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Sustainability Analysis of Domestic Wastewater Management System in Gundik Village Using Net Present Value (NPV) and Benefit Cost Rasio (BCR) Methods

Tri Sunan Agung[1*], Arseto Yekti Bagastyo[2]
Sepuluh Nopember Institute of Technology
Corresponding Author: Arseto Yekti Bagastyo, bagastyo@enviro.its.ac.id

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A B S T R A C T

The construction of the Centralized Domestic Wastewater Management System (SPALD-T) in Gundik Village realizes the goal of SDGs 2030 point 2 and RPJPN 2025-2045, namely 70% proper sanitation. After four years of operation since 2021, the sustainability of SPALD-T needs to be re-analyzed, especially in terms of the economy. Based on the KPP report and initial observations, there are indications that the economic cycle of this management system has not been running optimally. The method of sustainable economic analysis used the Net Present Value (NPV) and Benefit-Cost Ratio (BCR) methods. The results of the NPV analysis were IDR 25,930,265 (positive) and BCR was 1.22 (more than 1), the SPALD-T project was declared economically feasible and had the potential to provide sustainable benefits. SPALD-T is designed to operate for 20 years or more, providing benefits such as health cost efficiency, improving environmental quality, and strengthening the local economy. The domestic wastewater management system in Gundik Village encourages sustainable infrastructure development to create an independent and equitable society. The economic sustainability of SPALD-T can be a model for domestic waste management that supports sustainable development in Indonesia

INTRODUCTION

Indonesia is facing a domestic wastewater management crisis, especially in residential areas in the district. Ponorogo Regency is included in the Regency/City that has this problem. Domestic wastewater that is not managed properly can have adverse impacts on health, the economy, and the environment. Domestic wastewater contains millions of intestinal bacteria and a small number of other organisms, as well as detergent, phosphate, and nitrate content, causing foam formation and endangering aquatic organisms in freshwater ecosystems through eutrophication (Koul et al., 2022). Meanwhile, in terms of socio-economic aspects, the amount of domestic wastewater is related to the increasing population and the potential cost of community expenditure on health (Li et al., 2023). The world faces the challenge of managing a severe water crisis due to population growth, rapid urbanization, industrialization, climate change, and poor use of natural resources (Shan et al., 2020). These adverse impacts must be addressed appropriately, both in terms of infrastructure and understanding the community.

Dinas Pekerjaan Umum Perumahan dan Kawasan Permukiman (DPUPKP) of Ponorogo Regency built a Centralized Domestic Wastewater Management System (SPALD-T) in Gundik Village in 2021. The infrastructure was built by collaborating the roles of the government and the community in overcoming sanitation problems. Community involvement in decision-making, planning, and implementation is also important for the success of the sanitation program (Manisha et al., 2023). SPALD-T realizes the goals of the 2030 Sustainable Development Goals (SDGs) point 2 and the 2025-2045 National Long-Term Development Plan (RPJPN), namely 70% proper sanitation.

SPALD-T Gundik Village, Slahung District covers RT 01 and RT 02, with a total service of 196 people. This system consists of 1,057.8 meters of main pipe and wastewater treatment installation consisting of units: sedimentation tank and anaerobic filter. After construction in 2021, SPALD-T was handed over to the Post-Project Group (KPP) "Honggo Taruna Berkah" with supervision from DPUPKP Ponorogo Regency. The construction of SPALD-T is planned to be sustainable for the next 20 years, namely 2041 (PermenPUPR No. 4 of 2024; RPJPN 2025-2045; SDGs 2030). SPALD-T was built based on the principle of sustainable infrastructure, socially, economically, and environmentally.

After four years of operation since 2021, the sustainability of SPALD-T needs to be re-analyzed, especially in terms of economic aspects. Based on the KPP report and initial observations, there are indications that the economic cycle of this management system has not been running optimally. Problems such as operational costs are not commensurate with the low community contribution. In addition, the lack of a strategy for utilizing waste management results as additional economic value is another challenge. Infrastructure development still faces various obstacles, including limited funds, bureaucratic complexity, inequality between regions, and low public awareness (Awainah et al., 2024). Therefore, a comprehensive and simple analysis is needed to evaluate the extent to which this system is feasible and sustainable in terms of economy.

