Feasibility Study of Dam Development: Sustainable Flood Mitigation Strategies

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Feasibility Study of Dam Development: Sustainable Flood Mitigation Strategies

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Abstract: *Flooding in the downstream region of the Citarum River, coupled with the increasing population growth in West Java Province, necessitates effective intervention strategies. One potential solution is the construction of Cijurey Dam in the downstream area. This study evaluates the economic feasibility of the dam's construction through a comprehensive economic analysis, including Net Present Value (NPV), Economic Internal Rate of Return (EIRR), Benefit-Cost Ratio (BCR), and sensitivity analysis. The analysis yielded an NPV of* $ 132, *a BCR of 4.99, an EIRR of 18.54%, and a payback period (PP) of 9.20 years. Additionally, the feasibility assessment considered three alternative design plans for the Cijurey Dam, impacting reservoir storage volume and the dam's overall benefits. The results indicate that Alternative 1 offers the highest benefit value and the greatest economic feasibility.*

Keywords: Economic Feasibility; NPV; EIRR; BCR; Sensitivity Analysis

1. INTRODUCTION

Flooding in the downstream area of the Citarum River is a significant concern for West Java Province. The region's increasing population has heightened the demand for food, emphasizing the need for effective water management as part of food security programs [1]. A key government initiative aims to ensure a reliable water supply for irrigation during the dry season and to expand irrigation areas [2]. To meet these objectives, sustained efforts in the protection, control, development, and utilization of water resources are essential. One effective strategy is the construction of dams, which can regulate water flow, prevent flooding, and support agricultural irrigation needs [3].

The construction of the Cijurey Dam in the lower Citarum River is a critical flood control measure designed to address the region's challenges. This dam aims to reduce flood discharge and mitigate flood inundation in the lower Citarum River [4]. Moreover, it will increase water availability for raw water supply, irrigation, and mini hydro power. The proposed site for the Cijurey Dam is in Sukamakmur Sub-district, Bogor Regency, West Java Province, located approximately 120 km from Bandung City via the Sawahan Line (Bandung City - Jonggol - Sukamakmur Bogor Regency).

To realize the construction of the Cijurey Dam in the downstream region of the Citarum River, it is essential to conduct an economic feasibility study. This study aims to ensure the project's economic sustainability by evaluating its effectiveness, timeliness, and efficient use of funds and resources throughout the project period. A project is considered economically feasible if it is necessary and capable of providing greater benefits or comparable benefits at a lower cost compared to alternative options.

2. MATERIALS

This economic feasibility analysis offers a comprehensive evaluation from the government's perspective, considering social costs and benefits that impact society. It includes key economic indicators such as Net Present Value (NPV), Economic Internal Rate of Return (EIRR), Benefit-Cost Ratio (BCR), and sensitivity analysis. The feasibility analysis is based on two main concepts: economic analysis and financial analysis [5]. Project evaluation involves assessing feasibility by calculating the values of EIRR, NPV, and BCR. Moreover, providing affordable, sustainable, and modern energy is a key objective of the United Nations' sustainable development goals. Therefore, it is crucial to explore the interconnections between energy consumption, economic growth, and CO_2 emissions [15]. Land use and land cover changes significantly impact the economic feasibility of projects due to their influence on climate dynamics, particularly in areas prone to flooding [16].

The economic value of a project typically extends over many years, with benefits and costs that vary over time. To account for this variability, it is necessary to select a specific time point and convert all future benefits and costs to that time. In this study, the economic feasibility analysis examines the benefits and costs associated with the construction of the Cijurey Dam.

2.1 Benefit Analysis

The benefits of the Cijurey Dam project stem from the incremental advantages of irrigation water, raw water, small-scale hydroelectric power, and flood control. The value of the flood control benefits is based on the estimated total losses due to flooding in the Lower Citarum River, as detailed in the previous subchapter, amounting to $ projected 59-year useful life of the Cijurey Reservoir. Annual benefit values are determined and adjusted with an inflation rate of 4.13%, resulting in a total flood control benefit of $ 3,179,374.

The water supply benefit is analyzed based on the annual clean water production, multiplied by the clean water tariff set by the local government of Bogor Regency. This tariff is calculated at 50% of the average unit price of clean water for each class in PDAM Tirta Pakuan Bogor City in 2018 and projected for 2025 with an inflation rate of 4.13%. Consequently, the total benefit of providing raw water for households and industry is estimated at $ 2,050,320.

