



Original Article

## Technical Planning and Construction Cost Analysis of a Marine Shrimp Hatchery: A Case Study of Kutai Kartanegara Regency, Indonesia

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**Abstract:** The development of marine shrimp hatchery infrastructure represents a strategic investment to strengthen aquaculture productivity, seed quality control, and regional economic resilience in coastal Indonesia. However, hatchery construction requires substantial capital allocation and integrated technical planning to ensure operational efficiency and long-term sustainability. This study aims to develop a comprehensive technical planning framework and conduct a detailed construction cost analysis for a proposed marine shrimp hatchery facility in Kutai Kartanegara Regency, East Kalimantan. An integrated engineering and cost evaluation approach was employed, including site surveys, topographic measurements, geotechnical assessment, architectural and structural design, and preparation of a Bill of Quantities based on standardized regional unit price analysis for 2024. The findings indicate that the selected site in Muara Badak is technically feasible for development and strategically located near seawater sources. The total estimated construction cost amounts to IDR 39,096,689,000, with the largest allocation directed to core hatchery production buildings (39.18%), followed by supporting facilities (36.78%) and water treatment systems (12.87%). This distribution highlights the capital-intensive nature of controlled production environments and biosecure water management systems in intensive shrimp hatchery operations. The study concludes that integrated technical design combined with transparent cost estimation is essential to ensure financial accountability, structural reliability, and environmental sustainability. The proposed hatchery is expected to function as a regional seed supply hub, supporting smallholder farmers and strengthening the aquaculture value chain in Kutai Kartanegara Regency.

**Keywords:** Marine Shrimp Hatchery; Construction Cost Analysis; Aquaculture Infrastructure; Water Treatment Systems.



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## 1. Introduction

The fisheries and aquaculture sector has become one of the most dynamic contributors to global food systems, economic development, and rural livelihoods. Aquaculture has experienced rapid growth over the past three decades and now accounts for more than half of global fish production for human consumption (Troell et al., 2014; Boyd et al., 2021). Shrimp aquaculture represents one of the most valuable export-oriented commodities within this sector, especially in tropical countries where environmental conditions are favorable for marine culture systems. In Indonesia, shrimp farming plays a strategic role in strengthening food security, generating foreign exchange earnings, and providing employment across coastal communities. Empirical evidence indicates that shrimp aquaculture significantly contributes to regional economic multipliers and poverty reduction in coastal districts (Bush et al., 2010; Hall et al., 2011).

Kutai Kartanegara Regency in East Kalimantan possesses substantial ecological and geographic advantages for marine shrimp production, including extensive coastal zones, estuarine systems, and brackish-water resources. The dominant cultivated species include tiger shrimp (*Penaeus monodon*) and whiteleg shrimp (*Litopenaeus vannamei*), both of which demonstrate strong market demand domestically and internationally. However, despite this potential, production performance remains constrained by structural bottlenecks in the upstream supply chain, particularly in the availability of high-quality shrimp seed (post-larvae). Studies have shown that seed quality is a critical determinant of survival rates, growth performance, feed conversion efficiency, and overall farm profitability (Arnold et al., 2006; Marsden et al., 1997). Dependence on seed sourced from natural waters or distant hatcheries often results in inconsistent quality, disease transmission risks, and logistical inefficiencies. Disease outbreaks such as White Spot Syndrome Virus and Early Mortality Syndrome have further highlighted the vulnerability of shrimp production systems that lack controlled hatchery management and biosecurity protocols (Lightner, 2011; Stentiford et al., 2012).

The establishment of medium- to large-scale hatchery facilities has been widely recognized as a strategic intervention to stabilize aquaculture supply chains and improve sectoral resilience. Hatcheries provide controlled environments for broodstock management, larval rearing, and water quality monitoring, thereby enhancing genetic quality, survival rates, and biosecurity standards (FAO-based research cited in Boyd et al., 2021; Lightner, 2005). Research indicates that the availability of certified, disease-free post-larvae significantly increases pond productivity and reduces production risks for smallholder farmers (Tran et al., 2013; Moss et al., 2012). Furthermore, hatcheries function as technological innovation hubs, facilitating knowledge transfer, training, and extension services for local aquaculture communities (Belton et al., 2018). Integrated hatchery infrastructure thus contributes not only to biological performance but also to institutional capacity building and sustainable rural development.

