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Development of a Sustainable Action Framework for Contractors in the Construction Industry

Pengembangan Kerangka Kerja Tindakan Berkelanjutan bagi Kontraktor di Industri Konstruksi

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Abstract

Sustainable development has become a strategic issue in the global construction industry, including Indonesia. This study aims to identify and prioritize the most relevant sustainability indicators in building construction projects based on the perceptions of construction professionals. The research method consists of three stages: a literature review to identify initial indicators, a questionnaire using the Analytical Hierarchy Process (AHP) to determine indicator priorities, and a final stage interview with contractors to assess the applicability of the indicators in practice. The literature review identified 17 indicators grouped into five dimensions: environmental, social, economic, management/lean, and unclassified/culture. The AHP results prioritized the dimensions as follows: environmental, social, economic, management/lean, and culture. The validation results indicated that social and management indicators such as safety, time and resource efficiency, and sustainability monitoring were the easiest to implement. The novelty of this research lies in the development a sustainable action framework for Indonesian contractors through the integration of AHP and field validation. This study concludes that indicators directly related to efficiency and safety are easier to implement, while policy support and financial incentives were recommended to enhance the implementation of environmental and economic sustainability indicators in future construction projects.

Kata Kunci:
Analytical hierarchy process (AHP)
Indikator keberlanjutan
Industri konstruksi indonesia
Konstruksi berkelanjutan
Prioritas indikator

Abstrak

Pembangunan berkelanjutan telah menjadi isu strategis dalam industri konstruksi global, termasuk Indonesia. Penelitian bertujuan untuk mengidentifikasi dan memprioritaskan indikator keberlanjutan yang paling relevan dalam proyek konstruksi di Indonesia berdasarkan persepsi para profesional konstruksi. Metode yang digunakan dalam penelitian dimulai dari studi literatur untuk mendapat indikator awal, penyebaran kuesioner dengan metode *analytical hierarchy process* (AHP) untuk menentukan urutan prioritas indikator dan tahap akhir wawancara kontraktor untuk mengetahui keterterapan indikator di lapangan. Hasil studi literatur terdapat 17 indikator yang diklasifikasikan ke dalam lima dimensi yaitu lingkungan, sosial, ekonomi, manajemen, *unclassified indicators* atau budaya. Hasil AHP menunjukkan bahwa dimensi lingkungan menempati peringkat pertama diikuti oleh indikator sosial, ekonomi, manajemen, dan budaya. Sedangkan hasil validasi menunjukkan bahwa indikator sosial dan manajemen seperti keselamatan kerja, efisiensi waktu dan sumber daya serta pengawasan berkelanjutan merupakan indikator yang paling mudah diterapkan. Kebaruan penelitian terletak pada pengembangan kerangka kerja tindakan keberlanjutan bagi kontraktor Indonesia melalui integrasi metode AHP dan validasi lapangan. Penelitian menyimpulkan bahwa indikator yang terkait langsung dengan efisiensi, keselamatan lebih mudah diterapkan, sementara dukungan kebijakan dan insentif finansial disarankan untuk meningkatkan penerapan indikator keberlanjutan lingkungan dan ekonomi pada proyek konstruksi mendatang.

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A. INTRODUCTION

Infrastructure is the tangible outcome of civil engineering that functions as a primary driver of both economic and social development. Based on its function, infrastructure is generally classified into two categories: economic infrastructure, such as transportation networks and utilities and social infrastructure, including schools and hospitals (Engel, et al., 2022). Furthermore, the construction sector itself is commonly divided into two major branches: the building sector and infrastructure development, each oriented toward meeting social and economic demands (Norouzi, et al., 2021).

As development needs continue to rise, so does the consumption of natural resources as raw materials for construction (Chen, et al., 2024). This process often results in negative environmental impacts, due to the exploitation of natural resources and changes in ecosystems during and after construction (Banihashem, et al., 2021). Large-scale land-use changes such as the development of residential and industrial areas can degrade environmental quality and reduce ecological carrying capacity. For instance, construction in watershed areas can trigger flooding, reduce clean water availability, and cause pollution that deteriorates river water quality (Pang & Guan, 2024). Additional environmental impacts arise from the emissions of heavy equipment and the accumulation of construction waste, which contaminate both air and soil (Dehkordi, et al., 2024).

