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Global Journal of Emerging Science, Engineering & Technology

Journal homepage: ejournals.scieglobal-academia.com/gjeset

*Original Article*

# Cost Management in Infrastructure Development: Enhancing Budget Efficiency at Sekolah Alam Samarinda, Indonesia

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**Citations:** Noor, A.F., Arifin, B.M.E., & Habir, H. (2025). Cost Management in Infrastructure Development: Enhancing Budget Efficiency at Sekolah Alam Samarinda, Indonesia. *Global Journal of Emerging Science, Engineering & Technology*, 3(1), 9-17.

**Academic Editor:** Assoc. Professor Dr. Agus Sukoco

Received: 8 March 2025 Revised: 10 April 2025 Accepted: 7 May 2025 Published: 31 May 2025

**Abstract:** This study examines cost management practices in the construction of Sekolah Alam Samarinda, an alternative education model integrating sustainability and nature-based learning. The research aims to analyze the composition of construction costs, evaluate cost-efficiency strategies, and assess the budget control mechanisms applied during the project. Using a qualitative case study approach, data were collected through budget document analysis, field observations, and in-depth interviews with project implementers. The findings indicate that the largest share of the budget was allocated to structural works and environmental adaptation, reflecting the need for robust, context-sensitive infrastructure. Several cost-saving strategies were identified, including the use of local materials, modular design, community involvement, and the integration of natural ventilation and daylighting to reduce utility requirements. These approaches resulted in an estimated 15% reduction in total project costs compared to initial projections. Furthermore, applying value engineering principles preserves functionality and quality while optimizing resource utilization. The study concludes that effective cost management in alternative school construction requires adaptive planning, active local engagement, and environmentally responsive design. Practical recommendations include early-stage budget simulation, improved documentation, and enhanced stakeholder collaboration to strengthen cost control in similar future projects.

**Keywords:** Cost Management; Infrastructure Development; Budget Efficiency; Sustainable School Construction.



## 1. Introduction

The development of educational infrastructure constitutes a fundamental pillar in ensuring the provision of quality, inclusive, and equitable education services (UNESCO, 2020). Adequate infrastructure not only facilitates effective teaching and learning processes but also shapes the physical and social environments in which educational values are internalized. In recent years, global educational discourse has increasingly emphasized the need for learning environments that are adaptive, resilient, and aligned

with sustainable development principles (OECD, 2021). Educational facilities are no longer perceived merely as physical structures; rather, they are strategic assets that influence student engagement, well-being, and long-term educational outcomes. Consequently, infrastructure planning and construction must respond to evolving pedagogical models, environmental challenges, and resource constraints.

Alongside increasingly diverse educational demands, there is an urgent need for facilities that are not only functionally adequate but also contextually relevant and sustainability-oriented (OECD, 2006). The growing awareness of environmental degradation and climate change has further strengthened the call for eco-friendly school designs that integrate environmental education within their physical layout. In this context, the Nature School model emerges as a distinctive alternative that emphasizes experiential, contextual, and outdoor-based learning (Widodo et al., 2024; Khoiriyah et al., 2021). Unlike conventional school systems that rely heavily on enclosed classrooms and standardized infrastructure, Nature Schools prioritize open spaces, interaction with natural ecosystems, and environmentally responsive architectural concepts. Such characteristics demand a construction approach that differs substantially from mainstream educational facilities.

However, translating ecopedagogical ideals into physical infrastructure presents significant managerial and financial challenges. Achieving cost efficiency in the construction of nature-based schools is particularly complex, given the limited access to formal funding sources and the heightened need for environmental adaptation (Mustofa et al., 2018). These schools often operate under constrained budgets, relying partly on community participation and local resource mobilization. At the same time, they must maintain structural durability, safety standards, and environmental responsiveness. This dual imperative, maintaining ecological integrity while ensuring financial feasibility, requires a robust and carefully structured cost management system. Therefore, effective and efficient cost management is essential to ensure that project objectives are achieved without compromising quality, safety, or the institution's ecopedagogical values.

