. The effect of each environmental attributes](image)

The water conservation area is the most sensitive factor for the environmental dimension. Nearly 70% of Balikpapan residents only rely on the rainfed Manggar Reservoir. There are three water conservation areas managed by the Kalimantan Ecoregion Development Control Center. The location is in the Manggar Reservoir area, Telaga Sari Village and Sungai Nangka Village. The water conservation area can be planned and developed by individuals or community groups.
Water conservation activities can be carried out by rehabilitating forests and land, making civilian buildings that function to control flooding and drought [6]. One of the strategies in water conservation is making rainwater harvesting systems in residential areas. Rainwater harvesting provides substantial rainwater use, but this volume is relatively small compared to total household water use [7].

There are several methods and techniques that can help accelerate the implementation of water conservation. Firstly increasing water rate, this method has the fastest results in supporting water conservation as it encourages users to save water. The second is the existence of a carbon tax to reduce the carbon footprint of the water and sanitation sector which produces greenhouse gas emissions. The third is modification of equipment such as the piping system. This modification can save water consumption by about 10%. Fourth, by increasing public awareness and education regarding water saving. Fifth, by reusing treated wastewater. This method is one of the water conservation measures for water-deficient cities and as a way to restore the quantity and quality of groundwater [8].

3.2. Economic Dimension Status

The results of the analysis using the Rap-Balikpapan for the 7 attributes, the index value is obtained sustainability for the economic dimension is 63.49 means relatively sustainable (the index is located at between the values 50.01 - 75.00) (Figure 4). Based on analysis leverage on economic attributes obtained 3 (three) attributes that are judged sensitive to the level Sustainability from the economic dimension, namely Availability of paying for water usage (RMS = 6.53), Water rates (RMS = 5.79), operational and maintenance costs (RMS = 4.49).
Figure 5. The effect of each economic attributes

Based on figure 5, the ability to pay for water, water rates and operation and maintenance are the most sensitive factors affecting the sustainability of water supply in Balikpapan city. These factors are related to one another. The low ability of the community to pay for water is an obstacle to the sustainability of the water supply system. Sustainability can be guaranteed with good management and supported by community participation, both in the form of smooth payment for water use and direct involvement in every stage of clean water service activities.

The amount of water rate is a collective agreement between clean water service providers and clean water service users, while the role of the government is in carrying out its function as a regulator in the field of water resources. Drinking water rate require consideration that is oriented towards the ability of customers to buy water and the sustainability of the company. It is necessary to evaluate the affordability of the purchasing ability from drinking water customers in paying which includes analysis of willingness to pay and analysis of the ability to pay for the prevailing water rate.

3.3. Social Dimension Status

The results of the analysis using the Rap-Balikpapan for the 7 attributes, the index value is obtained sustainability for the social dimension is 47.69 means relatively unsustainable (the index is located at between the values 25.01 - 50.00) (Figure 6). There are several things that cause the value of the social dimension sustainability index to be not continuous. Based on the leverage analysis on 7 social attributes, it was obtained 3 (three) attributes that were considered sensitive to the level of sustainability from the social dimension, namely Community Participation in Reforestation Programs (RMS = 3.69), Community Empowerment in Clean Water Utilization Activities (RMS = 2.87), The Role of Indigenous People in Water Utilization Activities (RMS = 2.82). The intervention of these three attributes causes the social dimension to be unable to support the sustainability of water supply in Balikpapan City. Therefore, these three attributes must be considered in order to increase the value of the social dimension sustainability.
Figure 7 shows that community participation in reforestation programs is a very sensitive factor to affect the sustainability of water supply in the social dimension. There is an influential relationship between community participation and water sustainability. The provision of punishment or rewards can encourage residents to participate in development projects [9]. The knowledge has a positive relationship with the level of community participation in water resources management. So that efforts are needed to increase information on water resources management to increase community participation. In addition, several factors affect community participation in water resources management, namely the level of trust in the government and satisfaction with the previous program [10].

3.4. Infrastructur and Technology Dimension Status

The results of the analysis using the Rap-Balikpapan for the 5 attributes, the index value is obtained sustainability for the infrastructur and technology dimension is 50.57 means relatively sustainable (the index is located at between the values 50.01 - 75.00) (Figure 8). Based on analysis leverage on Status of Infrastructur and Technology attributes obtained 2 (two) attributes that are judged sensitive to the
level sustainability from the infrastructur and technology dimension, namely water treatment plant condition (RMS = 1.36) and integration with sanitation systems (RMS = 1.05).

Base on figure 9, the condition of water treatment plants is the most sensitive factor in terms of technology and infrastructure dimensions compared to other factors. This can be caused by still using simple technology, ineffective treatment units used, processing units that do not adapt to environmental conditions, especially the quality of raw water. the influential element for sustainability of the water supply system is a suitable technology. The clean water system technology that is built must be appropriate with environmental conditions and surroundings. Along with technical and non-technical factors, willingness to pay can help determine the choice of clean water facility technology to be built [11].
Some of the performance of water treatment plants in the Balikpapan city is still not optimal in providing services to the community. This is proven by the fact that the community's satisfaction with the quality and quantity of clean water, such as the bacteria content in water, the taste and smell of water, the flow of water, the frequency of water flow in one day, and the availability of water in the morning are still very low. If it compared to people's expectations in Balikpapan city [12].

