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Original Article

Analysis of Clean Water Services in Dili City Based on Service Ratio

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Abstract

Adequate availability of clean water is an essential basic need for urban communities, including in Dili City, the capital of Timor Leste, as clean water supports health, hygiene, and various economic activities. However, Dili City faces a number of challenges in providing optimal clean water supply, such as rapid population growth, uncontrolled urbanization, inadequate infrastructure, and a distribution leakage rate of up to 30%, which causes difficulties in accessing clean water for some communities. This study aims to analyze the demand and availability of clean water in Dili City, and calculate the ratio of clean water services based on existing data, using a positivistic approach and theoretical-analytical and empirical-analytical methods. The results show that the demand for clean water in Dili City reaches 129,060 liters per second, with the highest production capacity in Comoro Village, but the distribution of clean water services is not evenly distributed. Becora Village has the highest service ratio, while Balibar Village shows a low ratio.

Keywords: Clean Water Availability, Dili City, Clean Water Demand, Population Growth, Water Service Ratio.

1. Introduction

Clean water is a basic human need that is essential for health, well-being and quality of life. Its availability is not only necessary for daily purposes such as drinking, cooking and sanitation, but also plays a role in preventing infectious diseases such as diarrhea. However, in Timor Leste, particularly in Dili City, the provision of clean water faces major challenges due to rapid urbanization, population growth, and inadequate infrastructure. Data from Timor Leste's Central Bureau of Statistics (2022) notes that approximately 15.7% of households do not have access to safe drinking water sources, increasing public health risks.

Dili City is under great pressure to meet its clean water needs, mainly due to limited distribution infrastructure and contamination of raw water sources. According to Noerbambang and Morimura (1985), much of the piping network in Dili City is old and leaking, resulting in compromised water distribution efficiency (Noerbambang & Morimura, 1985). In addition, poor water quality, due to domestic and industrial waste pollution, is the main cause of various infectious diseases in the region (Linsley et al., 1982).

Population growth and rapid urbanization in Dili City further exacerbate this situation. Rural-to-urban migration, driven by economic opportunities, puts additional pressure on the city's infrastructure, particularly the water distribution system. As a result, inequitable access to clean water occurs between the city center and peripheral areas (Mangkoedihardjo, 2012).

This condition requires more inclusive infrastructure planning to reach all areas, including areas that are difficult to access by conventional piped systems.

On the other hand, low water tariffs in Dili City are a major obstacle to sustainable management. Masduqi (2010) mentioned that insufficient tariffs often make it difficult for service providers to cover operational costs, so investments in infrastructure improvements cannot be made (Masduqi, 2010). This results in low coverage and continuity of clean water services, which greatly affects the lives of low-income communities.

According to Grigg (2003), careful planning of water infrastructure is necessary to ensure continuity of supply, distribution efficiency, and sustainability of services (Grigg, 2003). However, in Dili City, technological and budgetary limitations are often the main obstacles in implementing clean water management programs (Kodoatie, 2002). For this reason, a holistic approach that includes community involvement, sustainable water resources management, and improved management capacity is needed (Rengganis & Kusumawati, 2011; Sutrisno, 2008).

Community participation in water resources management is also key to the success of efficient distribution. Anisah (2023) revealed that community-based management can help overcome distribution constraints, especially in hard-to-reach areas (Anisah et al., 2023). In addition, community education on the importance of maintaining clean water sources and good waste management needs to be improved through joint campaigns between the government and non-governmental organizations (Suripin, 2002).

Pollution of raw water sources, such as rivers and groundwater, is another significant challenge. Domestic, industrial and agricultural effluents often pollute these water sources, requiring extensive treatment to ensure water quality is maintained (Linsley et al., 1982). Planting trees in watersheds and implementing sustainable agricultural practices can help maintain the sustainability of water resources (Paradis et al., 2024).