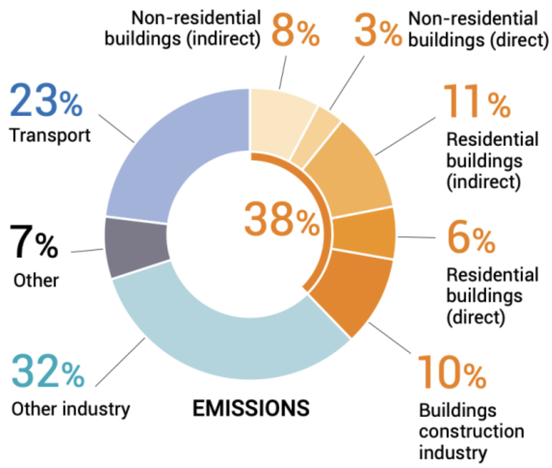

Figure 1. *Contribution of global emissions*
(United Nations Environment Programme, 2020)

Globally, the construction sector contributes approximately 38% of total CO_2 emissions comprising 28% from building operations and 10% from construction processes themselves (Figure 1) (United Nations Environment Programme, 2020). To mitigate these impacts without compromising social and economic development, a sustainable development approach is necessary. The concept of sustainability was formally introduced by the Brundtland Commission in 1987, with the aim of integrating environmental and economic issues in a balanced manner (Hariram, et al., 2023). In the context of construction, this concept emphasizes material and energy efficiency, waste minimization, and the preservation of the natural environment (Alnsour, et al., 2022). Its classical definition emphasizes meeting present needs without compromising the ability of future generations to meet theirs (Meutia, 2020).

The application of sustainability principles in construction projects can be analyzed through the project life cycle (PLC) framework, which consist of design, construction, and operational phases. The design phase typically focuses on cost efficiency, initial environmental impacts, and design quality (Backes & Traverso, 2021). Meanwhile, the operational phase has been extensively examined through sustainable building rating systems such as LEED, BREEAM, and GREENSHIP (Hanif, 2022; Norouzi, et al., 2021), the evaluation of green building concepts (Koesalamwardi, et al., 2024) and energy efficiency (Retno, et al., 2024). However, the construction phase has received comparatively limited attention, despite its substantial contribution to environmental impacts through material use and execution methods (Backes & Traverso, 2021), particularly in Asian countries, including Indonesia.

The implementation of sustainable construction is crucial because conventional construction processes consume large amounts of resources and generate a high carbon footprint. Therefore, the appropriate selection of materials and environmentally friendly construction methods can significantly reduce carbon emissions and support the realization of zero-energy buildings (Rajabi, et al., 2022). In this regard, contractors who are the key actors during the implementation phase play a strategic role in operationalizing sustainable actions, supported by supervision consultants and project owners (Fei, et al., 2021).

Sustainable construction research still exhibits several critical gaps. First, most existing studies have predominantly focused on the design and operation phases, while limited attention has been given to the construction phase, which significantly contributes to environmental degradation. Second, many sustainable action indicators have been developed in developed countries such as LEED, BREEAM, and GREENSHIP but there is a lack of indicators specifically tailored to the Indonesian construction context. Third, previous research in Indonesia has rarely employed a combination of the Analytical Hierarchy Process (AHP) and interviews to validate the applicability of sustainability indicators in actual construction projects. Fourth, there is still a lack of research addressing the practical challenges of implementing sustainable construction, particularly those related to high costs, limited availability of sustainable materials, and insufficient regulatory support.