From an infrastructure and public investment perspective, hatchery development requires comprehensive technical planning and rigorous cost evaluation. Infrastructure projects in the aquaculture sector involve complex integration of structural engineering, water treatment systems, environmental management, and operational workflow design. Empirical studies emphasize that inadequate technical planning often leads to cost overruns, operational inefficiencies, and environmental degradation (Flyvbjerg, 2014; Love et al., 2014). In aquaculture facilities specifically, improper structural design or insufficient water filtration systems may compromise biosecurity and increase disease vulnerability (Crab et al., 2007). Therefore, multidisciplinary planning approaches incorporating geotechnical investigation, structural modeling, architectural layout optimization, and detailed Bill of Quantities preparation are essential to ensure technical feasibility and financial sustainability.

In the context of regional development policy, public-sector hatchery investments must also align with principles of cost efficiency, environmental sustainability, and long-term operational viability. Sustainable aquaculture development increasingly requires environmentally responsible infrastructure that minimizes effluent discharge, optimizes water reuse, and integrates sedimentation and filtration technologies (Bostock et al., 2010; Diana et al., 2013). Moreover, transparent, data-driven construction cost estimation enhances fiscal accountability and reduces the risks associated with public infrastructure projects (Cantarelli et al., 2012). Integrating sustainability considerations into hatchery design can improve resource efficiency, reduce ecological impacts, and strengthen the legitimacy of government-led aquaculture initiatives. In response to these structural and developmental needs, the Marine and Fisheries Office of Kutai Kartanegara Regency has proposed the construction of an integrated, modern marine shrimp hatchery. The planned development aims to establish a reliable source of high-quality post-larvae, enhance technological capacity, and support productivity improvements in smallholder shrimp ponds across the region. However, to ensure successful implementation, a comprehensive technical and financial feasibility assessment is required.

This study aims to develop an integrated technical planning framework and conduct a detailed construction cost analysis for the proposed hatchery development. The scope of the study encompasses site assessment, topographic measurement, geotechnical investigation using cone penetration testing,

structural and architectural design, water system planning, preparation of detailed cost estimates, and evaluation of sustainability implications. By employing a multidisciplinary approach involving structural, architectural, mechanical, electrical, geodetic, geotechnical, and environmental expertise, this research seeks to produce an accurate, data-driven, and operationally feasible planning document. The findings are expected to serve as a technical guideline for construction implementation and to contribute to the broader discourse on sustainable aquaculture infrastructure development in emerging coastal economies.

## 2. Materials and Methods

The study was conducted at the proposed hatchery development site located on Muara Badak Main Road, Tanjung Limau Village, Muara Badak District, Kutai Kartanegara Regency, East Kalimantan, Indonesia. The selected site is situated within a coastal aquaculture development zone characterized by brackish water availability, relatively flat topography, and accessibility to transportation networks. The geographic setting was preliminarily assessed to ensure suitability for marine shrimp hatchery operations, considering proximity to seawater sources, elevation relative to tidal influence, soil bearing capacity, and accessibility for logistics and operational support. This research adopted an integrated technical planning and cost evaluation approach that combines engineering assessment, quantity surveying principles, and budget efficiency analysis. The methodological framework consisted of three major stages: site investigation and data collection, cost estimation and budgeting, and construction budget efficiency assessment. These stages were designed to ensure that the proposed hatchery facility meets technical feasibility standards, financial accountability requirements, and operational sustainability criteria.

The first stage involved a comprehensive site survey to collect primary physical and environmental data. Field observations were conducted to document existing land conditions, surrounding infrastructure, drainage patterns, and environmental characteristics. Topographic measurements were performed using a theodolite and measuring tape to determine land contours, elevation differences, and horizontal distances across the project area. The resulting topographic data were used to generate site layout drawings and establish appropriate building elevations relative to natural ground level and tidal conditions. In addition to topographic mapping, preliminary soil investigations were undertaken to assess subsurface conditions relevant to structural foundation design. Soil bearing characteristics were evaluated to determine the suitability of shallow or reinforced foundation systems. The collected data were subsequently processed using engineering drawing software to produce detailed architectural layouts, structural plans, and infrastructure schematics, including water supply systems, sedimentation tanks, filtration units, reservoirs, and supporting utilities.