To ensure the sustainability of clean water services in Dili City, collaboration between the government, private sector, and local communities is required. The Udin Study (2024) emphasizes the importance of wide service coverage, continuity of supply, and low leakage rates as key indicators of successful water management (Udin et al., 2024). By ensuring these factors, equitable access to clean water can be achieved, supporting sustainable development goal (SDGs) number 6 on clean water and sanitation.

Based on this background, this study aims to analyze the ratio of clean water services in Dili City by considering technical, social, and economic aspects. In addition, this study also seeks to identify the main problems in service distribution and formulate optimization strategies. With an in-depth understanding of the various inhibiting factors and strategic solutions, it is hoped that clean water services in Dili City can be improved to support sustainable development and improve community welfare.

2. Methods

2.1. Research Location

The research site is located in Dili City, the capital city of Timor Leste. Dili City has a land area of 48.27 km². Astronomically, Dili City is located at 8°34′S 125°34′E south latitude and Timor Leste is located between latitudes 8° and 10° S, and longitudes 124° and 128° E. Dili City administratively has the following boundaries:

1) North : Manatuto Region
2) South : Tibar Region
3) East : East Sea of Leste
4) West : Aileu Region

Administratively, Dili City is divided into 6 sub-districts and 31 villages. This research focuses on two sub-districts, Dom Aleixo and Cristo Rei. Kecamatan Dom Aleixo, which has the largest population in Dili City, includes Comoro, Madohi, Bairopite, Bebonuk, Maneluan, Kampo Alor, and Fatuhada. Meanwhile, Cristo Rei sub-district includes Becora, Culu Hun, Camea, Bidau Santana, Hera, Metiaut, Ailok, and Balibar.

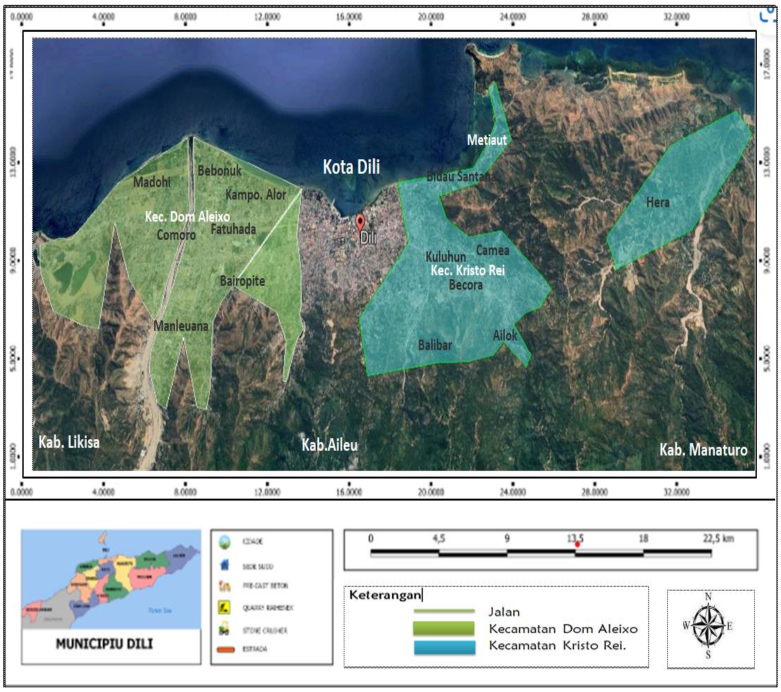

Figure 1. Dili City Map

Table 1. Population development in 2021-2023

No	Village	Total Population		
		2021	2022	2023
Don Aleixo District				
1	Comoro	47,025	47,308	47,594
2	Madohi	12,723	12,8	12,877
3	Bairopite	25,37	25,523	25,677
4	Bebonuk	15,725	15,82	15,915
5	Manleuan	11,796	11,867	11,939
6	Kampo Alor	4,506	4,534	4,561
7	Fatuhada	9,38	9,437	9,494
Cristo Rei District				
8	Becora	23,184	23,324	23,465
9	Culu Hun	7,616	7,662	7,708
10	Camea	12,6	12,676	12,753
11	Bidau Santana	7,812	7,86	7,907
12	Hera	10,346	10,408	10,471
13	Metiaut	2,291	2,307	2,321
14	Ailok	5,02	5,05	5,086
15	Balibar	1,723	1,734	1,744

