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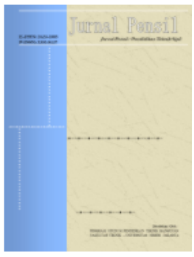

HIERARCHICAL TWO-WAY SENSITIVITY ANALYSIS IN DIVERSE BENEFIT SCENARIO OF MATENGGENG DAM FEASIBILITY

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P-ISSN: 2301-8437
E-ISSN: 2623-1085

ARTICLE HISTORY
Accepted:
7 Agustus 2023
Revision:
29 Januari 2024
Published:
30 Januari 2024

ARTICLE DOI:
10.21009/jpensil.v13i1.37725

Abstract

The Indonesian government formulated plans for the construction of the Matenggeng Dam, aiming to enhance local agricultural productivity. This dam will store water from the Cijolang River, a tributary of the Citanduy River. The construction of Matenggeng Dam encompasses option of municipal water enhancement and four normal water levels: 190m, 194m, 197m, and 199m. According to the hydrology, social-economic, and dam structure design reports, each option entails distinct benefits and costs. The report informed dam's agriculture potential benefit, land use, and cost by each water level option. To assess the project's viability, an economic analysis and hierarchical two-way sensitivity analysis has been conducted to examine the impact of water level variations on the economic evaluation outcomes. Results obtained at a discount rate of 10.08% indicate that 194m and 197m water level options exhibit positive NPV, IRR greater than the interest rate, PBP less than 50 years, and a BCR exceeding 1. While both options demonstrate feasibility, the 194m appears more favorable. Despite the 197m water level presenting a slightly higher IRR by 0.02%, respectively, it incurs a cost deviation of IDR 100 billion. However, the 194m water level emerges as a more enticing choice due to its lower cost implications.

Keywords: Matenggeng Dam, Feasibility Study, Sensitivity Analysis

Introduction

The construction of Matenggeng Dam has several preferences and alternatives to consider. Each alternative may bring diverse benefit and disbenefit, which affect the utilization of the dam. The dam itself is a national project which is located in the Matenggeng area and impounds water from the flow of the Cijolang River, the tributary of the Citanduy River. There are three districts affected by the construction of this dam, namely Cilacap, Ciamis, and Kuningan (Handoko et al., 2014; KPPIP, 2023; Pangaribuan et al., 2014). The Matenggeng Dam is a multi-purpose dam, thus its main benefit as a supplier of raw water for irrigation. Alongside the benefits, there are also impacts from the acquisition, such as the loss of livelihoods and the conversion of areas into reservoirs or water storage areas (Pujiriyani et al., 2021).

Contemporary infrastructure project feasibility studies employ a holistic approach, encompassing technical, economic, and environmental assessments. This comprehensive analysis quantifies the monetary valuation of anticipated environmental, social, and economic changes associated with each project option, thereby informing the selection of the most advantageous course of action (Bracarense et al., 2016). Economic analysis serves as a fundamental approach to assess the viability of project development (Ssegawa & Muzinda, 2021). Parameters such as Net Present Value (NPV), Benefit Cost Ratio (BCR), Payback Period (PBP) or Discounted Payback Period (PBP), and Internal Rate of Return (IRR) are commonly utilized indicators (Marsudi et al., 2021). Several prior studies have focused on conducting economic analyses within the context of feasibility studies for national infrastructure projects in Indonesia. For instance, Kalsum et al. (2020) conducted an economic feasibility assessment of the Gintung Dam renovation, Marsudi et al. (2021) evaluated the development of raw water intake and pipelines in Kota Bangun, and Nashrulloh et al. (2021) examined the feasibility of the hydropower project at the Sepaku Semoi Dam. Furthermore, the economic analyses can be combined with sensitivity analysis on certain parameters to evaluate the change impact on the project feasibility. For instance, Gracia-Faure et al. (2023) used the sensitivity analysis on two options of wind turbine feasibility study.