Sustainability economic analysis can be done using the Net Present Value (NPV) and Benefit-Cost Ratio (BCR) methods. NPV is Net Present Value (NPV) is an economic indicator that calculates the difference between the benefits and costs of an investment by considering time preference, representing the net effect throughout the life of the project after being discounted to the present value, namely at the beginning of the investment. (Tushar et al., 2022; Cetkovic et al., 2022). While BCR shows how much net benefit can be achieved per unit cost (Cetkovic et al., 2022). Such an analysis allows the assessment of the economic benefits of SPALD-T based on current conditions. NPV will help determine the investment value in SPALD-T providing added economic value, while BCR will provide an overview of the value of the benefits obtained greater than the costs incurred.

The renewal in this study is at the research location, namely in SPALD-T Gundik Village, Ponorogo Regency. The analysis of the sustainability of the economic aspect is supported by a simple but comprehensive method, namely NPV and BCR. By using these two methods, it is expected that the value of economic sustainability and solutions to SPALD-T in Gundik Village can be identified. This has the potential to have an impact on this program not only providing environmental benefits but also supporting the economic welfare of managers and the

community in the long term. The potential for the economic aspect of sustainability has a target of 20 years after development, namely 2041.

METHODS

The research method uses quantitative types and approaches. Quantitative research (result) is an objective, inductive, and scientific approach, where data is obtained in the form of numbers, scores, or results from questions that are assessed and analyzed using statistical techniques (Sugiyono, (2019). The flow of this research is listed in the following figure:

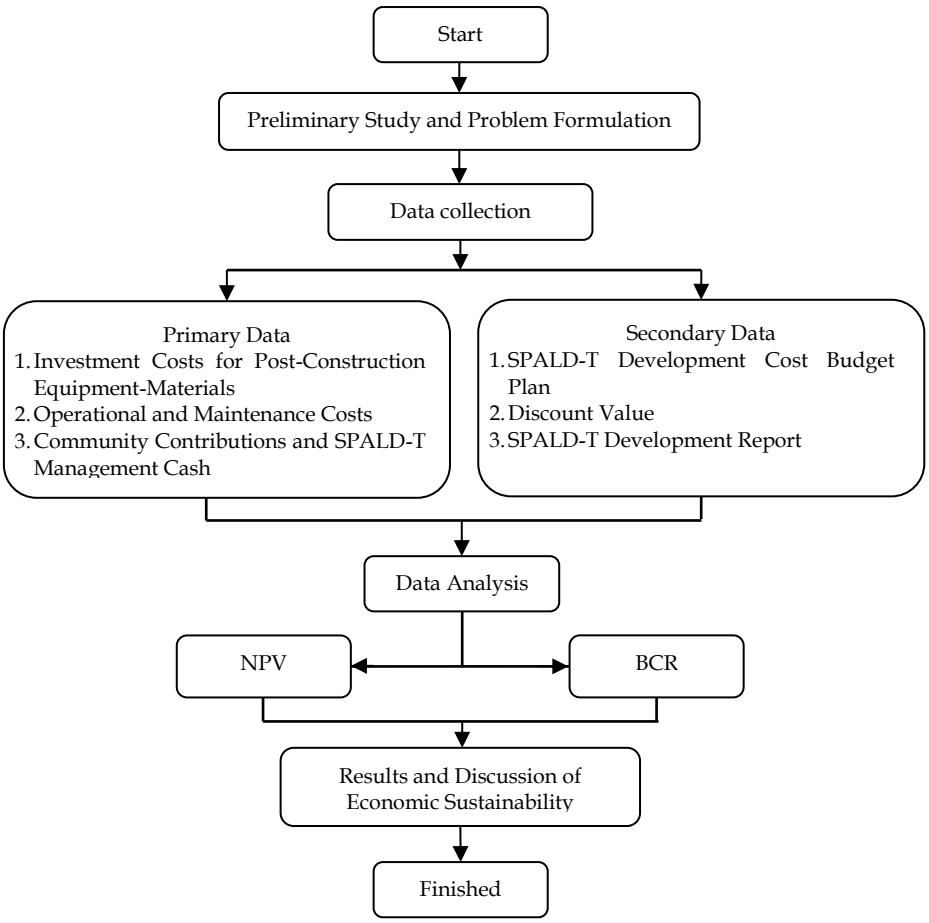

Figure 1. Research Flow Diagram

Data Collection Technique

Data collection techniques in this study are divided into 3, namely:

1. Observation
   Data collection method by directly observing the object or phenomenon being studied. Observation can be done in a structured manner. This method is useful for obtaining empirical data related to the situation, behavior, or economic conditions in SPALD-T.
2. Interview
   Interviews through direct interaction between researchers and SPALD-T. Interviews can be conducted in a structured manner based on research data needs. This method allows researchers to dig up in-depth information, including experiences, opinions, or views from KPP SPALD-T
3. Literature Study
   Data is collected by tracing information from various written sources, such as books, scientific journals, research reports, official documents, or other reliable sources. This method is used to understand concepts, theories, or secondary data that are relevant to the research, as well as to support the analysis or discussion of research results.

Data Analysis Techniques

Data analysis in the study used Net Present Value (NPV) and Benefit Cost Ratio (BCR)

calculations. The NPV formula is presented by (Agung & Zuhri, 2023; Fanani, 2021) as follows:

$$NPV = \sum_{t=0}^{n} \frac{(C)t}{(1+i)^t} - \sum_{t=0}^{n} \frac{(Co)t}{(1+i)^t}$$

Information:

NPV = Net present value
(C)t = Cash flow in t-year
(Co)t = Cash outflow t-year
n = Investment age (years)
i = Return current (ROR)
t = Year

SPALD-T infrastructure is declared feasible if the NPV value is positive (+) and not feasible if value is negative (-).

NPV helps researchers determine the investment value in SPALD-T to provide added economic value, while BCR will provide an overview of the value of benefits obtained greater than the costs incurred. The BCR formula is presented by (Fanani, 2021; Trisna et al., 2022; Maelani et al., 2022) as follows:

$$BCR = \frac{PWB}{PWC}$$

Information:

BCR = Benefit Cost Ratio
PWB = Present Worth of Benefit
PWC = Present Worth of Cost

If the BCR value is as follows:

BCR $\geq$ 1, the project is feasible.
BCR < 1, the project is not feasible.

RESULTS AND DISCUSSION

The Centralized Domestic Wastewater Management System (SPALD-T) is an important part of improving the quality of community sanitation and reducing the risk of environmental pollution. Inadequate sanitation contributes to 2 billion cases of diarrhea each year, as reported by WHO and UNICEF, showing a close relationship with direct infectious diseases (Belinda et al., 2024). Therefore, the construction of SPALD-T can be a sustainable solution in terms of environment, social, health, and economy for the communities served.

The assessment of the economic sustainability of the project uses two main indicators, namely NPV and BCR. A positive NPV indicates that the project provides net benefits, while a BCR of more than 1 indicates that the benefits of the project exceed its costs. In this study, SPALD-T has an NPV of IDR 25,930,265 (positive) and a BCR of 1.22, which means that the project is economically feasible.