The benefit of irrigation water from the Cijurey Dam is calculated as the profit from the sale of agricultural products minus the costs incurred during the planting period. This benefit is projected over the next 59 years, with the value increasing annually to an inflation rate of 4.13% and discounted at an interest rate of 5.75%. Consequently, the total benefit of providing irrigation services is estimated to be $ 385,074.

The benefits of providing electrical energy are derived from selling electricity to state electricity companies for distribution to customers and from the electrical energy output produced by mini hydro power (MHP). These benefits are calculated by multiplying the annual electricity generation by the electricity sales tariff set by the Ministry of Energy and Mineral Resources in 2021, which is $ 0.10 per kWh. This tariff is projected to increase to $ 0.12 per kWh by 2025, considering an inflation rate of 4.13%. Consequently, the total benefit is estimated to be $ 178,170.

Table 1. Recapitulation of Benefit Value of Cijurey Dam Construction

No	Benefit Analysis	Benefit Value ($)
1	Benefits of Flood Control	3,179
2	Benefits of Raw Water Provision	2,050
3	Benefits of Irrigation Service Provision	385
4	Benefits of Mini Hydro Power	178

The total benefits highlighted in Table 1 underscore the multifaceted advantages of constructing the Cijurey Dam. The significant economic value derived from flood control and raw water provision reflects the critical need for effective water management and disaster mitigation strategies. By addressing water scarcity and flood risks, the dam contributes to both immediate and long-term economic stability and development.

Furthermore, the benefits associated with irrigation services and mini hydro power demonstrate the broader environmental and social impacts of the dam. Improved agricultural productivity and renewable energy generation contribute to sustainable development goals, supporting local economies and enhancing the quality of life for surrounding communities.

In conclusion, the Cijurey Dam's construction presents a compelling case for its multifaceted benefits, which extend beyond mere economic value to encompass environmental sustainability and social well-being. These benefits justify the investment and highlight the importance of integrated water resource management in achieving sustainable development objectives.

2.2 Economic Cost Analysis

In the economic analysis, the cost value of the economic component includes construction costs (direct costs), administrative costs, consultant service costs, unexpected costs, and operational and maintenance costs, all adjusted by a conversion factor. The construction cost component for the Cijurey Dam in Bogor Regency, as analyzed in this report, encompasses expenses from initial preparation to complementary structures, with a total economic cost of $ 157,876,620.

The total initial investment cost is the sum of the construction cost of Cijurey Dam. In allocating the initial investment cost, the cost components will be used simply using the joint cost calculation. Furthermore, it allocates separable costs according to each objective. The value of the joint cost and separable cost will be summed up to obtain the initial investment cost. Furthermore, the depreciation value is calculated by charging the initial investment cost minus the residual value at the end of the age (assuming $ 0.00 / no residual) during the useful life of each construction benefit.

Operational costs are costs incurred to support operations during the useful life such as maintenance costs and wages of OP officers. The operational costs incurred in the first year are assumed to be 10% of the depreciation value. Then, for the following years the cost is assumed to increase by 4.13%. A recapitulation of each cost can be seen on the table below.

Table 2. Recapitulation of Cost Value of Cijurey Dam Construction

No	Cost Analysis	Cost Value ($)
1	Construction Cost	16,915,352
2	Initial Investment Cost of Raw Water Supply	1,031,096
	Initial Investment Cost of Electric Energy Supply	206,564
	Initial Investment Cost of Irrigation Services	188,910
	Initial Investment Cost of Flood Control	1,559,742
3	Operational Cost of Raw Water Supply	103,109
	Operational Cost of Electricity Supply	20,656
	Operational Costs of Irrigation Services	18,891
	Operational Cost of Flood Control	155,974

3. RESULT AND DISCUSSION

3.1 Economic Feasibility Analysis

Economic feasibility analysis is an analysis of the economy seen from the government's point of view, so that the costs and benefits considered are social costs and benefits that have an overall impact on society. Broadly speaking, economic feasibility analysis includes economic analysis consisting of Net Present Value (NPV), Economic Internal Rate of Return (EIRR), Benefit Cost Ratio (BCR) and sensitivity analysis.