2.2. Data Collection

This research was organized with the following data collection stages:

a) Literature Study

Collecting and studying various relevant literature, such as books, papers, and scientific journals that discuss clean water services, water distribution, and the factors that influence them.

b) Primary Data Collection

Primary data was obtained through direct field surveys in Dom Aleixo Subdistrict and Cristo Rei Subdistrict, Dili City. The survey was conducted by interviewing local communities to find out the level of access to clean water, the quality of service, and the problems they face.

c) Secondary Data Collection

Secondary data was obtained from government agencies and related institutions, such as data on population, population growth rate, pipeline infrastructure condition, water leakage rate, water source capacity, and clean water distribution costs based on user categories. This data was used to support the analysis of water demand and services in the study area.

2.3. Data Analysis Technique

The data analysis technique in this study was carried out through the following stages:

1) Identification of Clean Water Needs and Availability

The first stage is the identification of clean water demand and availability in the study area. This analysis aims to calculate domestic clean water demand, which generally includes household needs. Non-domestic needs are also taken into account, which is about 20-25% of the total water demand, in accordance with the guidelines proposed by Kodoatie (2005). Domestic water demand is calculated using the following equation:

$$\textbf{Domestic clean water demand} = \textbf{a x b x c}$$

Description:
a = Total population (people)
b = Total domestic clean water demand based on area category (liter/person/day)
c = Percentage of clean water services, which is 100% of the total population

According to the Integrated City Infrastructure Development Program (P3KT) of the Regional Cipta Karya Public Works Office of East Java Province, the classification of cities based on population and water demand per person per day is as follows:

a. Rural (<3,000 inhabitants): 45-60 liters
b. Sub-district capital (3,000-20,000 inhabitants): 45-60 liters
c. Small town (20,000-100,000 inhabitants): 60-100 liters
d. Medium city (100,000-500,000 inhabitants): 90-125 liters
e. Large cities (500,000-1,000,000 inhabitants): 100-150 liters
f. Metropolitan cities (>1,000,000 inhabitants): 150-200 liters

2) Calculating Clean Water Production Capacity

Clean water production capacity is calculated by multiplying the number of people served by the standard daily water demand. More details can be seen through the following equation:

$$\textbf{Water production capacity} = \textbf{a x b}$$

Description:
a = Total population served by clean water (people)

b = Average population clean water demand (liter / person / day)

3) Calculating the Water Service Ratio

The next step is to calculate the water service ratio. This ratio reflects the comparison between the water supply capacity and the population's water demand. The formula used refers to the SPM formula for the reliability of clean water availability (Permen PU No. 14 of 2010), namely:

$$\textbf{Clean water availability ratio} = (\mathbf{a}/\mathbf{b})\ \mathbf{x}\ \mathbf{100}$$

Description:
a = Production capacity/month (m^3/month)
b = Capacity of total clean water demand of population/month (m^3/month)