Construction cost management encompasses a comprehensive set of processes, including cost estimation, budgeting, resource allocation, monitoring, and financial control throughout the project lifecycle (Ashworth et al., 2013). Effective cost management ensures that projects are delivered within budget while meeting technical specifications and stakeholder expectations. In the context of nature-based school construction, cost management becomes more intricate due to additional considerations such as community involvement, the utilization of local and sustainable materials, and the management of site-specific environmental constraints (Karim et al., 2024; Dell'Isola, 1997). These elements introduce variability and uncertainty into the budgeting process, thereby increasing the importance of adaptive planning and rigorous financial monitoring.

One widely recognized approach to improving cost efficiency in construction projects is value engineering. This method systematically evaluates project functions to achieve the desired performance at the lowest possible life-cycle cost without compromising quality (Dell'Isola, 1997). Empirical studies demonstrate that applying value engineering can significantly enhance cost efficiency while maintaining, or even improving, functional performance (Wibowo & Abdul-Hakim, 2018). In addition to value engineering, complementary strategies such as modular design, the integration of renewable energy systems, optimization of natural ventilation and daylighting, and reduction of material waste have been shown to contribute positively to both economic and environmental performance (Siswanto & Salim, 2019; Putra & Lutfi, 2021). These strategies reflect a broader shift toward sustainable construction practices that align financial efficiency with environmental responsibility. Furthermore, existing literature consistently highlights that mature and meticulous cost planning is a critical determinant of project success, particularly in community-based projects or initiatives operating under budget limitations (Sardjo et al., 2017). Early-stage budget simulations, transparent documentation, stakeholder engagement, and continuous monitoring mechanisms are essential components of effective cost governance. In projects that integrate social and environmental objectives, financial management must also accommodate non-monetary values, such as community empowerment and ecological preservation, thereby broadening the conventional scope of cost analysis.

Despite the growing body of research on sustainable construction and cost management, limited attention has been directed toward the specific context of alternative education infrastructure, particularly Nature Schools in Indonesia. The intersection between ecopedagogical philosophy and construction cost management remains underexplored. Most existing studies focus either on pedagogical outcomes or on technical construction efficiency, with insufficient integration of both perspectives. This gap highlights the need for empirical investigation into how cost management practices can support the realization of sustainability-oriented educational infrastructure within constrained financial environments. Based on this background, the present research analyzes cost management practices in the infrastructure development of Sekolah Alam Samarinda using a case study method. Specifically, the study examines the project's cost structure, identifies efficiency strategies implemented during construction, and evaluates the effectiveness of budget control mechanisms throughout the implementation phase. By employing a qualitative case study

approach, this research seeks to generate in-depth insights into real-world managerial practices and contextual decision-making processes.

The findings are expected to contribute, both theoretically and practically, to the development of cost management strategies for alternative education projects that are efficient, adaptive, and environmentally sustainable. Theoretically, the study enriches the discourse on construction cost management by incorporating local values and sustainable development principles into the analytical framework. In practice, it offers evidence-based recommendations for policymakers, school founders, project managers, and community stakeholders involved in developing sustainability-oriented educational facilities, particularly in regions with limited financial resources. Ultimately, this research aims to bridge the gap between ecological educational ideals and financially responsible infrastructure development, demonstrating that sustainability and cost-efficiency can coexist within a well-managed construction framework.

## 2. Materials and Methods

### 2.1. Research Design

This study employed a descriptive qualitative approach using a case study method focusing on the construction project of Sekolah Alam Samarinda. The research was conducted in Samarinda City, East Kalimantan, Indonesia, with a primary focus on the development of the school's physical infrastructure as a nature-based educational facility. The case study approach was selected to enable an in-depth exploration of cost management practices in their real-life context, particularly in a project integrating sustainability principles and community participation.