3.1.1 NPV (Net Present Value)

NPV is the difference between benefits and costs at the present value of costs. Based on the calculation, the NPV value of various benefits > 0, so the purpose of the Cijurey Dam construction for flood control in the downstream of the Citarum River, the provision of industrial raw water in the Jonggol area, for irrigation services covering an area of 2047 ha in Cihoe – Cikompeni irrigation area, and the Cijurey plant electrical energy provider is said to be economically feasible.

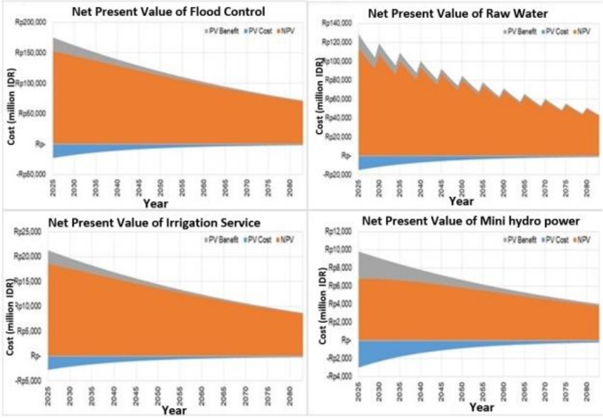

Fig 1. NPV graph of various benefits

Table 3. NPV of Various Benefits

Benefits	PV Benefit ($)	PV Cost ($)	NPV ($)
Flood Control	456.94	-29.75	427.20
Raw Water Provider	302.07	-19.67	282.40
Irrigation Service	55.34	-3.60	51.74
Electrical Energy Provider	25.57	-3.94	21.63

3.1.2 BCR (Benefit Cost Ratio)

BCR analysis is an analysis needed to see the extent of the comparison between benefit and cost under present value conditions. The economic evaluation of the project shows a significant benefit-cost ratio, illustrating its high potential for financial returns. The economic evaluation of a project is crucial in determining its feasibility and potential financial returns. When the Benefit-Cost Ratio (BCR) value at the prevailing interest rate is greater than 1 (BCR > 1), the project is considered feasible, indicating that the benefits outweigh the costs. Otherwise, if the BCR value is less than 1 (BCR < 1), the project may not be deemed feasible for implementation [8].

In the context of Indonesia, where various development projects are being considered, such as the development of irrigation channels [9], the improvement of maritime affairs through port development [10], and the construction of economic flyovers [11], conducting thorough economic feasibility studies becomes essential. These studies typically involve assessing parameters like Net Present Value (NPV), Internal Rate of Return (IRR), and BCR to gauge the economic viability of the projects [12]. Moreover, the application of sustainable drainage systems, such as Low Impact Development (LID) techniques like permeable pavement [13], can contribute to improving water quality and reducing environmental impacts in Indonesia. These sustainable practices not only address drainage issues but also offer economic benefits by potentially lowering capital costs and operating expenses [14]. The economic evaluation of projects in Indonesia, including drainage systems and infrastructure development, plays a significant role in decision-making processes. By considering factors like BCR, NPV, and IRR, stakeholders can assess the financial viability of projects and make informed choices to ensure sustainable and economically feasible outcomes.

The Total Present Value Benefit (PVB) of the project is $ 839,923,940, which indicates the aggregate expected benefits from the project over its lifespan. In contrast, the Total Present Value Cost (PVC) stands at $ 168,163,838, reflecting the total anticipated expenses required to complete and maintain the project. By dividing the PVB by the PVC, we calculate the Benefit-Cost Ratio (BCR), which is 4.99. This means that for every unit of currency spent, the project yields nearly five units in benefits. Such a high BCR underscores the project's economic viability, suggesting that it is a highly profitable investment with substantial potential returns compared to its costs. This ratio is crucial for stakeholders and investors as it provides a clear indication of the project's financial attractiveness and efficiency in resource utilization.

The Benefit Cost Ratio (BCR) value of Cijurey Dam Construction with the average interest rate of the last 10 years (i = 5.75%) is 4.99 where the BCR value > 1, it can be concluded that the Cijurey Dam Project is economically feasible.

3.1.3 EIRR (Economic Internal Rate of Return)

The Benefit Cost Ratio (BCR) value of Cijurey Dam Construction with the average interest rate of the last 10 years (i = 5.75%) is 4.99 where the BCR value > 1, it can be concluded that the Cijurey Dam Project is economically feasible.

3.1.4 PP (Payback Period)

Payback Period (PP) is the time required for any project objective to return the initial investment capital. Under the PP criteria, a proposal is considered economically feasible if the PP is less than the useful life. To calculate PP, benefits, and operating costs in the first year are used as a reference.