NPV, IRR, BCR, and PBP are commonly used metrics for evaluating the feasibility of the dam project. Typically, one-way sensitivity analysis is employed in project feasibility studies to assess the impact of individual factors on these metrics (Iooss & Saltelli, 2015; Karanovic et al., 2010; Wantah & Kitri, 2021). However, the Matenggeng Dam project offers multiple options, including water levels and the implementation of municipal water enhancement. Each option presents variations in irrigation field area, construction cost, and land acquisition cost, all of which significantly influence the feasibility of the dam. Moreover, the dam holds considerable potential for diverse beneficial activities and purposes, necessitating comprehensive calculations during the analysis. With two options for municipal water enhancement and four water level choices, the project presents a total of 48 scenarios that involve various changes in benefit, disbenefit, and cost factors. Consequently, a hierarchical two-way sensitivity analysis approach becomes crucial to evaluate the project comprehensively.

This study aims to assess the economic feasibility of the Matenggeng Dam development plan by considering the benefits gained by local residents, incurred losses, and expenses. Moreover, this study is important to explain how the project will affect the economy, making sure that building it brings real benefits to the surrounding population. This analysis is meant to help make decisions and back the creation of a project that clearly improves the economic situation in the area. Factors that influence the project feasibility change over project options. Therefore, an analysis needs to be performed to understand how changes in these factors can affect the feasibility results. This study explores the result of various water level options and benefit scenarios in the project feasibility by conducting a hierarchical analysis, and performing two-way sensitivity analysis. In addition, the analyses can be used to select the most advantageous options.

Research Methodology

This research study will utilize an investment evaluation framework, which is a valuable tool for assessing the long-term feasibility and profitability of an investment. To determine the feasibility of the investment, certain criteria are considered. The BCR value should be greater than 1, indicating positive returns. The NPV value should be greater than 0, signifying a positive value of future cash flows. The PBP should be shorter than the project's lifespan, ensuring timely recovery of the initial investment. Additionally, the IRR should exceed the MARR or the specified interest rate used in the analysis (Kalsum et al., 2020; Wiratama, 2020).

For this research, secondary data will be employed, obtained from reports and analyses conducted by expert teams involved in the feasibility assessment of the Matenggeng Dam construction project. The data sources include socio-economic reports, hydrological reports containing information on river discharge and water flow from the dam, estimated construction and acquisition costs, reports on the plan for hydropower plant (HPP/PLTA) development, and statistical data from the local Central Bureau of Statistics (BPS) report.

Matenggeng Dam

The Matenggeng Dam is located in three regencies, namely Cilacap, Ciamis, and Kuningan. There are 14 villages affected by the construction of the dam, as shown in **Error! Reference source not found.**, and the dam location in **Error! Reference source not found.**. The construction of the Matenggeng Dam is divided into three phases, namely land acquisition in 2024, construction period from 2025 to 2029, and impoundment period for two years after the construction. Consequently, the optimal utilization of the dam is projected at 2032.

Considering the critical role dams play in infrastructure and resource management, their design lifespan generally ranging from 50-100 years (Ho et al., 2017; Jia et al., 2008; Perera et al., 2021). Hence, modern safety regulations enforce rigorous modeling and failure scenario examination for up to 100 years to ensure public safety (Wan-Wendner, 2018). Therefore, the intended lifespan of the Matenggeng Dam is 50 years, thus benefits, maintenance cost, and cash flow calculations are forecasted up to 2082.

The construction of the Matenggeng Dam offers four normal water level (NWL) options which are 190m, 194m, 197m, and 199m. In the other hand, the construction of Matenggeng Dam also considered the enhancement of municipal water by increasing the raw water supply as the dam functioned. Each alternative entails specific agricultural benefits and costs, outlined in **Error! Reference source not found.**.