Based on leverage analysis. The first thing to improve the sustainability of the technology dimension is to improve the water treatment plant. The change in the quality of raw water causes the water treatment plant in Balikpapan City to not work optimally. So that the water treatment installation needs to be redesigned or added to the pre treatment unit which is adjusted to the quality of the raw water to be processed. Furthermore, the government must plan an integrated sanitation system. The aim is to protect the potential of clean water reserves such as groundwater and rainwater due to pollution.

3.5. Legal and Institutional Dimension Status

The results of the analysis using the Rap-Balikpapan for the 5 attributes, the index value is obtained sustainability for the legal and institutional dimension is 56.14 means relatively sustainable (the index is located at between the values 50.01 - 75.00) (Figure 10). Based on analysis leverage on legal and institutional attributes obtained 2 (two) attributes that are judged sensitive to the level Sustainability from the legal and institutional dimension, namely cooperation between stakeholders (RMS = 4.40) and the existence of a water quality monitoring center (RMS = 4.28).

The biggest obstacle faced in managing raw water for clean water supply is the lack of coordination and integration of water resource management among related stakeholders. This constraint will give high contribution to other elements such as limited supporting facilities and infrastructure, lack of adequate human resources, lack of capacity of clean water management institutions, decreased function of water absorption due to reduced vegetation in water catchment areas [2].

![Figure 10. Index and sustainability status of legal and institutional dimension](image-url)
4. Conclusion
The conclusion of this research is that supply of clean water in Balikpapan City is quite sustainable in the environmental dimension (51.48), the economic dimension (63.49), the infrastructure and technology dimension (50.57), and the legal and institutional dimensions (56.14), but not sustainable in the social dimension (47.69).

Based on the leverage analysis on all dimensions, it is found that the five attributes that are most sensitive or influence the sustainability of water supply in Balikpapan city. They are water conservation areas, availability of paying for water usage, community participation in reforestation programs, water treatment plant conditions, cooperation between stakeholders.

There are several recommendations that can be used to rectify the sustainability of the social dimension, namely increasing community knowledge by providing information about water resource management, providing rewards to encourage residents to participate in development projects, especially water resources management, increasing public trust in the government by providing satisfaction with previous program.

Acknowledgement
The author is very grateful to the Directorate for Research and Community Service, Ministry of Research, Technology and Higher Education / National Research and Innovation Agency for providing the Beginner Lecturer Research (PDP) grant.

References
[1] Bakeri S, Yanuar J P M, Riani E and Sutjahjo S H 2016 Analisis MDS (Multi Dimensional Scaling) Untuk Keberlanjutan Pengelolaan Air Lintas Wilayah Studi Kasus DKI Jakarta J. Teknol. Lingkung. 13 13
[2] Surya R A, Yanuar J P M, Sapei A and Widiatmaka 2010 Analisis Status Keberlanjutan Pengelolaan Air Baku 213–25
[3] Taufik I, Yanuar J P M, Pramudya B and Saptomo S K 2019 Sustainability Status of Raw Water Supply at Ciliman Watershed J. Eng. Appl. Sci. 15 567–73
[4] Supardi S, Hariyadi S and Fahrudin A 2017 Analisis Keberlanjutan Pembangunan Kota Tepian Pantai (Studi Kasus: Kota Baubau Provinsi Sulawesi Tenggara) J. Wil. dan Lingkung. 5 188
[5] Azmanajaya E and Paulus C A 2018 Factors Affecting Sustainability of Water Supply in Coastal Community of Tarakan Island North Kalimantan: an Application of Mutidimensional Scaling Method Russ. J. Agric. Socio-Economic Sci. 78 505–13
[6] Sihotang I V, Sudarmaji, Purnama S and Baiquni M 2016 Model Konservasi Sumberdaya Air
Sebagai Upaya Mempertahankan Keberlanjutan Air di Sub DAS Aek Silang Journal SPATIAL 15 1-11

[7] Tsai Y, Cohen S and Vogel R M 2011 The Impacts Of Water Conservation Strategies On Water Use: Four Case Studies J. Am. Water Resour. Assoc. 47 687–701

[8] Jenny H, Fan M, Wang Y, Bulson P and Peibin L 2019 Water Consrvation Strategies For Beijing Capital Region , China 1–7

[9] Ofuoku A U 2011 Effect Of Community Participation On Sustainability Of Rural Water Projects In Delta Central Agricultural Zone Of Delta State, Nigeria J. Agric. Ext. Rural Dev. 3 130–6

[10] Bagherian R, Bahaman A S, Asnarulkhadı A S and Shamsuddin A 2012 Factors Influencing Local Community Participation In Sustainable Management Of Land And Water Resources In Iran Int. Conf. soil Sci. Congr. Turkey, May.2012.

[11] Saniti D 2012 Penentuan Alternatif Sistem Penyediaan Air Bersih Berkelanjutan di Wilayah Pesisir Muara Angke J. Reg. City Plan. 23 197

[12] Andini R, Ulimaz M and Sulistijono S 2018 Evaluasi Kinerja Penyediaan Air Bersih di Kelurahan Baru Ulu, Kecamatan Balikpapan Barat, Kota Balikpapan J. Reg. Rural Dev. Plan. 1 307