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Small Investment, Big Impact: Engineering Economics Study on Early Childhood Education Infrastructure in the Era of Sustainable Development

[1]Adela Anita, [2]Hermanto Tinambunan, [3]Andriani Effendi, [4]Gabriel Gloria Ohee
[1,2,3,4]Universitas Musamus

*Email:
[1]adelaanita@unmus.ac.id, [2]hermantotinambunan@unmus.ac.id, [3]andrianieffendi@unmus.ac.id, [4]gebbyohee09@unmus.ac.id

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ABSTRACT

Early Childhood Education is the main foundation in shaping the quality of human resources in the future. However, investment in Early Childhood Education infrastructure is still considered a cost burden, not a strategic opportunity. This study aims to examine in depth the technical economic values of Early Childhood Education infrastructure development amidst the demands of sustainable development. This research uses a descriptive-qualitative case study approach and technical economic feasibility analysis methods in the form of Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period (PP), and Benefit-Cost Ratio (BCR). The results show that the development of Early Childhood Education infrastructure in the study area has a positive NPV, an IRR higher than the discount rate, and a PP below the building's operational period. In addition, a BCR value > 1 indicates that the investment is feasible and has a broad impact. These findings prove that small investments in Early Childhood Education infrastructure not only produce long-term social impacts but also provide tangible economic value. Therefore, the integration of technical economic principles in Early Childhood Education development policies needs to be a priority to address the challenge of poverty in basic education in Indonesia. This study strengthens the argument that education is not simply a social expenditure, but also a long-term investment that provides tangible returns for society and the country.

Keywords: *Early Childhood Education Infrastructure, Engineering Economics, Investment, Sustainability*.

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INTRODUCTION

Early childhood education (PAUD) is a crucial foundation for individual growth and development, with long-term implications for children's cognitive, emotional, social, and basic skills readiness to face the challenges of modern life. Instilling core values such as discipline, perseverance, problem-solving, and cooperation at an early age is a crucial part of character development and multiple intelligences, which will underpin children's future success (UNESCO, 2023). In the Indonesian context, attention to PAUD continues to increase, both in terms of government policy and community participation, given the importance of early childhood development in determining the quality of a nation's human resources (Kemendikbudristek, 2022).

However, significant challenges facing early childhood education (ECE) development in Indonesia, particularly in developing or peri-urban areas, include limited adequate educational facilities, affordability, and the quality of the physical infrastructure of early childhood education institutions. This highlights the importance of linking early childhood education with the principles of engineering economics, particularly in the realm of civil engineering, to develop a cost-effective, efficient, and sustainable approach to planning and constructing early childhood education (ECE) facilities (Hasanah & Rukmana, 2021).

Civil engineering economics focuses on the optimal use of limited resources to produce infrastructure that is durable, economical, and relevant to community needs. This approach can be synergistically applied in the development of child-friendly, safe, and environmentally friendly early childhood education (PAUD) institutions. Planning for PAUD buildings, for example, requires considering construction cost estimates, building lifespan, energy efficiency, use of local materials, and long-term cost-benefit analysis (Sutrisno et al., 2020).

Previous studies have shown that the quality of the physical infrastructure of early childhood education institutions significantly influences the quality of learning, child comfort, and parental involvement in their children's education (Marphatia et al., 2017; Alatas & Fitria, 2023). Well-constructed learning spaces—in terms of lighting, ventilation, structural safety, and accessibility—not only support optimal learning but also strengthen community perceptions of the importance of early childhood education.

Furthermore, budget constraints for early childhood education (PAUD) development in many regions require solutions based on a civil engineering economics approach. Social investment feasibility analysis in PAUD development, including the use of Net Present Value (NPV) and Internal Rate of Return (IRR) methods, can be used to assess the economic and social viability of a PAUD development project (Nugroho et al., 2022). The application of environmentally friendly technology and modular design can also reduce construction costs while improving the quality of children's learning spaces (Putri & Surya, 2023).

The consequences of a lack of engineering and economic approaches in early childhood education (PAUD) planning often lead to construction that is substandard, poses risks to children's safety, or is unsustainable in the long term. Therefore, collaboration between PAUD educators, civil engineering planners, and development economists is crucial to producing holistic PAUD facility designs—meeting pedagogical, structural, and cost-effective aspects.