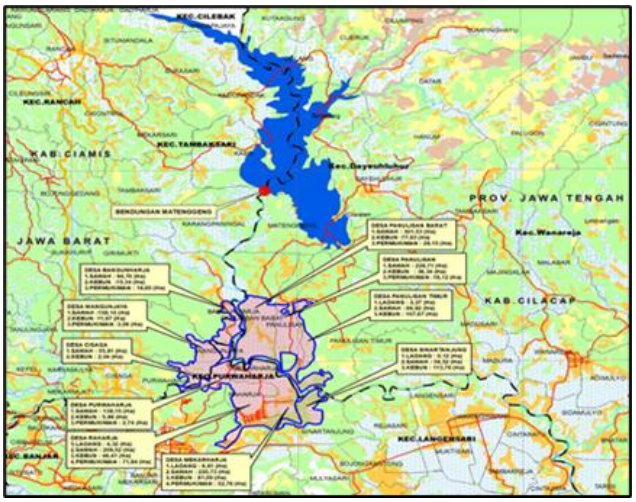

Figure 1. Matenggeng Dam Location

Table 1. Affected Area of Matenggeng Dam Construction

West Java Province		
District	**Sub-district**	**Village**
Ciamis	Rancah	Situmandala
	Tambaksari	Kadupandak
		Kaso
		Karangpaningal
Kuningan	Cilebak	Mandapajaya
Central Java Province		
District	**Sub-district**	**Village**
Cilacap	Dayeuhluhur	Dayeuhluhur
		Matenggeng
		Ciwalen
		Bolang
		Kutaagung
		Datar
		Cijeruk
		Bingkeng

Table 2. Additional Field, Construction Cost, and Land Acquisition Cost for Each Option

	Water Level (m)	Additional Field (Ha)			Construction Cost (IDR 1,000,000)	Land Acquisition (IDR 1,000,000)
		Season 1	Season 2	Season 3		
Without Municipal	190	5,958	1,002	15,631	6,528,730	1,227,880
	194	11,236	1,002	15,825	6,156,099	2,388,688
	197	11,261	1,002	15,825	6,243,137	2,388,688
	199	11,261	1,002	15,825	9,289,280	2,851,052
With Municipal	190	4,680	3,547	13,376	6,528,730	1,227,880
	194	12,665	3,547	18,370	6,156,099	2,388,688
	197	13,273	3,547	18,370	6,243,137	2,388,688
	199	13,806	3,547	18,370	9,289,280	2,851,052

Research Results and Discussion

Discount Rate

Discount rate is utilized to transform the costs and benefits of distinct years into the monetary value of a reference year. Typically, the discount rate fluctuates based on the investment inclinations of investors, the investment interest rate, and other related factors.

In the investment perspective, Minimum Acceptable Rate of Return (MARR) has to be decided as the minimum expected return where the investment is attractive. The selected MARR level will be utilized as the discount factor in the calculation of the economics analysis. Researchers have explored the best discount rate to use when evaluating the costs and benefits of transportation infrastructure projects. (Asplund, 2018) studied this in Sweden and found that a rate of 5.1% is most suitable, which is higher than the current preferred rate of 3.5%. Similarly, (Hargianti, 2021) and (Hanun et al., 2023) used a rate of 5.75% which taken from Indonesia's national bank rates in their project feasibility analysis. (Amalia et al., 2015) and (Yafril & Priyambodho, 2023) utilized a 10% interest rate in their feasibility analysis, which was also employed as the MARR. (Hutasoit et al., 2021) referred to the company's standard MARR of 10.25% when analyzing the upcoming project. In contrast, (Novirani & Irianto, 2009), (Reskita Lubis & Fitriani, 2018), (Mentari & Daryanto, 2018), and (Irwanto & Abi, 2023), did research on business investment and infrastructure project feasibility, they adopt 12% as the interest. According to these previous research, 10% and 12% is normally used as the interest of project feasibility study.

Based on the World Bank data (www.data.worldbank.org), loan interest rates in five consecutive years from 2017 to 2021 for Indonesia are 11.07%, 10.54%, 10.37%, 9.55% and 8.92%. The average of these rates is 10.08%, which was then selected as the interest rate to calculate the project feasibility. The upper limit of the discount rate is set to be 12%. The 10.08% and 12% of interest rate meet the conventional administrative rate used by Asian Development Bank (Castillo & Zhangallimbay, 2021).