The second stage focused on preparing a detailed construction cost estimate. The cost calculation was based on the Indonesian Standard Unit Price Analysis (Analisis Harga Satuan Pekerjaan or AHSP), which provides standardized coefficients for labor, materials, and equipment in public infrastructure projects. Quantity take-offs were derived directly from finalized engineering design drawings, including structural components, architectural works, mechanical installations, electrical systems, plumbing networks, and supporting facilities. Each work item was itemized in a Bill of Materials (BoM), specifying volume, unit, and corresponding cost parameters. Material prices and labor wages were adjusted to reflect local market conditions in Kutai Kartanegara Regency for the fiscal year 2024, ensuring contextual accuracy and budget realism. Equipment rental rates and transportation costs were similarly localized to account for regional logistical conditions. The total estimated construction cost was obtained by aggregating all work components, including preparatory works, substructure, superstructure, architectural finishing, mechanical-electrical installations, water treatment systems, and external works.

The third stage involved an analysis of construction budget efficiency to evaluate the proportional distribution of costs and identify optimization opportunities. This analysis examined cost structures across major building components, including grow-out buildings, broodstock facilities, administrative offices, water reservoirs, filtration systems, and supporting infrastructure. Cost allocation patterns were assessed to determine which components contributed the highest financial burden and whether these allocations were technically justified based on functional requirements. Potential cost-saving measures were explored using value engineering principles, including material substitution without compromising structural integrity, design simplification, modular construction, and spatial layout optimization. The analysis ensured that financial efficiency was achieved without reducing technical quality, structural safety, or operational performance of the hatchery facility. The methodological approach integrates technical engineering planning, standardized cost-estimation procedures, and fiscal-efficiency evaluation to produce a comprehensive, implementable hatchery development plan. By combining field-based data collection with systematic budgeting analysis, this study ensures that the proposed hatchery construction is technically feasible, economically rational, and aligned with sustainable aquaculture infrastructure development objectives.

### 3. Results

The estimated construction cost for the hatchery facility is detailed in Table 1, which provides a breakdown by major work components.

**Table 1.** Construction Cost Breakdown by Major Components

No.	Work Component	Total Cost (IDR)	Percentage (%)
1	Grow-Out Buildings (H-1 to H-4) & Broodstock Building (H-5)	14,900,963,000	38.11
2	Road, Parking, & Landscaping Infrastructure	3,701,558,991	9.47
3	Office Building	1,970,211,000	5.04
4	Water Reservoir & Treatment Tanks	5,032,630,000	12.87
5	Fence, Gate, & Ulin Wood Bridge	3,643,871,000	9.32
6	Supporting Buildings (Warehouse, Generator Room, etc.)	4,066,540,000	10.4
7	Utilities (Electricity, Water Supply, Drainage)	1,532,202,767	3.92
8	Preparatory Works & Occupational Health and Safety (OHS)	650,060,917	1.66
9	Staff Housing & LAP Building	3,466,485,000	8.87
10	Miscellaneous (Flagpole, Green Open Space)	132,166,325	0.34
<b>TOTAL</b>		<b>39,096,689,000</b>	<b>100</b>

Table 1 presents a comprehensive breakdown of the total estimated construction cost of IDR 39,096,689,000, distributed across ten major work components. The largest allocation is to the Grow-Out Buildings (H-1 to H-4) and the Broodstock Building (H-5), totaling IDR 14,900,963,000, or 38.11% of the total budget. This substantial proportion reflects the central role of production facilities in hatchery operations, as these structures accommodate larval rearing, broodstock management, and core aquaculture processes. The dominance of this cost component indicates that structural integrity, controlled environmental conditions, and biosecurity measures are primary investment priorities in ensuring optimal hatchery productivity. The second-largest allocation is dedicated to Water Reservoir and Treatment Tanks, totaling IDR 5,032,630,000 or 12.87%. This component underscores the technical importance of water quality management systems in marine shrimp hatchery operations. Adequate sedimentation, filtration, and storage facilities are critical to maintaining stable water parameters, preventing disease transmission, and supporting sustainable production cycles. The allocation demonstrates that nearly one-eighth of the total budget is invested in water management infrastructure, reflecting its strategic role in operational sustainability.