Therefore, this study is essential to bridge these gaps by developing and validating a context-specific sustainable action framework for contractors in Indonesia through the integration of AHP *analysis and a pilot project. This study offers several novelties. First, it develops a specific sustainable action framework for Indonesian contractors, addressing the contextual needs of the local construction industry. Second, it combines the AHP method with a pilot project as a novel approach to assess the applicability of sustainability indicators in actual construction projects. Third, this research discusses sustainability indicators from the perspective of local work culture, highlighting the importance of cultural adaptation in achieving effective and practical implementation of sustainable construction practices.*

The urgency of this research lies in the high environmental impact of the Indonesian construction sector, particularly related to emission, waste generation, and inefficient use of materials. Moreover, national regulations and global commitments such as the Sustainable Development Goals (SDGs) and the National Medium-Term Development Plan (RPJMN) 2020-2024 require the implementation of sustainable construction practices. However, there is currently no specific action framework available for contractors to guide the practical application of these principles. In addition, only a few studies have examined the challenges in implementing of sustainable construction, including high cost, limited availability of sustainable materials, and insufficient regulatory support. Lastly, global sustainability frameworks such as LEED, BREEAM, and GREENSHIP are not fully relevant to the context of developing countries. Therefore, developing context specific sustainable action framework for Indonesian contractors is both timely and essential to support the transition toward sustainable construction practices.

This study thus aims to identify relevant sustainable action indicators to contractors in the Indonesian construction context. These indicators are expected to serve as a reference for measuring and evaluating construction practices aligned with sustainability principles and to support the achievement of SDGs targets in the national construction sector.

B. LITERATURE REVIEW

The concept of sustainable development (Figure 2) has been a global concern since the UN Conference on the Human Environment (1972), and was further reinforced by the Brundtland Report (1987) and the Earth Summit (1992). Its implementation was institutionalized through the Millennium Development Goals (MDGs), followed by the Sustainable Development Goals (SDGs) to be achieved by 2030. The SDGs comprise 17 goals and 231 indicators, explicitly emphasizing the role of the construction sector in achieving sustainable development (Fei, et al., 2021). Indonesia has incorporated the SDGs into its National Medium-Term Development Plan (RPJMN) 2020–2024, with a target to reduce emissions by up to 41% by 2030 (Pemerintah RI, 2016).

Within the PLC framework, the implementation of sustainability in the design and operational phases is commonly referred to as green building, while in the construction phase it is known as sustainable construction (Figure 3). Green building refers to design and operational practices that promote efficient energy, water, and material use, and are environmentally friendly and health-conscious. This definition aligns closely with the life cycle assessment (LCA) approach, which evaluates the environmental impacts of construction materials and activities (Hariram, et al., 2023). Although various certification systems such as LEED, BREEAM, and GREENSHIP have been developed to assess building *sustainability, they primarily focus on the design and operational phases rather than construction.*

However, the construction phase also has direct impacts on all three dimensions of sustainability: economic, social, and environmental. Thus, specific indicators of sustainable action are required to guide and measure sustainable construction practices. Key considerations in this phase include the use of environmentally friendly materials such as certified steel, FSC-verified timber, and recycled materials as well as efficient, and low-impact execution methods such as environmental management plans and traffic management Plans to minimize pollution and disruption (Norouzi, et al., 2021).