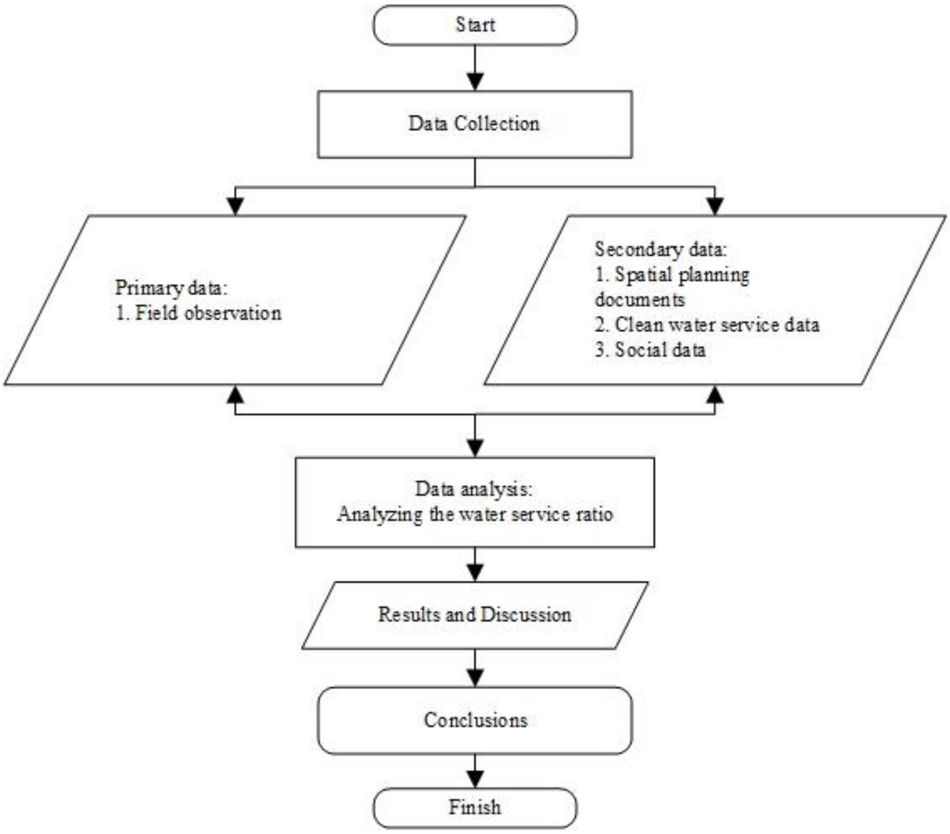

Figure 2. Research Flowchart

3. Results and Discussion

3.1. Identification of Clean Water Needs

From the analysis of clean water demand for urban residential areas in Dili City, a domestic demand of 129,060 liters/second was obtained. This figure has considered Dili City's clean water service target of 100% in accordance with the national Sustainable Development Goals (SDG's) standard. The regional category used is a medium city with an average demand of 100 liters / person / day. The following Table 2 Analyzes the Clean Water Needs of Settlements in the Research Area.

Table 2. Analysis of Clean Water Needs of Settlements in the Research Area

No	Village	Total Population (Soul)	Service Level (%)	Number Served (Soul)	Average water consumption (Lt/Person/Day)	Total Usage (Lt/Day)	Total Requirement (Lt/det)
		(a)	(b)	(c)	(d)	(e)	(f)
Don Aleixo District							
1	Comoro	47,594	100	25,250	100	2,525,000	29.22
2	Madohi	12,877	100	7,012	100	701,200	8.12
3	Bairopite	25,677	100	17,533	100	1,753,300	20.29
4	Bebonuk	15,915	100	8,565	100	856,500	9.91
5	Manleuan	11,939	100	6,820	100	682,000	7.89
6	Kampo Alor	4,561	100	2,338	100	233,800	2.71
7	Fatuhada	9,494	100	4,625	100	462,500	5.35
Cristo Rei District							
8	Becora	23,465	100	13,235	100	1,323,500	15.32
9	Culu Hun	7,708	100	4,876	100	487,600	5.64
10	Camea	12,753	100	6,277	100	627,700	7.27
11	Bidau Santana	7,907	100	4,809	100	480,900	5.57
12	Hera	10,471	100	5,336	100	533,600	6.18
13	Metiaut	2,321	100	1,735	100	173,500	2.01
14	Ailok	5,086	100	2,422	100	242,200	2.80
15	Balibar	1,744	100	675	100	67,500	0.78
Total							**129,060**