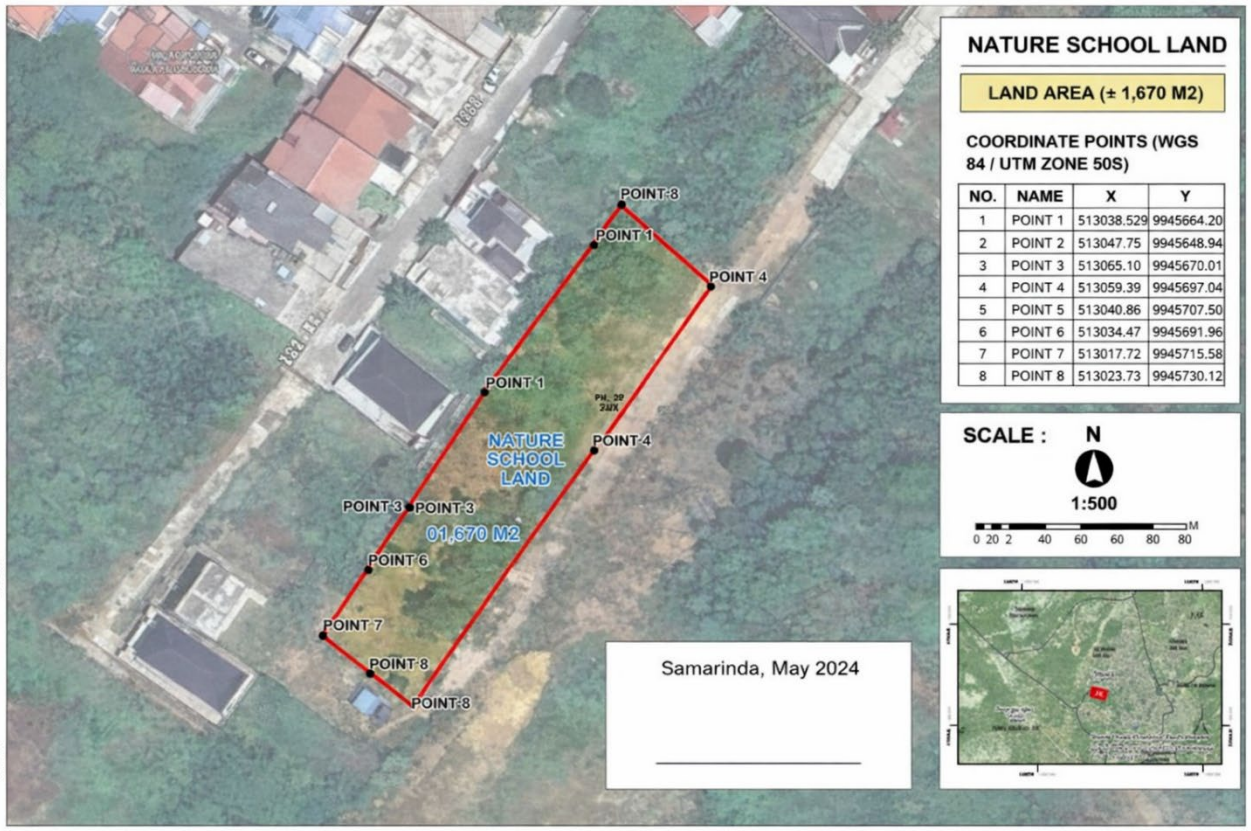


Figure 1. Case Study Location

### 2.2. Data Sources and Analysis Techniques

The study utilized both primary and secondary data sources to ensure comprehensive and reliable findings. Primary data were obtained through in-depth interviews with school management representatives and members of the project implementation team. These interviews aimed to capture detailed information regarding planning decisions, budgeting processes, cost control mechanisms, and efficiency strategies adopted during construction. In addition, direct field observations were conducted at the project site to document the physical implementation of construction activities and to verify information obtained from

interviews. Secondary data were collected from official project documents, including the Budget Plan (Rencana Anggaran Biaya), technical building drawings, procurement records, and project implementation reports. These documents provided quantitative and technical details necessary for analyzing the cost structure and evaluating financial management practices.