The Payback Period (PP) is a financial metric used to evaluate the time needed for an investment to recover its initial capital outlay. According to the PP criteria, a project is deemed economically feasible if the PP is less than the useful life of the investment. This criterion aids stakeholders in assessing the speed of recovering initial costs and acts as a guide for determining the acceptability of an investment project [19-22].

Calculating the PP involves using the benefits and operating costs in the first year as a reference point. By comparing the PP to the useful life of investment, decision-makers can assess the project's financial viability and alignment with the organization's investment objectives [23-25]. The Payback Period is a fundamental tool in financial analysis, offering insights into the time required for an investment to break even and generate positive returns. By utilizing the PP criterion, organizations can evaluate the economic viability of projects and make strategic investment decisions to achieve long-term sustainability and profitability.

The financial projection for the project's first year shows substantial benefits and a promising payback period. The First Year Benefit (B1) is calculated to be $ 23,689,712, which represents the revenue or savings generated by the project in its initial year of operation. The Operating Cost (OP1), the expense required to run the project for the same period, is $ 278,722. The Initial Investment Cost (I), the total upfront expenditure needed to launch the project, stands at $ 157,876,619. To evaluate the financial viability, we calculate the Payback Period (PP) using the formula.

$$\text{Payback Period (PP)} = \frac{B1 - OP1}{I} \quad (1)$$

Plugging in the values, the net benefit for the first year is $ 23,411,323 (B1 - OP1). Dividing this net benefit by the initial investment cost, we have a payback period of approximately 9.20 years. This means the project will recover its initial investment through net benefits generated over roughly nine years, indicating a strong long-term financial feasibility and making it an attractive investment for stakeholders.

The PP value for the Cijurey Dam Construction construction project is obtained for 9.20 years while the useful life of the reservoir is estimated for 59 years. So, it can be concluded that the Cijurey Dam construction project is economically feasible.

3.1.5 Sensitivity Analysis

Sensitivity analysis is an essential component of economic evaluations, providing a robust assessment of how changes in key project assumptions can impact outcomes. For the Cijurey Dam project, this analysis considers four critical factors: potential cost overruns, fluctuations in price levels, delays in project implementation, and deviations in yield estimates. Each of these factors can significantly influence the financial viability of the project. By examining these variables, the analysis helps to identify the potential risks and challenges that could arise during the project lifecycle, offering a clearer understanding of its resilience and reliability.

The study evaluates the Cijurey Dam project under four distinct scenarios to gauge its sensitivity. The first scenario assumes normal conditions with fixed costs and benefits, serving as a baseline for comparison. The second scenario explores a 10% increase in costs while keeping benefits constant, illustrating the impact of cost overruns. The third scenario combines a 10% increase in costs with a 10% decrease in profits, highlighting the effects of simultaneous adverse changes. The fourth and most comprehensive scenario considers a 10% rise in costs, a 10% drop in benefits, and a one-year project delay, representing a worst-case scenario. This thorough approach ensures a comprehensive evaluation of the project's economic viability under varying conditions.

Table 4. Recapitulation of Economic Feasibility Analysis Results of Cijurey Dam in Bogor Regency

Conditions	EIRR (%)	BCR i = 12%	NPV ($)
Normal	18.5	1.8	132
Investment Costs Up 10% - Fixed Benefit	17.2	1.6	115
Investment Costs Up 10% - Benefit Down 10%	15.9	1.5	85
Investment Costs Up 10% - Benefit Down 10%, Project delayed by 1 year	15.9	1.5	85

The table demonstrates that the Cijurey Dam project is economically viable under various scenarios, although its attractiveness diminishes with increasing costs and reduced benefits. Under normal conditions, the project shows strong economic returns. Even with a 10% increase in costs or a combination of increased costs and reduced benefits, the EIRR remains above the 12% threshold, suggesting the project will likely proceed.

The consistent EIRR and NPV in scenarios involving delays indicate that the primary economic concern lies with investment cost and benefit variations rather than time delays, at least within the one-year scope considered. This could imply robust project planning and management but may also mask potential operational and societal costs of delays. In conclusion, the economic feasibility analysis supports the development of the Cijurey Dam under normal and varied economic conditions, albeit with careful consideration for cost escalations and benefit reductions. Effective risk management and mitigation strategies are recommended to address potential fluctuations in investment costs and project benefits.