Net Present Value (NPV)

NPV is an indicator that shows the net value of project benefits after deducting investment costs by taking into account the time value of money. The following is the calculation and analysis of NPV in the construction of SPALD-T:

1. Initial Costs: Post-Construction Equipment
   After the construction has been carried out, the SPALD-T is fully handed over to the KPP with supervision by DPUPKP. There are initial costs to prepare tools to support the operation and maintenance of the SPALD-T, the details are as follows:

Table 1. Post-Construction Equipment Cost Details for SPALD-T

No.	SPALD-T Equipment	Cost
1.	Sewage Pump Machine	Rp. 10.000.000
2.	Backup Power Generator	Rp. 5.000.000
3.	Wastewater Quality Monitoring Tool	Rp. 3.400.000
4.	Sanitation and Cleaning Equipment	Rp. 1.900.000
5.	Work Safety Equipment	Rp. 1.500.000
Total SPALD-T Equipment		**Rp. 21.800.000**

2. Operational and Maintenance Costs
   The operations and maintenance referred to are activities, consumables and salaries for KPP SPALD-T.

Table 2. SPALD-T Operational and Maintenance Costs

No.	Operational Needs	Estimated Total Price (…/year)
1.	KPP SPALD-T Salary (Rp. 200,000/month x 5 people)	Rp. 2.400.000
2.	Sludge Suction Cost	Rp. 150.000
3.	Requirements for Tools and Consumables	Rp. 500.000
Total OP SPALD-T/Year		**Rp. 3.050.000**

3. Annual Cash/Contribution Fees
   Based on the initial agreement, each House Connection (SR) provides cash or contributions of Rp. 10,000/month. So it can be calculated:

$$Cont.SR = Rp.10.000 \times 49\,SR \times 12$$
$$Contribution\,SR = Rp.\frac{5.880.000}{tahun}$$

   Based on the contribution, Rp. 5,880,000/year was obtained. This figure was added to other business activities as income, such as: workshops and bazaars, amounting to Rp. 1,000,000/year. So the total Cash Income Cost is Rp. 6,880,000/year.

4. NPV calculation
   The data is as follows:
   a) Initial investment costs (Co)
      = Rp 21.800.000
   b) Annual income
      = Rp 6.880.000
   c) Annual operating costs
      = Rp 3.050.000
   d) Annual net cash flow (Ct)
      = Rp 6.880.000 - Rp 3.050.000
      = Rp 3.830.000
   e) Diskonto (r)
      = 5% or 0,05
   f) Time Period (n)
      = 20 years

   Calciulation:

$$NPV = \sum_{t=1}^{20} \frac{3.830.000}{(1+0{,}05)^t} - 21.800.000$$
$$NPV = 47.730.265 - 21.800.000$$
$$NPV = 25.930.265$$

In SPALD-T, the positive NPV result of IDR 25,930,265 indicates that this project generates net profits. A positive NPV value indicates that the wastewater management project provides economic benefits that exceed the costs incurred (Hernández-Sancho et al., 2021).

According to (Kalbar et al., 2020) it is emphasized that NPV is a reliable indicator to assess the long-term financial sustainability of wastewater management projects. In the context of SPALD-T, a positive NPV value not only indicates economic sustainability but also provides a strong basis for optimal project implementation and management.

Benefit Cost Rasio (BCR)

BCR measures the comparison between the benefits and costs of a project. The following is the calculation and analysis of BCR in the construction of SPALD-T.

1. Expenditure Costs
   The budget for the construction of the SPALD-T in Gundik Village is IDR 500,003,846.90 (DPUPKP, 2021). In the construction of the SPALD-T, all costs are borne by government funds. With the following details:

Table 3. Cost Budget for SPALD-T Construction

No.	Job description	Total price
1.	Preparatory work	Rp. 1.594.806,00
2.	Soil Work	Rp. 51.959.092,50
3.	Concrete Work	Rp. 163.916.384,65
4.	Plastering Work	Rp. 5.208.930,00
5.	Sanitation Work	Rp. 39.210.000,00
6.	Pipe Installation Work	Rp. 156.214.633,75
7.	Others Work	Rp. 81.900.000,00
8.	Program Operating Costs	Rp. 10.000.000,00
Total Cost of Construction of SPALD-T		**Rp. 500.003.846,90**

2. Entry Cost (Benefits)

The budget for the input costs is calculated during the construction until 2041, which is 20 years after the construction of SPALD-T. The estimation and calculation are calculated based on the service population of SPALD-T Gundik Village, which is 49 SR and 196 people.