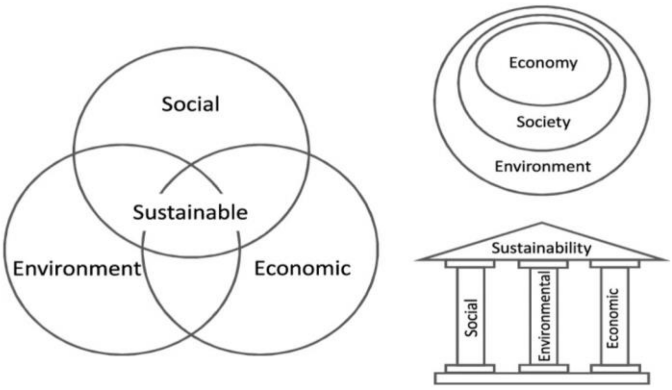

Figure 2. *Concept of sustainable development (Hariram, et al., 2023)*

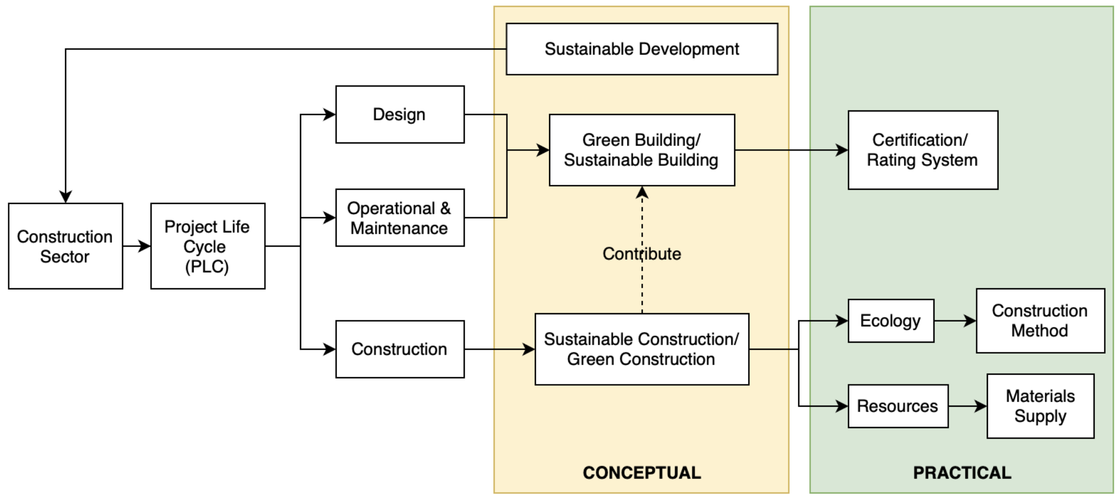

Figure 3. *General concept of sustainable construction*

Several studies have attempted to develop sustainable action indicators. For instance, Alnsour, et al., (2022) identified 78 indicators in Jordan across five main categories: environmental, social, economic, cultural, and lean manufacturing. Rajabi, et al., (2022), emphasized that relevant indicators may vary across countries depending on technological and social capacities. In Indonesia, several regulations have been issued to support sustainable construction implementation, including Law No. 2 of 2017, Government Regulation No. 14 of 2021, and Ministry of Public Works and Housing Regulation

No. 9 of 2021. These regulations emphasize the importance of sustainability standards in construction services, from material and equipment quality to environmental protection.

Nevertheless, the practical implementation of sustainable construction still faces various challenges, including limited technology adaptation, high initial costs, difficulties in sourcing eco-friendly materials, and lack of education and public awareness (Ayarkwa, et al., 2022). Therefore, there is a need to develop contextual and applicable sustainable action indicators specifically for contractors in Indonesia (Widyaningsih & Tanne, 2023).

C. METHODOLOGY

This research employed a mixed-method approach that combined a literature review, indicator formulation, and pilot testing in a real construction project. The overall design consisted of three main stages (Figure 4).

A preliminary study was conducted to extract the state-of-the-art sustainability concepts in the construction industry. This stage addressed the problems and defined the research objectives. In this process, an understanding of the sustainability concept and its development was established, followed by an initial identification of its adoption in the construction sector and the development of a concept map towards sustainable actions.

Sustainable action indicators were established through three processes following the preliminary study. The first process involved analysing relevant literature on sustainability principles in the construction phase. Keywords such as sustainability, action, behaviour, practices, contractors, and indicators were used to conduct the literature search, which was carried out using the Publish or Perish application. The literature reviewed consisted of the most recent studies published within the last five years (2020-2024). The collected papers were evaluated based on their background or introduction, research questions, discussions, and results. They were then classified according to the relationships and similarities among these factors to derive sustainable action indicators. Factors that could not be grouped were classified as unclassified indicators. From this stage, the initial set of indicators was obtained.