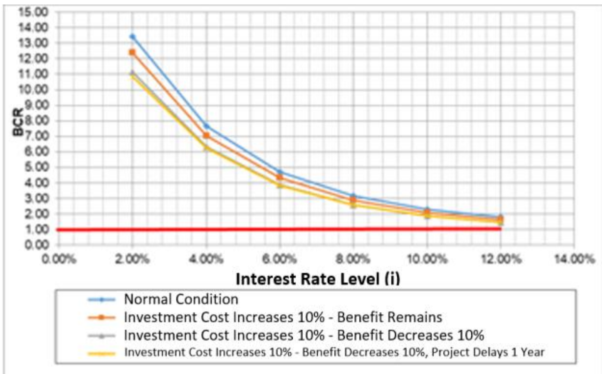

Fig. 2. EIRR Sensitivity Graph of Cijurey Dam Construction

The economic feasibility analysis of dam construction projects requires a thorough review based on several key financial metrics to determine if a project is viable. The primary criteria for assessing economic feasibility include Net Present Value (NPV) being greater than or equal to zero (NPV ≥ 0), a Benefit Cost Ratio (BCR) of at least one (BCR ≥ 1), and the Economic Internal Rate of Return (EIRR) exceeding the loan interest rate, specifically aiming for an EIRR greater than 12%. Meeting these criteria ensures that the project is not only viable but also economically beneficial.

In the case of the Cijurey Dam construction, the economic feasibility was analyzed considering an inflation rate of 4.13% and the average Bank Indonesia (BI) interest rate of 5.75% over the past decade. The analysis yielded the following results:

1. Net Present Value (NPV): The NPV of the Cijurey Dam project is $ 671,760,102. NPV measures the difference between the present value of cash inflows and outflows over the project's lifetime. A positive NPV indicates that the project's anticipated earnings exceed its costs, making it a sound investment.
2. Benefit Cost Ratio (BCR): The BCR for the Cijurey Dam is 4.99. This ratio compares the benefits of a project to its costs, with a BCR greater than 1 indicating that the benefits significantly outweigh the costs.
3. Internal Rate of Return (IRR): The IRR stands at 18.54%, well above the required 12%. IRR is the discount rate that makes the NPV of all cash flows from a project equal to zero. An IRR higher than the cost of capital suggests that the project is expected to generate substantial returns relative to its cost.

4. Payback Period (PP): The payback period for the project is 9.20 years. This metric indicates the time required for the project to recover its initial investment from its net cash inflows. A payback period of 9.20 years is reasonable, considering the project's long-term benefits.

These results collectively indicate that the Cijurey Dam project is economically feasible. The positive NPV, high BCR, strong IRR, and acceptable payback period all demonstrate that the project's benefits outweigh its costs, making it a viable investment that is expected to deliver significant economic returns.

3.2 Alternative Design Plans

In the economic feasibility analysis, a review was conducted in terms of the Cijurey Dam design plan. The design plan is carried out by alternatively lowering the height of the dam which will affect changes in the reservoir storage volume and the beneficial value of the dam itself. The following are some alternative design plans for the Cijurey Dam:

Alternative 1:

The Cijurey Dam's design incorporates several structural and functional elements to optimize flood control and conservation. The gated spillway is situated at an elevation of +280.00 meters above sea level (asl), with two gates measuring 8.00 meters wide and 7.00 meters high each. Complementing this, the ungated spillway is positioned at +286.00 meters asl and spans 2 x 16.00 meters in width. The dam's crest stands at +292.00 meters asl, while the base is at +207.00 meters asl, resulting in a total height of 85 meters. These design elements are critical for effective water flow management and structural stability.

For flood control, the Cijurey Dam has a storage volume of 3.74 million cubic meters, effectively reducing the flood peak (Q_{25}) by 59.33%. The maximum inflow rate is 291.47 cubic meters per second, while the controlled maximum outflow rate is 118.53 cubic meters per second. In terms of conservation, the dam provides a storage volume of 9.76 million cubic meters, enabling the irrigation of 2,047 hectares of rice fields with a cropping pattern of paddy-paddy-crops, achieving a planting intensity of 263% (MT1=100%, MT2=100%, MT3=63%). The average irrigation release discharge is 0.98 cubic meters per second, and the average raw water release discharge is 0.71 cubic meters per second. Additionally, the dam supports a mini hydro power (MHP) with a capacity of 2 x 0.50 MW, generating an annual energy output of 6,111.90 MWh. These multifaceted benefits underscore the dam's crucial role in regional water management and energy production.