Benefits and Disbenefits

The implementation of new infrastructure projects can lead to improvements in public living standards and knowledge through various means (Ayunda & Sambowo, 2020). There would be many benefits of the construction of a dam (Dinas Sumber Daya Air Provinsi Jawa Barat, 2019). At least seven benefits and two disbenefits may have occurred by constructing the Matenggeng Dam. As the dam is fully functional, there is potential to increase the irrigation flow and therefore there will be more additional agriculture fields. The main commodities in the surrounding area are rice and corn. Rice is usually planted twice a year while corn once at the end of the year (Badan Perencanaan Pembangunan Kabupaten Ciamis, 2021). According to the hydrology analysis report, on average there will be 9,000 to 11,000 hectares of new field. The dam is also expected to overcome the flood disaster which often strikes six villages near Cilacap regency. The flood was reported to be 50 centimeters inside the house. It potentially damages houses, furniture, delays income, causes crop failure, and afflicts the residents (BNPB, 2022; Dinas Sumber Daya Air Provinsi Jawa Barat, 2019). According to (Sawsan et al., 2019) the current of dam spillway is very potential as the source of energy, especially hydropower plant. Fortunately, a 17 megawatts hydropower plant has been planned for realization. The benefit of the hydropower plant is estimated to be IDR 77 billion. The water flow can also be utilized to supply the local water utility (PDAM). Around 4.3 m3/s of raw water is estimated to be used by the local water utility to increase the clean water supply. Dam area also very potential for tourism (Duda-Gromada, 2012; Teigland, 1999). Research that has done by (Partono & Rahman, 2017) found that Colo Dam can be developed for tourism activity. The construction of Matenggeng dam is expected to provide economic benefits in terms of business opportunities. This expectation is reflected in more than 60% of respondents based on the result of socio-economic study. This benefit can also be beneficial to the local government through ticket retribution.

Aside from the dam benefits, the dam construction also requires some effort from the local residents who lived in the inundation area. By itself, as a logical consequence, areas that previously could have been productive areas such as agricultural land, plantation areas and others became submerged by reservoir water. Due to the sinking of the area, there is reduced productive land, which means that the number of livelihoods that previously utilized productive land, could no longer be carried out (Heming et al., 2001; Lin, 2011). This condition illustrates the occurrence of losses from the construction of the Matenggeng dam. Several types of livelihoods that can no longer be carried out on the land such as farmers, farm laborers, casual daily laborers, shop traders, breeders and carpentry.

Hierarchical Two-Way Sensitivity Analysis

As previously mentioned, there are multiple options available for the dam construction, and each option needs to be carefully assessed to determine the most advantageous choice. The analysis considers two different interest rates: 10.08% and 12%. Additionally, there are two schemes to consider regarding the enhancement of municipal water supply. Furthermore, there are four water levels being evaluated: 190m, 194m, 197m, and 199m. These water levels vary in terms of the additional agriculture field, construction cost, and land acquisition cost. The analysis also takes into account three benefit scenarios: only agriculture benefit (S1), agriculture and hydropower benefit (S2), and all potential benefits as on the table 3 (S3). These benefit scenarios enact a crucial role in understanding the potential outcomes along with impacts of the dam development in the future.

By considering these various options and scenarios, a hierarchy can be established to guide the analysis, as depicted in **Error! Reference source not found.**. The analysis is structured into different levels. At the first level, the interest rate is varied to observe its impact. Moving to the second level, the analysis incorporates the presence or absence of municipal water enhancement and finally, the diverse options of water levels are examined. The results obtained from each level of analysis are then assessed within the three previously mentioned benefit scenarios.