Table 4. Cost Benefits of SPALD-T Development

No.	Income (Benefits)	Estimated Total Price (…/year)
1.	Reduction of Fecal Suction Costs	Rp. 100.000 – Rp. 200.000
2.	Public Health Improvement	Rp. 2.500.000 – Rp. 6.000.000
3.	Environmental Quality Improvement	Rp. 3.000.000 – Rp. 7.000.000
4.	Property Value Increase	Rp. 4.000.000 – Rp. 10.000.000
5.	Increasing Public Awareness	Rp. 3.500.000 – Rp. 5.000.000
Total Benefits of SPALD-T Development		**Rp.13.100.000 – Rp. 28.200.000**
Calculation for the Next 20 Years Maximum and Inflation of 8.39% as an average of 1997-2025 (Bank Indonesia)		**Rp. 611.319.600**

3. BCR Calculation

The following is the BCR calculation for the SPALD-T Development based on the development value (state money) and economic benefits for 20 years.

$$BCR = \frac{Rp.611.319.600}{Rp.500.003.846}$$
$$BCR = 1{,}22$$

In SPALD-T, a BCR value of 1.22 indicates that every Rp. 1 invested generates a benefit of Rp. 1.22. A BCR greater than 1 is a primary indication that a project is economically feasible (Fanani, 2021). This is in line with research (Nugroho and Rifai, 2020) which shows a value of 2.13, meaning that the wastewater treatment project has significant investment efficiency and is economically viable and sustainable.

Projects with BCR above 1 tend to have better sustainability, because their economic benefits are large enough to support long-term operations (Sandhyavitri and Herlina, 2015). In the case of SPALD-T, this BCR value emphasizes that this project is not only feasible but also has the potential for broad economic impacts, both directly and indirectly, on the surrounding community and environment.

The NPV result of Rp. 25,930,265 and the BCR ratio of 1.22 indicate an indication of economic sustainability, if the initial target of the SPALD-T development is achieved. Based on the Regulation of the Minister of PUPR in 2017 concerning the Implementation of the Domestic Wastewater Management System, the operation and maintenance period of the SPALD-T facility is generally planned for a duration of 20 years. During this period, the project is expected to provide sustainable benefits, including reducing health costs due to wastewater-based diseases, improving environmental quality,

and strengthening the local economy through investment efficiency.

The SPALD-T project is in line with the vision of the National Long-Term Development Plan (RPJPN) 2025–2045 which emphasizes the importance of sustainable infrastructure development as part of the transformation towards a prosperous, independent, and equitable society. This plan has the ultimate goal of "Golden Indonesia 2045". Within the framework of the RPJPN, the success of SPALD-T can be an indicator that environmentally friendly infrastructure is economically capable of supporting sustainable development nationally. Renewable innovation and infrastructure development are real efforts to support the sub-pillar of Golden Indonesia 2045 "scientific contribution and commitment to the environment" (Agung et al., 2024).

Overall, the economic sustainability of SPALD-T not only provides direct benefits during 20 years of operation, but also supports the long-term goals of sustainable development. This project has the potential to be a model for the implementation of other domestic waste management systems in Indonesia, by providing integrated economic, social and environmental benefits.

CONCLUSION

Based on the NPV analysis of Rp. 25,930,265 (positive) and BCR of 1.22 (more than 1), the SPALD-T project is declared economically feasible and has the potential to provide sustainable benefits. Referring to the PUPR Ministerial Regulation of 2017, this project is designed to operate for 20 years, providing benefits such as health cost efficiency, improving environmental quality, and strengthening the local economy. This is in line with the vision of the 2025–2045 RPJPN which encourages sustainable infrastructure development to create an independent and equitable society. The economic sustainability of SPALD-T can be a model for domestic waste management that supports sustainable development in Indonesia.

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