Table 5. Economic Feasibility Analysis Based on Alternative 1 Cijurey Dam Design Plan

Economic Parameters	Alternative 1 ($)
PV of Raw Water Benefits	314
PV of Irrigation Benefits	58
PV of MHP Benefits	27
PV Flood Reduction Benefits	475
Total Benefit Value	**874**

Table 6. Economic Feasibility Analysis Based on Alternative 1 Cijurey Dam Design Plan

Sensitivity Conditions	Alternative 1
1. Normal Condition	
BCR (I = 12%)	1.78
IRR (%)	18.54%
NPV ($)	132
Feasibility check (BCR≥1, EIRR≥12% and NPV≥0)	**Feasible**
2. Investment Cost Increases 10% - Benefit Remains	
BCR (I = 12%)	1.62
IRR (%)	17.22%
NPV	115
Feasibility Check (BCR≥1, EIRR≥12% and NPV≥0)	**Feasible**
3. Condition of Investment Cost Increases 10% - Benefit Decreases 10%	
BCR (I = 12%)	1.46
IRR (%)	15.87%
NPV ($)	85
Feasibility Check (BCR≥1, EIRR≥12% and NPV≥0)	**Feasible**
4. Conditions Investment Cost Increases 10% - Benefit Decreases 10%, Project Delays 1 Year	
BCR (I = 12%)	1.46
IRR (%)	15.87%
NPV ($)	85
Feasibility Check (BCR≥1, EIRR≥12% and NPV≥0)	**Feasible**

The analysis indicates that the Cijurey Dam project is economically viable under both normal and adverse conditions. Under normal conditions, the project demonstrates strong economic feasibility with high Benefit-Cost Ratio (BCR), Internal Rate of Return (IRR), and Net Present Value (NPV). In conclusion, the sensitivity analysis in Table 6 confirms the economic viability of the Cijurey Dam project under various conditions, emphasizing the need for meticulous cost management and benefit assurance to sustain its feasibility.

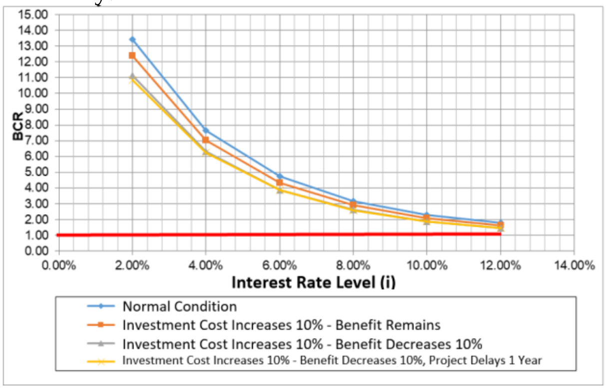

Fig. 3. EIRR Sensitivity Graph of Alternative 1

Alternative 2:

The Cijurey Dam is designed with several critical structural elements to optimize both flood control and conservation. The gated spillway is positioned at an elevation of +275.00 meters above sea level (asl), featuring two gates, each measuring 8.00 meters wide and 7.00 meters high. Additionally, the ungated spillway is located at +281.00 meters asl and spans 2 x 16.00 meters in width. The dam's crest is set at +287.00 meters asl, with the base at +207.00 meters asl, resulting in a total height of 80 meters. These specifications are essential for effective water flow management and ensuring the dam's structural stability.

The dam's flood control capabilities include a storage volume of 3.15 million cubic meters, reducing the flood peak (Q_{25}) by 43.58%. It can handle a maximum inflow rate of 291.47 cubic meters per second, while the controlled maximum outflow rate is 164.45 cubic meters per second. For conservation purposes, the dam provides a storage volume of 6.60 million cubic meters, supporting the irrigation of 2,047 hectares of rice fields. The cropping pattern is paddy-paddy-crops, achieving a planting intensity of 230% (MT1=100%, MT2=90%, MT3=40%). The average irrigation release discharge is 0.88 cubic meters per second, and the average raw water release discharge is 0.71 cubic meters per second. Additionally, the dam supports a mini hydro power (MHP) with a capacity of 2 x 0.50 MW, generating an annual energy output of 5,320.49 MWh. These features highlight the dam's multifaceted benefits in regional water management, agricultural irrigation, and energy production.