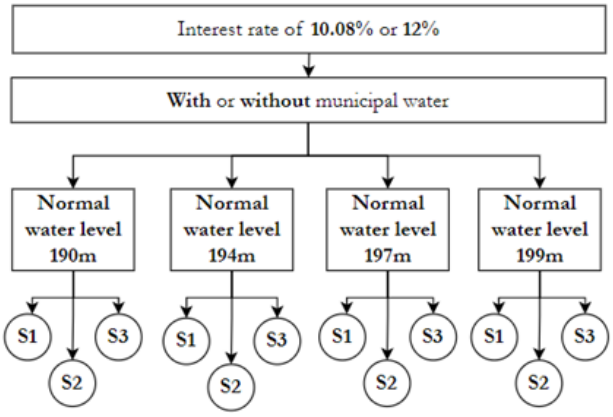

Figure 2. Model Hierarchy of Sensitivity Analysis

As delineated in **Error! Reference source not found.**, distinct agricultural field potentials accompany each water level alternative. **Error! Reference source not found.** delineates the NPV associated with the enhanced water availability for irrigation benefits corresponding to each water level option. The NPV attributed to agricultural benefits is notably greater when municipal water resources are considered, in contrast to scenarios where municipal sources are absent. Consequently, this observation does not hold true for the 190m water level, as the incremental agricultural field is diminished when the municipal infrastructure is established. The findings of the analysis are presented in **Error! Reference source not found.** for i=10.08%, which represents the expected results of the project investment, and **Error! Reference source not found.** for i=12%, representing the worst-case scenario. It is evident that when not considering the municipal water enhancement, none of the options are feasible, as indicated by negative NPV and a BCR below 1. However, when incorporating the municipal water enhancement, two water level options, namely 194m and 197m, are deemed feasible at i=10.08%. Furthermore, in the scenario considering only the agriculture benefit, the NPV for both water levels is approximately IDR 293 billion and IDR 344 billion respectively. The NPV significantly increases when considering all potential benefits, reaching around IDR 1.9 trillion and IDR 2 trillion respectively, with a PBP of approximately 22 years after the dam is fully operational. The BCR for both water levels is 1.29, indicating that the estimated benefits outweigh the costs incurred. However, at i=12%, both water level options remain infeasible due to an IRR of 11.52% and 11.54% respectively.

Among the various choices, only considering municipal water enhancement at water levels of 194m and 197m are feasible options. **Error! Reference source not found.** displays the calculated monetary values of the benefits and drawbacks for the feasible options, namely the 194m and 197m water levels. It is worth noting that the discrepancy between these options is observed in the agriculture benefit, with a deviation of approximately IDR 100 billion. According to **Error! Reference source not found.**, the construction cost deviation for both water levels is approximately IDR 90 billion or 1.5% higher than the construction cost of the 194m water level. When comparing the results of both water level options, the additional expense of IDR 90 billion seems unjustified for a mere 0.02% increase in the IRR. Consequently, opting for municipal enhancement at the 194m water level appears to be the most advantageous choice for the project.

Table 3. The Increased Water Availability for Irrigation Benefits of Each Water Level

Water Level (m)	Without Municipal (IDR 1,000,000)	With Municipal (IDR 1,000,000)
190	4,971,777	4,696,138
194	6,042,996	7,404,881
197	6,047,857	7,523,107
199	6,047,857	7,626,749

Table 4. Feasibility Analysis at i = 10.08%

	Water Level (m)	Agriculture Benefit (S1)				Agriculture and HPP Benefit (S2)				All Benefits (S3)			
		NPV (IDR 1,000,000)	PBP	IRR	BCR	NPV (IDR 1,000,000)	PBP	IRR	BCR	NPV (IDR 1,000,000)	PBP	IRR	BCR
With Municipal	190	-1,648,053	50+	8.37%	0.73	-1,641,034	50+	8.41%	0.73	-37,345	50+	10.04%	0.99
	194	293,260	40.74	10.31%	1.04	370,533	39.05	10.36%	1.05	1,974,222	22.03	11.52%	1.29
	197	344,430	39.64	10.35%	1.05	421,703	38.09	10.40%	1.06	2,025,391	21.86	11.54%	1.29
	199	-2,318,774	50+	8.59%	0.76	-2,177,985	50+	8.70%	0.78	-574,296	50+	9.73%	0.94
Without Municipal	190	-1,372,415	50+	8.68%	0.78	-1,365,395	50+	8.72%	0.78	-471,565	50+	9.61%	0.92
	194	-1,068,625	50+	9.16%	0.85	-991,353	50+	9.24%	0.86	-97,522	50+	9.99%	0.99
	197	-1,130,820	50+	9.11%	0.84	-1,053,548	50+	9.20%	0.85	-159,717	50+	9.94%	0.98
	199	-3,897,667	50+	7.38%	0.60	-3,756,877	50+	7.54%	0.61	-2,863,047	50+	8.18%	0.71