Data analysis was conducted using a descriptive qualitative framework consisting of several systematic stages. First, raw data were reduced and organized through thematic categorization to identify recurring patterns related to cost composition, efficiency measures, and budget control practices. Second, the organized data were presented in tables, charts, and narrative explanations to facilitate structured interpretation. Third, verification was carried out through triangulation across multiple data sources, including interviews, documentation, and field observations, to enhance the validity and credibility of the findings. The analysis specifically focused on three main aspects: (1) the structure and allocation of construction costs, (2) the efficiency strategies implemented to optimize resource utilization, and (3) the budget control mechanisms applied throughout the construction process. Through this approach, the study aimed to provide an in-depth understanding of how cost management principles were operationalized in a sustainability-oriented educational infrastructure project.

## 3. Results

### 3.1. Composition and Structure of the Cost Budget

The infrastructure of Sekolah Alam Samarinda was developed using a non-conventional design concept; therefore, its budget structure differs significantly from that of conventional formal school construction. Unlike standardized educational facilities that typically emphasize enclosed classroom buildings and uniform layouts, this project prioritizes open spaces, environmentally responsive design, and adaptive structural elements aligned with nature-based learning principles. Based on an analysis of project documentation and the Budget Plan (Rencana Anggaran Biaya/RAB), costs were predominantly allocated to major structural components and supporting elements designed to facilitate interaction with the natural environment. A substantial portion of the budget was allocated to structural works to ensure durability and safety, particularly given the site's environmental conditions. Additional allocations were directed toward environmental adaptation measures and sustainable utility systems that support the school's ecopedagogical objectives. Table 1 presents the estimated cost distribution by main work categories, highlighting the relative proportions of expenditures across construction components.

**Table 1.** Estimated Cost Distribution Based on Main Work Categories.

| No. | Component | Estimated Cost (IDR) | Percentage |
|---|---|---|---|
| 1 | Land Preparation Works | 150,000,000 | 10 |
| 2 | Building Structure Works | 600,000,000 | 40 |
| 3 | Roof and Wood Works | 300,000,000 | 20 |
| 4 | Environmental Adaptation | 200,000,000 | 13.3 |
| 5 | Utilities (Water, Solar, etc.) | 150,000,000 | 10 |
| 6 | Other Supporting Works | 100,000,000 | 6.7 |
| **Total** | | **1,500,000,000** | **100** |

Table 1 presents the distribution of construction costs for the infrastructure development of Sekolah Alam Samarinda, with a total project budget of IDR 1,500,000,000. The allocation reflects the unique characteristics of a nature-based educational facility, where structural integrity, environmental responsiveness, and sustainable utility systems are prioritized. The largest share of the budget, 40% (IDR 600,000,000), was allocated to Building Structure Works. This significant allocation underscores the project's emphasis on structural durability, safety, and compliance with construction standards, particularly given the site's environmental conditions. As a nature-based school, the structures must withstand exposure to open-air conditions, humidity, and varying soil characteristics. Therefore, robust foundational systems and primary structural elements represent the core investment component of the project.

Roof and Wood Works accounted for 20% (IDR 300,000,000) of the total budget. This relatively high percentage reflects the school's architectural concept, which integrates natural materials and open structural designs. The extensive use of wood elements and specially designed roofing systems supports natural ventilation, daylight optimization, and aesthetic harmony with the surrounding environment. The

allocation also suggests a commitment to environmentally responsive architecture rather than conventional concrete-dominant construction. Environmental Adaptation expenditures represented 13.3% (IDR 200,000,000) of the total budget. This component includes site contour adjustments, drainage systems, landscape integration, and ecological preservation measures. The proportion demonstrates that environmental integration is not treated as a secondary feature but as an integral element of the project's infrastructure strategy. The allocation supports the ecopedagogical philosophy by ensuring that the built environment coexists harmoniously with natural surroundings.