Supporting Buildings, including warehouses, generator rooms, and other auxiliary facilities, account for IDR 4,066,540,000 or 10.40% of the total cost. These facilities ensure operational continuity by providing storage, backup power supply, and logistical support. Similarly, Road, Parking, and Landscaping Infrastructure amount to IDR 3,701,558,991, or 9.47%, underscoring the importance of site accessibility, internal mobility, and spatial organization within the hatchery complex. Infrastructure elements, such as internal roads and parking areas, facilitate the transportation of inputs and outputs, while landscaping contributes to environmental management and site aesthetics. The Fence, Gate, and Ulin Wood Bridge component absorbs IDR 3,643,871,000 or 9.32%, highlighting investment in site security and structural connectivity. Secure perimeter systems are essential in aquaculture facilities to maintain biosecurity and restrict unauthorized access. Meanwhile, Staff Housing and the LAP Building account for IDR 3,466,485,000 or 8.87%, reflecting the provision of residential and operational accommodation to support workforce stability and on-site management efficiency.

The Office Building requires IDR 1,970,211,000, or 5.04% of the total budget, and serves as the administrative and coordination center for hatchery operations. Utilities, including electricity, water supply, and drainage systems, amount to IDR 1,532,202,767, or 3.92%. Although relatively smaller in proportion, utility systems are fundamental to ensuring uninterrupted operational performance and environmental compliance. Preparatory Works and Occupational Health and Safety (OHS) measures amount to IDR 650,060,917, or 1.66%, reflecting necessary initial site mobilization and safety compliance costs during the construction phase. Finally, Miscellaneous components, such as flagpoles and green open spaces,

amount to IDR 132,166,325, or 0.34%, representing minimal yet essential site-completion elements. This study indicates that cost distribution is a major investment, approximately 51% when combining production buildings and water treatment systems and is concentrated on core operational infrastructure. The remaining allocation supports administrative, logistical, residential, and safety functions, ensuring that the hatchery facility is not only technically robust but also operationally integrated and sustainable. This distribution pattern demonstrates a balanced approach between production efficiency, environmental management, and institutional functionality within the planned hatchery development.

**Table 2.** Construction Cost Distribution by Functional Category

No.	Functional Category	Related Work Components	Total Cost (IDR)	Percentage (%)
1	Preparatory Work & Management	Preparatory Works, Occupational Health and Safety Management System (OHS-MS / SMK3)	650,060,917	1.66
2	Basic Infrastructure & Utilities Works	Earthworks, Road & Parking Pavement, Box Culverts, Curbs, Electricity Poles, Water Towers, Green Open Space, Flagpoles	3,712,048,258	9.49
3	Core Hatchery Production Buildings	Rearing Buildings (H-1 to H-4), Broodstock House (H-5), Plankton House, Harvest House	15,322,066,000	39.18
4	Water Treatment System	Storage Tanks (Tank-1 & Tank-2), Sedimentation Tank, Filter Tank	5,032,630,000	12.87
5	Supporting Buildings & Facilities	Office, Warehouse, Generator House, Ulin Wood Bridge, Fence & Gate, Drainage System, Employee Housing (including LAP), Parking Area	14,379,884,825	36.78
TOTAL			39,096,689,000	100

Table 2 presents the distribution of construction costs by functional category, offering a strategic perspective on how financial resources are allocated across operational roles within the hatchery system. The total estimated construction cost amounts to IDR 39,096,689,000, distributed across five principal functional groups. The largest allocation is directed to Core Hatchery Production Buildings, totaling IDR 15,322,066,000 or 39.18% of the overall budget. This category includes the rearing buildings (H-1 to H-4), the broodstock house (H-5), the plankton house, and the harvest house. The dominance of this allocation reflects the central operational importance of production-related facilities within the hatchery complex. These structures accommodate broodstock maturation, larval rearing, feed culture, and harvesting processes, all of which directly determine production capacity, biosecurity standards, and output quality. The significant financial commitment to this category underscores the priority of ensuring structural robustness, effective environmental control systems, and efficient functional layout to optimize aquaculture productivity.