Table 7. Economic Feasibility Analysis Based on Alternative 2 Cijurey Dam Design Plan

Economic Parameters	Alternative 2 ($)
PV of Raw Water Benefits	304
PV of Irrigation Benefits	46
PV of MHP Benefits	23
PV Flood Reduction Benefits	338
Total Benefit Value	**712**

Table 8. Economic Feasibility Analysis Based on Alternative 2 Cijurey Dam Design Plan

Sensitivity Conditions	Alternative 2 ($)
1. Normal Condition	
BCR (I = 12%)	1.58
IRR (%)	16.89%
NPV ($)	90
Feasibility check (BCR≥1, EIRR≥12% and NPV≥0)	**Feasible**
2. Investment Cost Increases 10% - Benefit Remains	
BCR (I = 12%)	1.44
IRR (%)	15.71%
NPV ($)	75
Feasibility Check (BCR≥1, EIRR≥12% and NPV≥0)	**Feasible**
3. Condition of Investment Cost Increases 10% - Benefit Decreases 10%	
BCR (I = 12%)	1.30
IRR (%)	14.51%
NPV ($)	51
Feasibility Check (BCR≥1, EIRR≥12% and NPV≥0)	**Feasible**
4. Conditions Investment Cost Increases 10% - Benefit Decreases 10%, Project Delays 1 Year	
BCR (I = 12%)	1.30
IRR (%)	14.51%
NPV ($)	50
Feasibility Check (BCR≥1, EIRR≥12% and NPV≥0)	**Feasible**

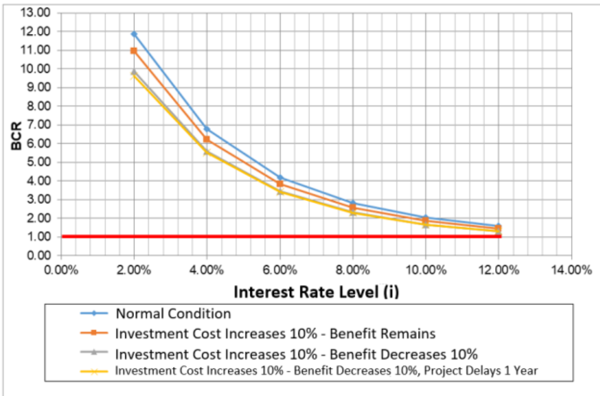

Fig. 4. EIRR Sensitivity Graph of Alternative 2

Alternative 3:

The Cijurey Dam is meticulously designed to enhance both flood control and conservation. The gated spillway, positioned at an elevation of +270.00 meters above sea level (asl), features two gates, each measuring 8.00 meters wide and 7.00 meters high. Additionally, the ungated spillway, located at +276.00 meters asl, spans 2 x 16.00 meters. The dam's crest is set at +282.00 meters asl, with the base at +207.00 meters asl, resulting in a total height of 75 meters. These structural elements are critical for effective water flow management and ensuring the dam's stability.

For flood control, the dam offers a storage volume of 2.61 million cubic meters, reducing the flood peak (Q_{25}) by 13.59%. It can handle a maximum inflow rate of 291.47 cubic meters per second, with a controlled maximum outflow rate of 251.85 cubic meters per second. The conservation benefits are significant, with a storage volume of 3.92 million cubic meters supporting the irrigation of 2,047 hectares of rice fields. The cropping pattern of paddy-paddy-crops achieves a planting intensity of 200% (Crop Session 1=100%, Crop Session 2=80%, Crop Session 3=20%). The average irrigation release discharge is 0.79 cubic meters per second, and the average raw water release discharge is 0.71 cubic meters per second. Additionally, the dam is equipped with a mini hydro power (MHP) with a capacity of 2 x 0.50 MW, generating an annual energy output of 4,613.70 MWh. These comprehensive benefits underscore the dam's essential role in regional water management, agricultural irrigation, and energy production.