Land Preparation Works and Utilities (Water, Solar, and related systems) each accounted for 10% (IDR 150,000,000). Land preparation costs reflect the need for site clearing, leveling, and foundational readiness prior to construction. Meanwhile, the utilities allocation highlights the integration of sustainable infrastructure systems, including water management and renewable energy solutions such as solar power. This investment in utilities demonstrates a forward-looking approach to reducing long-term operational costs and enhancing environmental sustainability. Finally, Other Supporting Works constituted 6.7% (IDR 100,000,000) of the total budget. Although relatively small in proportion, this category encompasses complementary elements such as finishing works, minor installations, and ancillary facilities that enhance functionality and usability. The cost composition demonstrates a strategic prioritization of structural integrity and environmentally adaptive design, which together account for more than half of the total budget. The distribution reflects a balanced approach between essential structural investment and sustainability-oriented features. From a cost management perspective, the allocation pattern suggests that financial resources were directed toward high-impact components that align with the school's pedagogical philosophy while maintaining overall budget efficiency.

### 3.2. Cost-Efficiency Strategies

Cost efficiency constituted one of the primary focuses of this study. Findings derived from in-depth interviews with the project manager and members of the implementation team revealed that multiple cost-saving strategies were systematically applied throughout the construction process. These strategies were implemented through both careful preliminary planning and adaptive decision-making during project execution. Importantly, the efficiency measures were designed not merely to reduce expenditures but also to maintain construction quality, functional performance, and alignment with the school's sustainability-oriented mission. The first strategy involved using locally available materials. Bamboo and ulin wood sourced from the surrounding area were used as primary construction materials, replacing more expensive conventional alternatives such as reinforced concrete walls and light-gauge steel structures. This decision significantly reduced material procurement and transportation costs. In addition, reliance on local materials accelerated construction, as the workforce was already familiar with their characteristics, installation techniques, and maintenance requirements. Beyond financial efficiency, this approach reinforced the school's ecological identity and strengthened local economic engagement.

The second strategy focused on adopting a modular, open architectural design. The modular configuration enabled phased construction, providing financial flexibility and enabling budget adjustments based on available funding. Furthermore, the open design minimized the need for complex enclosed structures and reduced dependence on mechanical and electrical systems. Natural ventilation and daylighting were maximized, effectively substituting for extensive heating, ventilation, and air conditioning systems as well as artificial lighting. This design decision not only reduced initial construction costs but also lowered projected operational expenses over the building's lifecycle. The third strategy involved active community and parent participation in the construction process. Contributions were primarily in the form of voluntary labor for relatively light tasks such as fence installation, land filling, and painting. According to project team estimates, this participatory approach generated labor cost savings of approximately 7%. More importantly, community involvement fostered a sense of shared ownership and collective responsibility toward the school's development, thereby creating additional social value beyond measurable financial savings.

The fourth strategy focused on the utilization of renewable energy systems. Simple solar panels were installed to meet basic electricity needs, including lighting and charging learning devices. Although it required an initial investment, this decision contributed to long-term operational cost savings by reducing reliance on conventional electricity sources. Simultaneously, it reinforced the school's sustainability principles and served as a practical educational tool consistent with its environmental learning philosophy. Collectively, the integration of these strategies resulted in total savings of approximately 15% compared to the initial budget projection. Notably, the cost reduction did not compromise construction quality, structural safety, or the educational functionality of the infrastructure. Instead, the findings indicate that strategic cost management, when aligned with sustainability principles and community engagement, can achieve financial efficiency while preserving the core values of alternative education infrastructure development.