The second-largest portion of the budget is allocated to Supporting Buildings and Facilities, amounting to IDR 14,379,884,825 or 36.78%. This category includes the office building, warehouse, generator house, Ulin Wood Bridge, fence and gate system, drainage network, employee housing (including the LAP building), and parking areas. Although these components are not directly involved in biological production processes, they play a critical enabling role in ensuring operational continuity, site security, administrative management, workforce accommodation, and logistical coordination. The relatively high proportion of this category indicates a comprehensive infrastructure planning approach that integrates production and non-production functions within a single, cohesive facility. The Water Treatment System represents IDR 5,032,630,000 or 12.87% of the total cost. This includes storage tanks, sedimentation tanks, and filter tanks, which are essential for maintaining water quality standards. In shrimp hatchery operations, water

quality stability is a fundamental determinant of larval survival rates and disease prevention. The substantial allocation to water treatment infrastructure demonstrates recognition of its strategic role in biosecurity management and sustainable aquaculture operations.

By dedicating nearly one-eighth of the total investment to water management systems, the project emphasizes environmental control and operational reliability. Basic Infrastructure and Utilities Works account for IDR 3,712,048,258 or 9.49% of total expenditures. This category includes earthworks, road and parking pavement, box culverts, curbs, electricity poles, water towers, green open space development, and flagpoles. These components establish the site's foundational physical framework, ensuring accessibility, drainage control, structural stability, and external utility support. While the percentage allocation is relatively moderate, these works are indispensable for supporting the functionality and longevity of the entire hatchery complex.

Finally, Preparatory Work and Management costs amount to IDR 650,060,917 or 1.66% of the total budget. This category includes site preparation activities and the implementation of the Occupational Health and Safety Management System (OHS-MS/SMK3). Although representing the smallest share of the total cost, this allocation is essential to ensure regulatory compliance, safe construction practices, and effective project mobilization during the initial phase of development. The functional cost distribution shows that approximately 52% of the total budget is allocated directly to core production and water treatment systems, while the remaining 48% supports infrastructure, management, and auxiliary facilities. This allocation pattern reflects a balanced investment strategy that prioritizes biological production capacity while simultaneously strengthening institutional support systems, environmental management, and operational sustainability. The distribution confirms that the hatchery development is designed not merely as a production facility but as an integrated aquaculture infrastructure system capable of supporting long-term economic and operational performance.

#### 4. Discussion

The findings of this study confirm the initial working assumption that hatchery development is a capital-intensive infrastructure investment, particularly for core production facilities. The cost structure reveals that nearly 40% of the total construction budget is allocated to grow-out and broodstock buildings, while an additional 12.87% is dedicated to water treatment systems. This concentration of financial resources in biologically sensitive and technically complex components supports the hypothesis that intensive aquaculture systems require substantial upfront investment in controlled production environments. Intensive shrimp hatcheries depend on stable environmental regulation, aeration systems, and water filtration technologies to maintain larval survival and growth performance (Bostock et al., 2010; Boyd et al., 2021). The present cost distribution reflects these technical requirements, indicating that infrastructure design prioritizes biosecurity, operational reliability, and production efficiency.

From a production systems perspective, the dominance of expenditure on rearing and broodstock facilities aligns with previous empirical studies demonstrating that hatchery performance is highly sensitive to environmental fluctuations and pathogen exposure. Disease outbreaks such as White Spot Syndrome Virus and Early Mortality Syndrome have shown how insufficient biosecurity and inadequate infrastructure can severely disrupt shrimp production systems (Lightner, 2011; Stentiford et al., 2012). Investment in enclosed, technically engineered production units therefore functions as a risk mitigation strategy. Research on selective breeding and biosecure hatchery systems further emphasizes that improved infrastructure directly enhances post-larvae quality and survival rates (Moss et al., 2012). The allocation of nearly half of the total budget to biological production and water treatment functions suggests that the project design follows a precautionary and resilience-oriented infrastructure model.

The strategic selection of Muara Badak as the project site also aligns with findings from aquaculture spatial planning research, which highlight the importance of proximity to water sources, logistical accessibility, and local production networks in improving operational efficiency (Belton et al., 2018; Diana et al., 2013). Locating hatchery infrastructure near seawater sources reduces pumping costs and energy consumption while facilitating consistent water exchange. Moreover, regional clustering of aquaculture activities has been shown to strengthen value chain integration and knowledge diffusion among small-scale operators (Bush et al., 2013). In this context, the proposed integrated hatchery is expected to function not only as a production facility but also as a regional supply hub that stabilizes post-larvae availability and improves production planning for surrounding farmers.