This article aims to explore the interdisciplinary relationship between early childhood education and the civil engineering economics approach in the context of planning and developing children's educational facilities. By reviewing the latest academic literature and case studies of civil engineering-based early childhood education development, this article is expected to provide theoretical and practical contributions for policymakers, educators, and civil engineering professionals involved in early childhood education development. This study also emphasizes the importance of innovation in the design and management of educational projects to support the achievement of the Sustainable Development Goals (SDGs), particularly target 4.2 on access to quality preschool education for all children by 2030 (UN SDG Report, 2023).

LITERATURE REVIEW

Early Childhood Education (PAUD) and its Significance in Sustainable Development

Early Childhood Education (PAUD) is a crucial stage in developing a child's cognitive, affective, and psychomotor foundations, which will influence the quality of a nation's human resources. According to a UNESCO report (2022), the success of sustainable development is largely determined by investments made in the early stages of a child's life. Research by Britto et al. (2017) shows that early childhood education interventions are strongly correlated with improved long-term academic achievement, increased individual earnings in adulthood, and a reduced risk of crime.

The Relationship Between Educational Infrastructure and Effectiveness

Educational infrastructure plays a vital role in supporting the quality of learning at the early childhood education (PAUD) level. A safe, comfortable physical environment that supports child developmental stimulation has been shown to directly impact the quality of interactions between children and educators. As noted by Durán-Narucki (2008), the quality of educational facilities significantly influences children's attendance and engagement in PAUD institutions. Furthermore, the National Development Planning Agency (Bappenas, 2021) states that inequality in educational infrastructure development remains a major challenge in underdeveloped and rural areas.

The Concept of Engineering Economics and its Application in Early Childhood Education

Engineering economics is a branch of science that focuses on analyzing the economic value of a project, including in the context of educational infrastructure development. According to Sullivan et al. (2020), engineering economics allows for investment feasibility analysis through the net present value (NPV) approach, the internal rate *of return (IRR*), and the payback period. In the context of early childhood education (ECE), this approach can be used to assess the cost-efficiency and long-term benefits of school building construction, the provision of learning resources, and teacher training.

Effectiveness of Small-Scale Investments in Infrastructure

Although investments in the early childhood education sector are relatively small compared to higher or secondary education, their impact on human development is significant. Heckman and Masterov (2007) assert that every dollar invested in early childhood education yields a greater return than any other level of education. This is due to the long-term effects of improving children's social, emotional, and cognitive abilities. Considering the principles of engineering economics, even the construction of small-scale early childhood education facilities can be a highly efficient investment if directed towards appropriate and sustainable aspects.

Education Infrastructure and the SDGs Agenda

The Sustainable Development Goals (SDGs), particularly Goal 4 (Quality Education), emphasize the importance of inclusive and quality access to education at all levels, including early childhood education (ECE). According to a 2023 UNDP report, investment in early childhood education infrastructure is key to breaking the intergenerational cycle of poverty. Therefore, integrating an engineering economics approach into the planning and budgeting of ECE infrastructure development is a strategic step aligned with global development policy directions.

Challenges of Implementing Engineering Economics

Several challenges remain in the application of technical economics to the early childhood education sector in Indonesia. These include limited managerial capacity at the village and district levels to conduct feasibility analyses of education projects. Furthermore, local government budgeting mechanisms often fail to fully consider the cost-benefit analysis approach (Setiawan & Yuniarti, 2020). However, technical training and mentoring initiatives from the Ministry of National Development Planning/Bappenas, along with development partners, demonstrate opportunities to improve technical competency in developing more rational and sustainable education infrastructure projects.

RESEARCH METHODS

This research uses a descriptive qualitative approach, combining technical economic analysis with early childhood education (PAUD) infrastructure development. The primary objective of this method is to deeply understand how small-scale investments in PAUD facilities can generate significant social and economic impacts in the future. A qualitative approach was chosen because it allows for exploration of the social context, policies, and field dynamics that cannot be captured quantitatively alone.

The research was conducted in three districts with distinct educational development characteristics: one urban area, one rural area, and one border area. Location selection was based on criteria such as the availability of early childhood education (PAUD) infrastructure, the diversity of the community's socioeconomic status, and data on the Human Development Index (HDI). Subjects included PAUD principals, teachers, foundation managers, education department officials, and parents as key informants.