Table 9. Economic Feasibility Analysis Based on Alternative 3 Cijurey Dam Design Plan

Economic Parameters	Alternative 3 ($)
PV of Raw Water Benefits	304
PV of Irrigation Benefits	36
PV of MHP Benefits	20
PV Flood Reduction Benefits	105
Total Benefit Value	**467**

Table 10. Economic Feasibility Analysis Based on Alternative 3 Cijurey Dam Design Plan

Sensitivity Conditions	Alternative 3
1. Normal Condition	
BCR (I = 12%)	1.08
IRR (%)	12.72%
NPV ($)	13
Feasibility check (BCR≥1, EIRR≥12% and NPV≥0)	**Feasible**
2. Investment Cost Increases 10% - Benefit Remains	
BCR (I = 12%)	0.99
IRR (%)	11.89%

Sensitivity Conditions	Alternative 3
NPV ($)	-3
Feasibility Check (BCR≥1, EIRR≥12% and NPV≥0)	**Not Feasible**
3. Condition of Investment Cost Increases 10% - Benefit Decreases 10%	
BCR (I = 12%)	0.89
IRR (%)	11.03%
NPV ($)	-19
Feasibility Check (BCR≥1, EIRR≥12% and NPV≥0)	**Not Feasible**
4. Conditions Investment Cost Increases 10% - Benefit Decreases 10%, Project Delays 1 Year	
BCR (I = 12%)	0.89
IRR (%)	11.02%
NPV ($)	-19
Feasibility Check (BCR≥1, EIRR≥12% and NPV≥0)	**Not Feasible**

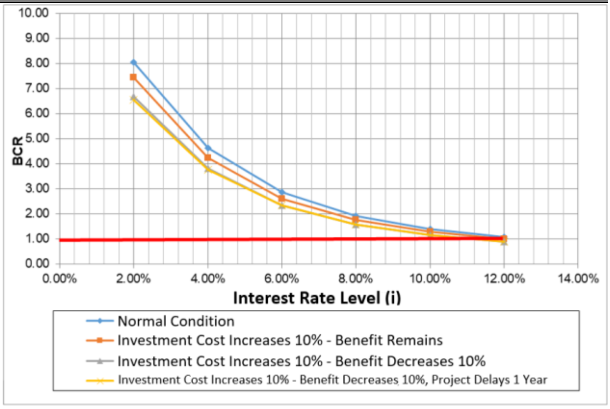

Fig. 5. EIRR Sensitivity Graph of Alternative 3

Based on the recapitulation results and sensitivity graphs, it can be concluded that alternative 1 has the greatest benefit value and has an economic feasibility value that is far greater than the economic feasibility requirements in both normal and critical sensitivity conditions. Thus, in determining the design plan for the construction of Cijurey Dam, Alternative 1 with a dam height of 85 m is selected.

Development of Flood Mitigation Strategies Toward Sustainable Development** explores the integration of structural and non-structural flood mitigation strategies, including dams, levees, watershed management, and increased channel capacity, all aiming to reduce flood damage while promoting sustainable development [17]. Additionally, the study on urban flood mitigation strategies emphasizes the use of coupled gray-green infrastructure measures and presents innovative modeling techniques for managing stormwater in urban areas. This highlights the importance of sustainable flood prevention and control measures [18]. These references collectively offer a comprehensive perspective on the feasibility and sustainability of dam development and other flood mitigation strategies, making them invaluable for research on sustainable flood mitigation through dam development.

4. CONCLUSSION

The economic feasibility analysis of the Cijurey Dam project indicates that it is a viable and economically advantageous investment. Under normal conditions, the project demonstrates robust economic returns, with an Economic Internal Rate of Return (EIRR) of 18.54%, significantly exceeding the 12% threshold. Additionally, the Benefit-Cost Ratio (BCR) of 4.99 reflects that the benefits substantially outweigh the costs. The Net Present Value (NPV) of the project is $ 132, affirming its profitability.

The sensitivity analysis further confirms the project's resilience. Even with a 10% increase in investment costs or a reduction in expected benefits, the EIRR remains above 12%, ensuring economic sustainability. Delays of up to one year do not significantly impact the project's viability, underscoring effective project planning and management.

Moreover, the project offers multifaceted benefits, including flood control, raw water provision, irrigation services, and energy production through a mini hydro power. These advantages extend beyond economic returns to encompass environmental sustainability and social well-being, enhancing regional water management, agricultural productivity, and renewable energy generation.

In conclusion, the development of the Cijurey Dam is economically feasible under various scenarios. However, careful attention must be given to managing potential cost escalations and benefit reductions. Effective risk management and mitigation strategies are essential to maintain economic viability and ensure the project's positive contribution to sustainable development goals. The comprehensive benefits justify investment, highlighting the importance of integrated water resource management in achieving long-term economic stability and development.

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