The functional cost distribution further indicates that approximately 36.78% of the budget is devoted to supporting buildings and facilities, including administrative, logistical, and workforce-related components. This allocation reflects the recognition that modern aquaculture systems operate as socio-technical complexes rather than purely biological production units. Integrated infrastructure that includes administrative offices, storage systems, and workforce housing enhances coordination, operational continuity, and institutional capacity (Hall et al., 2011). Research on aquaculture development emphasizes

that institutional and managerial support systems are critical determinants of long-term sectoral sustainability (Troell et al., 2014).

The allocation of nearly 9.49% to basic infrastructure and utilities highlights the importance of foundational engineering works in coastal environments. High-value items such as reinforced roads, box culverts, and drainage systems are essential in areas characterized by unstable soils and high rainfall intensity. Construction management literature has repeatedly demonstrated that inadequate early-stage site preparation increases the likelihood of cost overruns and structural failures (Cantarelli et al., 2012; Love et al., 2014). Robust foundational infrastructure thus represents a preventive investment that reduces long-term maintenance risks and enhances structural durability.

Transparent and detailed cost estimation is equally important for public infrastructure projects. Empirical research on large-scale construction projects shows that insufficient planning and underestimation of technical complexity are major contributors to budget overruns (Flyvbjerg, 2014). By applying standardized unit price analysis and a detailed Bill of Quantities, the present study contributes to fiscal accountability and risk mitigation. Such systematic financial planning approaches are particularly relevant in public-sector aquaculture investments, where efficient allocation of limited resources determines both economic viability and social legitimacy.

From an environmental sustainability perspective, allocating 12.87% of total costs to water treatment infrastructure aligns with responsible aquaculture principles. Sustainable aquaculture development increasingly requires integrated water management systems that minimize effluent discharge and environmental degradation (Bostock et al., 2010; Diana et al., 2013). Research has shown that inadequate wastewater management can lead to nutrient loading, ecosystem imbalance, and disease proliferation (Crab et al., 2007). The inclusion of sedimentation and filtration systems in the project design strengthens environmental safeguards and supports long-term ecological resilience.

The broader implications of these findings extend to regional economic development and food system resilience. Aquaculture has been identified as a key contributor to global food security and economic diversification in coastal regions (Troell et al., 2014). By establishing a centralized hatchery facility with strong technical and infrastructural foundations, the project has the potential to enhance supply chain stability, improve seed quality control, and reduce production volatility. This integrated approach aligns with research emphasizing that infrastructure investment in aquaculture must combine biological performance, institutional capacity, and environmental sustainability to achieve durable development outcomes (Hall et al., 2011; Bostock et al., 2010).

Despite these strengths, the present study is limited by its focus on construction cost analysis without incorporating comprehensive financial feasibility indicators such as life-cycle cost assessment or profitability projections. Future research should integrate operational cost modeling and long-term revenue scenarios to more comprehensively evaluate economic sustainability. Comparative studies examining performance differences between public hatcheries and private-sector facilities would also provide valuable insights into governance. Furthermore, incorporating life-cycle assessment methodologies and carbon footprint analysis would enhance understanding of environmental impacts across the infrastructure lifespan. Finally, socio-economic impact assessments could evaluate how the hatchery influences farmer income stability, employment generation, and value chain integration at the regional level.

This study demonstrates that hatchery construction is a capital-intensive yet strategically justified investment in aquaculture infrastructure. The concentration of resources in core production and water treatment systems reflects technical priorities consistent with intensive shrimp farming requirements, while substantial investment in supporting infrastructure underscores the importance of institutional integration and operational resilience. When interpreted within the broader literature on aquaculture and infrastructure management, the results highlight the need for integrated technical planning, transparent cost estimation, and sustainability-oriented design to ensure long-term economic and environmental viability.