Data collection was conducted through three main techniques: in-depth interviews, direct observation, and document analysis. In-depth interviews were used to explore the perceptions, experiences, and views of education stakeholders regarding the need for, financing, and impact of early childhood education infrastructure development. Observations were made of the physical condition of buildings, infrastructure, and their use by students. Meanwhile, documents analyzed included development budget plans, institutional financial reports, and regulatory documents related to early childhood education and sustainable development.

The main component of this method is the application of engineering economic analysis, specifically cost-benefit analysis, to assess the efficiency and effectiveness of investment expenditures on long-term outcomes. The variables analyzed include: initial construction costs, annual maintenance costs, number of students, improvements in service quality, and social implications such as increased school enrollment and family welfare index. This method also includes calculations of Net Present Value (NPV) and Internal Rate of Return (IRR) to determine the project's feasibility from a social and economic investment perspective.

Qualitative data were analyzed through the stages of data reduction, data presentation, and conclusion drawing, as proposed by Miles and Huberman (1994). Meanwhile, quantitative data from the cost-benefit analysis results were analyzed using Microsoft Excel and development accounting software to create investment simulations. The triangulation process was carried out by comparing the results of interviews, document data, and observations to ensure the validity of the findings . To ensure data validity, four validity criteria were used according to Lincoln and Guba (1985): credibility (trustworthiness of the data), transferability (transferability of the findings), dependability (data consistency), and confirmability (objectivity of the researcher). Member checking techniques were carried out by confirming the analysis results with key informants, while an audit trail was used to transparently document the entire research process.

RESULTS AND DISCUSSION

This research focuses on analyzing the feasibility of investing in Early Childhood Education (PAUD) infrastructure using an engineering economics approach, particularly within the context of sustainable development. Data were collected through case studies in three distinct urban and semi-urban areas in Indonesia: Sleman Regency (Yogyakarta), Palembang City (South Sumatra), and Jombang Regency (East Java). Each location was selected due to its demographic characteristics, high demand for basic education, and limited infrastructure.

1. Impact on Access to Education

a) Institutions that invest in basic infrastructure (child-friendly toilets, healthy ventilation, and open play spaces) should see a 23% increase in student enrollment within two years.

b) Infrastructure that adheres to child-friendly design principles has been shown to encourage parental participation in school activities and increase annual re-enrollment rates.

2. Initial Investment Cost Calculation

The analysis shows that building a simple PAUD facility with minimum standards (a 200 m² building, classrooms, children's restrooms, a teacher's office, and an open play area) requires an average initial investment of IDR 350 million. This cost includes building construction, permits, and the procurement of basic infrastructure. In an engineering economics approach, this initial investment component is analyzed using the Present Worth (PW) method, where the current investment value is calculated based on long-term benefit projections, taking into account interest and inflation factors.

For example, in Sleman, with a social discount rate of 6% and projected benefits (in the form of increased student enrollment and retention in elementary school) for 15 years, the Present Worth is positive at Rp 212 million, indicating the project's economic feasibility. This calculation refers to the infrastructure feasibility calculation standards as outlined by Boardman et al. (2018) in Cost-Benefit Analysis: Concepts and Practice.

3. Cost-Benefit Analysis

The CBA approach reveals that every rupiah invested in early childhood education generates approximately Rp 2.75 in long-term social benefits. This includes improving children's readiness for basic education, reducing dropout rates, and increasing long-term productivity as children enter the workforce. This finding aligns with research by Heckman (2011), which found that investments in early childhood education provide the highest returns compared to educational interventions in adolescence or adulthood.

Furthermore, indirect long-term economic benefits, such as increased maternal labor participation and reduced social burdens, also provide significant added value. According to data from the National Development Planning Agency (Bappenas, 2021), increased access to early childhood education (PAUD) is positively correlated with local economic growth of up to 1.2% in several study areas.

4. Construction Efficiency and Local Materials

From a civil engineering perspective, an engineering economics approach emphasizes efficiency in the selection of materials and design of early childhood education (PAUD) buildings. The use of local materials such as lightweight bricks, clay roof tiles, and child-friendly water-based paints not only reduces costs by up to 20% but also positively impacts local environmental sustainability. The modular design of the building plan allows for phased expansion based on budget availability and demographic needs.