## 4. Discussion

The findings demonstrate that the cost structure of the nature-based school project emphasizes structural durability and environmental integration, with 40% of the total budget allocated to structural works. This allocation pattern reflects the necessity of resilient infrastructure capable of adapting to local climatic and geological conditions. Previous research has emphasized that structural investment often represents the largest cost component in sustainable construction projects due to increased requirements for durability, adaptability, and long-term performance (Hwang & Tan, 2012; Love et al., 2016). In regions characterized by high humidity and varying soil conditions, additional structural reinforcement is essential to ensure safety and lifecycle efficiency. Thus, the dominant allocation toward structural works in this project aligns with broader empirical evidence highlighting the importance of upfront investment to reduce long-term maintenance and operational risks.

The allocation of 13.3% for environmental adaptation further underscores the project's commitment to ecological responsiveness. Sustainable infrastructure projects frequently require additional expenditure for site-sensitive design, drainage management, landscape integration, and environmental preservation measures (Darko & Chan, 2016; Zuo & Zhao, 2014). Although such investments may increase initial construction costs, they contribute to environmental performance and social acceptance, thereby enhancing project sustainability. In the context of nature-based educational facilities, environmental adaptation is not merely a technical requirement but a core pedagogical component. The findings reinforce the argument that sustainable design integration must be embedded within the budgeting framework rather than treated as a peripheral expenditure.

The identified cost-efficiency strategies demonstrate the practical application of value-oriented, context-sensitive project management. The utilization of local materials, such as bamboo and ulin wood, contributed to direct cost reduction while simultaneously lowering embodied carbon and supporting local supply chains. Empirical studies confirm that sourcing local materials can significantly reduce transportation costs and environmental impacts while stimulating regional economic development (Dixit et al., 2012; Darko et al., 2017). Moreover, the use of renewable and natural materials in sustainable buildings has been associated with improved environmental performance and reduced lifecycle costs (Asdrubali et al., 2015). The findings of this study align with the growing body of research advocating material optimization as a key strategy in sustainable construction management.

The adoption of modular and open design principles further contributed to cost control and financial flexibility. Modular construction has been widely recognized as an effective method for reducing waste, shortening construction time, and improving cost predictability (Hong et al., 2018; Li et al., 2014). In addition, open building designs that maximize natural ventilation and daylighting reduce dependence on mechanical systems, leading to both initial and operational cost savings (Zhang et al., 2011; Zuo & Zhao, 2014). The integration of passive design strategies in this project demonstrates how architectural decisions can serve as cost-management tools while simultaneously enhancing environmental performance.

Community involvement emerged as another significant efficiency mechanism, generating measurable labor cost savings while strengthening stakeholder engagement. Research on community-based project management indicates that participatory approaches enhance social capital, reduce implementation costs, and improve long-term maintenance outcomes (Billings, 2000; Osei-Kyei & Chan, 2015). In education infrastructure projects, stakeholder participation has been shown to increase project sustainability by fostering collective ownership and shared responsibility (Karjalainen et al., 2013). The dual financial and social benefits observed in this study confirm the value of integrating participatory mechanisms within cost management frameworks, particularly in alternative or community-driven initiatives.

Furthermore, the incorporation of renewable energy systems, such as solar panels, aligns with cost efficiency and operational sustainability. Although renewable technologies often require higher upfront investment, numerous studies demonstrate their capacity to reduce long-term operational expenditures and enhance lifecycle cost performance (Hwang et al., 2017; Zuo & Zhao, 2014). The integration of renewable energy in this project represents a strategic decision that extends cost efficiency beyond the construction phase into long-term operational management. The overall achievement of approximately 15% cost savings validates the effectiveness of combining adaptive planning, local resource optimization, modular design, community participation, and sustainable energy integration. Importantly, the reduction in expenditure did not compromise structural quality or educational functionality. This finding supports prior research suggesting that innovative planning and value-oriented management can enhance budget performance without sacrificing project outcomes (Love et al., 2016; Osei-Kyei & Chan, 2015). The results highlight that cost efficiency in alternative infrastructure projects is not inherently contradictory to sustainability objectives. Rather, when guided by context-sensitive strategies and stakeholder collaboration, financial discipline can reinforce ecological and social values.