## 5. Conclusions

This study provides a comprehensive technical planning and construction cost analysis for the proposed marine shrimp hatchery facility in Kutai Kartanegara Regency, Indonesia. The findings demonstrate that hatchery development is a capital-intensive public infrastructure investment, with the majority of financial resources allocated to core production buildings and water treatment systems. Approximately 39% of the total construction budget is allocated to rearing and broodstock facilities, while nearly 13% is devoted to water management infrastructure. This allocation pattern confirms the central importance of controlled production environments and biosecure water systems in intensive shrimp hatchery operations. In addition, substantial investment in supporting facilities and basic infrastructure reflects the integrated nature of modern aquaculture systems, which require not only biological production units but also administrative, logistical, and workforce support structures to function effectively.

The results indicate that the proposed hatchery design follows a balanced and strategic cost structure, prioritizing operational efficiency, environmental management, and institutional functionality. The selection of Muara Badak as the project site further strengthens the development's feasibility, given its proximity to seawater sources and established aquaculture activities. By combining detailed engineering planning with standardized cost-estimation methods, the study contributes to greater transparency, fiscal accountability, and technical reliability in public aquaculture infrastructure projects. Overall, the findings suggest that integrated technical planning and rigorous budgeting are essential to ensure that hatchery investments deliver long-term economic, environmental, and operational benefits.

From a theoretical perspective, this study contributes to the literature on aquaculture infrastructure development by linking engineering cost structures with production system requirements. The findings reinforce the concept that intensive aquaculture should be analyzed as a socio-technical system in which biological performance, environmental control, and institutional capacity are interdependent. By categorizing expenditures into functional groups, the study demonstrates how capital allocation reflects underlying production priorities and risk management strategies. This integrative approach extends infrastructure planning theory in aquaculture studies by emphasizing alignment among technical design, cost engineering, and sustainability principles. Furthermore, the study supports broader public infrastructure management theory by demonstrating the importance of detailed cost breakdowns and standardized unit-price analyses in mitigating budget overruns and enhancing transparency. The structured cost evaluation framework adopted here may serve as a reference model for future research on aquaculture infrastructure in developing coastal economies.

In practice, the study provides a data-driven planning framework to guide local governments and marine resource agencies in developing hatchery infrastructure. The detailed cost breakdown provides decision-makers with a clear understanding of the major investment components, enabling better budget allocation and prioritization. Emphasizing core production and water treatment systems ensures that operational reliability and biosecurity are not compromised. From a policy standpoint, the results suggest that government-supported hatchery projects should integrate comprehensive technical planning with transparent financial evaluation to minimize construction risks and inefficiencies. Policymakers are encouraged to adopt standardized cost analysis methods and value engineering approaches during the pre-construction phase. In addition, future policy frameworks should incorporate environmental sustainability measures, such as improved wastewater treatment systems, energy-efficient technologies, and green building principles, to reduce long-term ecological impacts. The hatchery can also be positioned as a regional production hub that supports smallholder farmers through reliable seed supply and technical training, thereby strengthening local aquaculture value chains and enhancing regional economic resilience.

Despite its contributions, this study has several limitations. First, the analysis focuses primarily on construction cost estimation and does not include a comprehensive financial feasibility assessment, such as net present value, internal rate of return, or payback period calculations. Second, operational expenditures, maintenance costs, and long-term life-cycle performance were not quantitatively evaluated. Third, while environmental considerations were integrated into the design framework, a full environmental impact assessment was beyond the scope of this study. Finally, the analysis is site-specific and may not fully capture variability in soil conditions, market prices, or regulatory environments in other regions.

Future research should extend the present analysis by incorporating life-cycle cost assessment and long-term operational performance evaluation to determine the economic sustainability of the hatchery. Comparative studies between public and private hatchery models would provide valuable insights into the efficiency of governance and productivity outcomes. Additionally, integrating environmental impact assessment tools, carbon footprint analysis, and renewable energy feasibility studies would strengthen sustainability evaluation. Socio-economic impact research examining employment generation, income stabilization for smallholders, and regional value chain development would further enhance understanding of the broader developmental implications of hatchery infrastructure investment. This study demonstrates that integrated technical planning, transparent cost analysis, and sustainability-oriented design are fundamental to the successful development of marine shrimp hatchery infrastructure. By aligning engineering rigor with economic accountability and environmental responsibility, the proposed hatchery project could serve as a strategic catalyst for sustainable aquaculture development in coastal Indonesia.

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