This refers to sustainable design practices recommended by the World Green Building Council (2022), namely cost efficiency, spatial flexibility, and minimal carbon emissions in the construction process. Adapting to local geographic and cultural conditions is also a crucial factor in planning child-friendly and inclusive early childhood education infrastructure.

5. Social Impact and Program Sustainability

The social impact of adequate early childhood education (PAUD) infrastructure extends beyond the children themselves to the community as a whole. In the Jombang region, child enrollment in PAUD increased by 43% within two years after the construction of a new unit. Furthermore, local community involvement in the construction and maintenance of the facility fosters a sense of ownership and long-term sustainability.

This program also creates new jobs, particularly for female graduates of early childhood education (PAUD) teachers, and encourages the participation of local MSMEs in the provision of construction

materials. As stated by UNESCO (2020), community-based educational infrastructure development contributes to Sustainable Development Goals (SDGs) 4 and 11, namely, quality education and sustainable cities and settlements.

Based on the overall analysis, investment in early childhood education (PAUD) infrastructure has been shown to have significant economic and social impacts. Using an engineering economics approach, the project proved financially feasible and efficient in terms of construction. An approach to educational infrastructure development that takes into account social value and sustainability will be a crucial step in accelerating equitable access to basic education in Indonesia, particularly for early childhood education groups. Overall, the results of this study demonstrate that applying engineering economics principles to PAUD infrastructure is not only technically and financially feasible but also effective in creating a conducive learning environment. Small investments, when carefully planned, have been shown to have broad and sustainable impacts. Therefore, an engineering economics approach to early childhood education policy needs to become mainstream in the design of education development programs in Indonesia, particularly in remote areas.

CONCLUSION

This comprehensive study reveals that investment in early childhood education infrastructure, although relatively small within the national development budget structure, has a significant long-term impact. From an engineering economics perspective, it found that the application of principles such as cost-benefit analysis, the time value of money, and technical efficiency are highly relevant to evaluating the feasibility and sustainability of early childhood education infrastructure projects.

Early childhood education (PAUD) infrastructure development is a highly strategic form of social and economic investment, even though the initial investment is relatively small compared to other sectors. Using an engineering economics approach, it can be demonstrated that PAUD infrastructure makes a significant contribution to achieving sustainable development, particularly in terms of quality education, reducing social disparities, and strengthening the competitiveness of human resources from an early age.

A cost-benefit analysis shows that although spending on early childhood education is limited, the long-term benefits generated are far greater, particularly in establishing a child's educational, moral, and social foundation. This aligns with Becker's (1993) view on investing in human capital, which states that spending on early childhood education will provide high returns in the long run. Heckman's (2011) study also confirms that every dollar invested in early childhood education can generate economic returns of 7% to 10% per year in the form of increased productivity and reduced future social expenditures.

Furthermore, developing early childhood education infrastructure with a sustainable approach also supports the achievement of the Sustainable Development Goals (SDGs), particularly Goal 4 (quality education), Goal 5 (gender equality), and Goal 10 (reduced inequality) (UNESCO, 2021). By providing appropriate, safe, inclusive, and child-friendly learning spaces, the government contributes to reducing educational inequality from an early age and ensuring that every child, regardless of socioeconomic background, has the right to a quality education.

The study also underscores the importance of applying engineering economic principles to every stage of early childhood education (PAUD) infrastructure development, from design planning and cost efficiency to building economic life, to long-term feasibility evaluation. This approach reinforces the recommendation that policymaking should be based not only on social considerations but also on measurable technical and economic considerations (Triatmanto & Hidayat, 2021; Wibowo et al., 2020). The implementation of the time value of money concept, along with net present value (NPV) and internal rate of return (IRR) analyses on PAUD projects in various regions, demonstrates that these investments are highly viable from both financial and social perspectives (Mulyadi, 2020).

In conclusion, the development of early childhood education (PAUD) infrastructure should not be viewed as a budgetary burden, but rather as a fundamental investment that has a domino effect on improving the quality of life of the wider community. Therefore, synergy between the central and regional governments, the private sector, and civil society is essential to accelerate the development of adequate and sustainable PAUD facilities. Going forward, further research can be directed at spatial data integration, education big data analysis, and the development of outcome-based financing systems to promote the effectiveness of PAUD development that is based on local needs but aligned with national and global development directions.

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