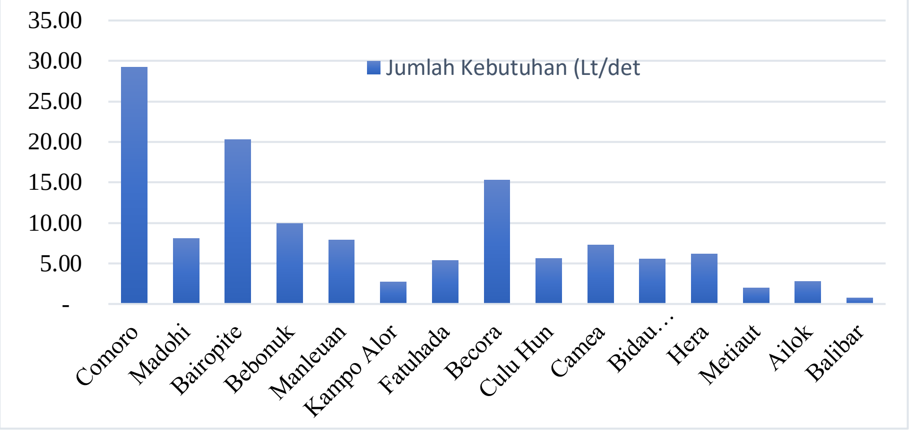

Figure 3. Clean water needs of each village

In Figure 3, it can be seen that the distribution of water demand in each urban village shows significant variation, mainly influenced by the different populations in each area. Comoro Village has the highest water demand at 29.22 liters per second, reflecting the large population and high activity in the area. Meanwhile, Balibar village has the lowest water demand at 0.78 liters per second, which may be due to a smaller population or lower activity compared to the other villages.

Based on the analysis conducted, the level of water loss or leakage in the distribution network reaches a fairly high rate of 30%. This indicates that some of the produced water does not reach the community due to leaks in the distribution system. This condition causes an increase in clean water demand of 20.01 liters per second to replace water lost due to leakage, as shown in Table 3.

Table 3. Water demand is based on adding capacity to the water leakage rate

No	Village	Total Water Demand (Lt/Det)	Clean Water Demand X (30% leakage rate)	Demand based on additional capacity against water leakage (Lt/det)	Needs based on additional capacity against water leakage (m^3/month)
		(a)	(b)	(c)	(d)
Don Aleixo District					
1	Comoro	49,58	14,87	64,45	167,054
2	Madohi	14,9	4,47	19,37	50,204
3	Bairopite	29,72	8,92	38,64	100,155
4	Bebonuk	18,42	5,53	23,95	62,078
5	Manleuan	13,82	4,15	17,97	46,578
6	Kampo Alor	5,28	1,58	6,86	17,781
7	Fatuhada	10,99	3,3	14,29	37,04
Cristo Rei District					
8	Becora	27,16	8,15	35,31	91,524
9	Culu Hun	8,92	2,68	11,6	30,067
10	Camea	14,76	4,43	19,19	49,740
11	Bidau Santana	9,15	2,75	11,9	30,845
12	Hera	12,12	3,64	15,76	40,850
13	Metiaut	2,69	0,81	3,5	9,072
14	Ailok	5,89	1,77	7,66	19,855
15	Balibar	2,02	0,61	2,63	6,817
Total				**293,08**	**759,660**

3.2. Identification of Clean Water Availability

From the analysis of the availability of clean water production in the study area, the water production capacity is obtained based on the number of people served by the PDAM pipeline network. This analysis uses the small city category (20,000 - 200,000 people) according to the Integrated City Infrastructure Development Program (P3KT) of the Dili City Cipta Karya Public Works Office, with a standard water demand of 100 liters / person / day. Based on the data, the number of people served by the pipeline network reached 199,512 by the end of 2024. The following Table 4 shows the production capacity of clean water provided in each village.