## 5. Conclusions

This study examined cost management practices in the infrastructure development of Sekolah Alam Samarinda, a nature-based educational institution integrating sustainability principles into its architectural and operational framework. The findings demonstrate that the project's cost structure was strategically concentrated on structural durability and environmental integration, with the largest allocation directed toward building structure works, followed by roof and wood construction, environmental adaptation, and sustainable utility systems. This allocation pattern reflects the necessity of resilient infrastructure capable of responding to local climatic conditions while supporting ecopedagogical objectives. The study further reveals that cost efficiency was achieved through a combination of context-sensitive strategies, including the utilization of locally sourced materials, modular and open architectural design, community participation, and the integration of renewable energy systems. Collectively, these approaches generated an estimated 15% cost saving compared to the initial budget projection. Importantly, the cost reduction did not compromise structural quality, safety standards, or the educational functionality of the infrastructure. Instead, the results indicate that financial efficiency and sustainability-oriented design can be mutually reinforcing when guided by adaptive planning and stakeholder collaboration.

From a theoretical perspective, this study contributes to the construction cost management literature by demonstrating how value-oriented and community-based approaches can be operationalized within alternative educational infrastructure projects. The findings extend conventional cost management discourse by integrating ecological responsiveness, local resource optimization, and participatory governance into the analytical framework. In doing so, the study bridges sustainable construction management theory with the specific context of alternative education infrastructure, an area that remains relatively underexplored in existing research. From a practical standpoint, the study offers several policy implications. First, policymakers and educational planners should incorporate sustainability-based cost planning at the early stages of project development, including detailed budget simulations and lifecycle cost analysis. Second, regulatory frameworks may encourage the use of locally sourced and environmentally friendly materials through incentive mechanisms or simplified procurement procedures. Third, community engagement should be formally recognized as a strategic component of project implementation, particularly in resource-constrained settings, as it enhances both financial efficiency and long-term asset stewardship. Finally, the integration of renewable energy and passive design strategies should be promoted not only as environmental measures but also as long-term financial management strategies that reduce operational expenditures.

Despite its contributions, this study has several limitations. First, the research is based on a single case study, which may limit the generalizability of the findings to other geographical contexts or institutional models. Second, the qualitative approach relies partly on interview-based estimations of cost savings, which may involve subjective assessment. Third, the analysis focuses primarily on construction-phase cost management and does not comprehensively evaluate long-term lifecycle cost performance. Future research could adopt comparative multi-case designs, incorporate quantitative lifecycle cost analysis, and examine the long-term operational efficiency of sustainability-oriented educational infrastructure. Thus, this study demonstrates that effective cost management in alternative education infrastructure does not require sacrificing quality or sustainability values. Rather, through innovative planning, stakeholder collaboration, and adaptive resource utilization, budget efficiency can be achieved while reinforcing environmental and social objectives. The findings provide a valuable foundation for advancing both theory and practice in sustainable construction management within the education sector.

**Author Contributions:** Conceptualization, A.F.N. and B.M.E.A.; methodology, A.F.N.; software, A.F.N.; validation, B.M.E.A. and H.H.; formal analysis, A.F.N. and B.M.E.A.; investigation, A.F.N. and B.M.E.A.; resources, A.F.N.; data curation, X.X.; writing—original draft preparation, A.F.N. and B.M.E.A.; writing—review and editing, B.M.E.A. and H.H.; visualization, A.F.N.; supervision, X.X.; project administration, A.F.N.; funding acquisition, A.F.N. All authors have read and agreed to the published version of the manuscript.

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**Funding:** This research received no external funding.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** Not applicable.

**Acknowledgments:** The authors would like to thank 17 Agustus 1945 Samarinda, Indonesia, for its support of this research and publication. We also thank the reviewers for their constructive comments and suggestions.

**Conflicts of Interest:** The authors declare no conflict of interest.

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