Table 5. Feasibility Analysis at i = 12%

	Water Level (m)	Agriculture Benefit (S1)				Agriculture and HPP Benefit (S2)				All Benefit (S3)			
		NPV (IDR 1,000,000)	PBP	IRR	BCR	NPV (IDR 1,000,000)	PBP	IRR	BCR	NPV (IDR 1,000,000)	PBP	IRR	BCR
With Municipal	190	-4,043,193	50+	8.59%	0.55	-3,976,775	50+	8.70%	0.56	-2,897,870	50+	9.73%	0.68
	194	-2,659,011	50+	8.37%	0.53	-2,682,939	50+	8.41%	0.53	-1,604,034	50+	10.04%	0.72
	197	-1,570,888	50+	10.35%	0.76	-1,547,368	50+	10.40%	0.76	-468,463	50+	11.54%	0.93
	199	-1,590,524	50+	10.31%	0.75	-1,567,005	50+	10.36%	0.76	-488,100	50+	11.52%	0.92
Without Municipal	190	-2,471,331	50+	8.68%	0.56	-2,495,260	50+	8.72%	0.56	-1,844,580	50+	9.61%	0.67
	194	-2,517,819	50+	9.16%	0.61	-2,494,299	50+	9.24%	0.61	-1,843,619	50+	9.99%	0.71
	197	-2,575,371	50+	9.11%	0.60	-2,551,851	50+	9.20%	0.61	-1,901,171	50+	9.94%	0.71
	199	-5,118,245	50+	7.38%	0.43	-5,051,827	50+	7.54%	0.44	-4,401,147	50+	8.18%	0.51

Table 6. Benefits and Disbenefits Monetary of 194m and 197m Water Level

Benefits	NPV at i = 10.08%		NPV at i = 12%	
	194m*	197m*	194m*	197m*
The increased water availability for irrigation	7,404,882	7,523,108	5,041,910	5,122,409
Development of hydropower plant (HPP)	77,272	77,272	23,520	23,520
Reduce the flood risk	616,548	616,548	435,822	435,822
Water supply to meet the demand for clean water	709,858	709,858	428,225	428,225
District income from ticket retribution	747	747	512	512

Benefits	NPV at i = 10.08%		NPV at i = 12%	
	194m*	**197m***	**194m***	**197m***
Small scale business opportunities	197,594	197,594	138,714	138,714
Local residents work during the construction period	78,941	78,941	75,633	75,633
Disbenefits				
Loss livelihoods in inundated areas	60,724	60,724	59,189	59,189
Handling during the relocation process	138,134	138,134	135,766	135,766

*Monetary unit IDR 1,000,000

Conclusion

Based on the analytical examination conducted in this study, certain conclusions can be derived.

a. There are numerous benefits associated with the construction of the Matenggeng Dam, with its primary advantage being agricultural benefits.
b. There are drawbacks experienced by local residents, primarily stemming from the land acquisition and relocation process.
c. Based on economic valuation at a 10.08% interest rate, constructing the dam with municipal water enhancement at water levels of 194m and 197m proves to be feasible options, even when solely considering the agricultural benefit. Calculating all the estimated benefits further enhances the project's appeal.
d. The marginal increase of 0.02% in the Internal Rate of Return (IRR) by incurring an additional construction cost of approximately IDR 90 billion between the 194m and 197m water levels appears to be unjustifiable
e. Constructing the dam with municipal water enhancement at the 194m water level emerges as the most advantageous choice.

The outcomes of this study have significant implications for future practice and research. Given that the economic evaluations do not surpass the upper limit of i=12%, it becomes crucial to ensure that the dam's benefits are genuinely experienced by the residents, thus justifying the retention of the 10.08% interest rate threshold.

The metadata for a project feasibility study typically originates from researchers interpolating historical and current data to model the trajectory of variables such as price and population. In subsequent research endeavors, it is anticipated that historical socio-economic data could serve as a database for machine learning. This advancement holds the potential to enhance the precision of future projections, consequently leading to a more accurate assessment of feasibility.

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