Table 4. Water production capacity provided by each village

No	Village	Total Population Served (Soul)	Demand Standard (Lt/Soul/Day)	Production Capacity (Lt/Day)	Production Capacity (m^3/Month)
		(a)	(b)	(c)	(d)
Don Aleixo District					
1	Comoro	25,250	100	2,525,000	75,750
2	Madohi	7,012	100	701,200	21,036
3	Bairopite	17,533	100	1,753,300	52,599
4	Bebonuk	8,565	100	856,500	25,695
5	Manleuan	6,820	100	682,000	20,460
6	Kampo Alor	2,338	100	233,800	7,014
7	Fatuhada	4,625	100	462,500	13,875
Cristo Rei District					
8	Becora	13,235	100	1,323,500	39,705
9	Culu Hun	4,876	100	487,600	14,628
10	Camea	6,277	100	627,700	18,831
11	Bidau Santana	4,809	100	480,900	14,427
12	Hera	5,336	100	533,600	16,008
13	Metiaut	1,735	100	173,500	5,205
14	Ailok	2,422	100	242,200	7,266
15	Balibar	675	100	67,500	2,025

Table 4 shows that the highest water production capacity is found in Comoro Village, reaching 75,750 m³/month. This is because the number of people served by the PDAM pipeline network in Comoro Village is the largest compared to other villages in the study area. Meanwhile, the lowest production capacity is found in Balibar Village, which shows a smaller number of residents served.

3.3. Clean Water Service Ratio

From the analysis of the demand and availability of clean water in the study area, it is obtained that the percentage of clean water services can be calculated by comparing the production capacity of clean water with the clean water needs of the population, then multiplied by 100%. This equation can be formulated as follows:

$$\textbf{Clean water service ratio} = \frac{\mathbf{a}}{\mathbf{b}} \times \mathbf{100\%}$$

Description:
a = Net Water Availability/month (m^3/month)
b = Population Clean Water Needs/month (m^3/month)

Table 5. Ratio of clean water services in the study area

No	Village	Total Population Served (Soul)	Water Requirements (m^3/month)	Water Availability (m^3/month)	Clean Water Service (%)
		(a)	(b)	(c)	(d)
Don Aleixo District					
1	Comoro	25,250	167,054	75,750	43,345
2	Madohi	7,012	50,204	21,036	41,901
3	Bairopite	17,533	100,155	52,599	52,518
4	Bebonuk	8,565	62,078	25,695	41,391
5	Manleuan	6,820	46,578	20,460	43,926
6	Kampo Alor	2,338	17,781	7,014	39,447
7	Fatuhada	4,625	37,04	13,875	37,46
Cristo Rei District					
8	Becora	13,235	91,524	39,705	43,382
9	Culu Hun	4,876	30,067	14,628	48,651
10	Camea	6,277	49,740	18,831	37,859
11	Bidau Santana	4,809	30,845	14,427	46,773
12	Hera	5,336	40,850	16,008	39,187
13	Metiaut	1,735	9,072	5,205	57,374
14	Ailok	2,422	19,855	7,266	36,595
15	Balibar	675	6,817	2,025	29,705

Description:
[a] = Total population per village
[b] = Needs based on additional capacity for water leakage (m3 / month)
[c] = Production capacity
[d] = Clean water service level = (c/b)*100%

From the calculation results in table 5 above, it is known that the average clean water service in the study area has not been able to reach the 100% target in accordance with the national clean water service standard. Based on the data, Don Aleixo District has the highest service ratio in Bairopite Village, while the lowest service ratio is in Fatuhada Village. In Cristo

Rei District, Culu Hun Village shows the highest service ratio, while the lowest service ratio is found in Balibar Village.

4. Conclusion

The results of the analysis of the demand and availability of clean water in Dili City, Timor Leste show that the demand for clean water in the study area reaches 129,060 liters/second, with a service target of 100% according to national SDG's standards. Dom Aleixo sub-district has the highest demand, while Cristo Rei sub-district has proportionally lower demand. The water leakage rate in the distribution network reaches 30%, so an additional demand of 20.01 liters/second is needed to replace the lost water, while the lowest service ratio is in the village of Compo Alor. For the sub-district of Cristo Rei, the highest service ratio is in the village of Becora, while the lowest service ratio is in the village of Balibar.

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