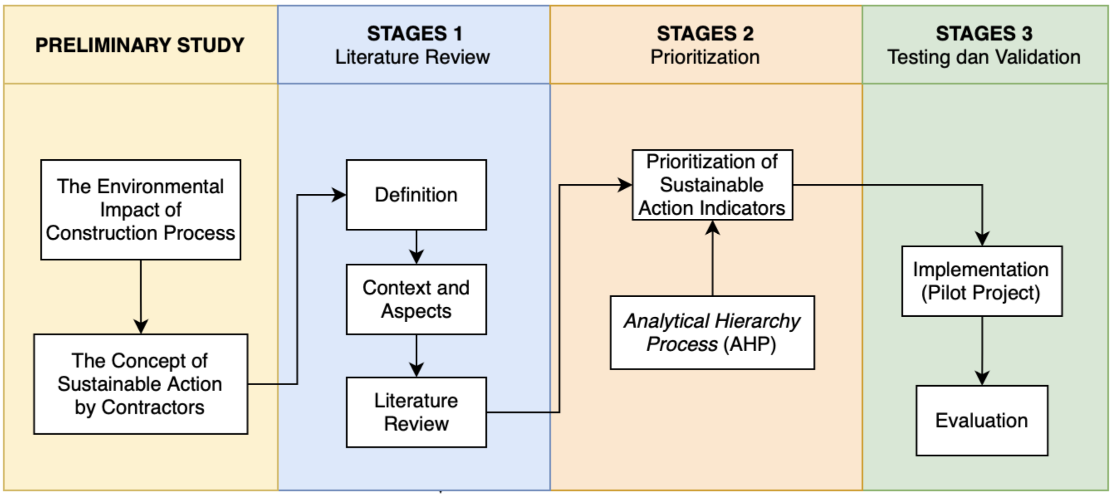

***Figure 4.** Research design*

The second process involved refining the selected indicators into a proposed framework tailored to the Indonesian construction context. At this stage, the AHP was employed to prioritise and rank the most influential indicators. The application of AHP provided a structured decision-making method that integrated expert judgement with pairwise comparisons, ensuring that the resulting framework reflected not only theoretical comprehensiveness but also practical relevance.

The prioritization of sustainable action indicators was carried out using the AHP with several steps:

1. Hierarchical structure

Hierarchy of prioritization are shown in Figure 5.

2. Pairwise comparison

Each criterion and alternative is compared using a scale from 1 to 9. Definitions of the scale are shown in Table 1.

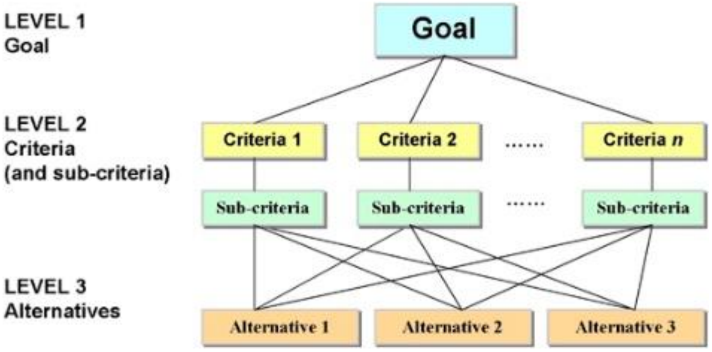

Figure 5. *Hierarchy of prioritization*

Table 1. *Pairwise comparison scale*

Intensity of Importance	*Definition*	*Description*
1	*Equal importance*	*Both elements are equally important.*
3	*Slightly more important*	*One element is slightly more important than the other, but not convincingly so.*
5	*More important*	*One element is clearly more important than the other in several situations.*
7	*Much more important*	*One element is obviously and significantly more important than the other in several cases.*
9	*Absolutely more important*	*One element is proven to be very significantly more important in multiple cases, with the highest level of consensus.*
2, 4, 6, 8	*Intermediate values*	*A compromise between the two judgments.*
Reciprocals	*Reversed comparison*	*If activity i is rated with a number when compared to activity j, then activity j has the reciprocal value when compared to activity i.*

The comparison results for each pair of factors were described as an integer value from 1 (equal importance) to 9 (absolutely more important), where a higher number means that the selected factor is more important than the other compared factor. For example, if criterion A is more important than criterion B with a value of 5, the reciprocal comparison of B to A is 1/5.

3. Determining priority weights

The priority weight was calculated by the geometric mean calculation of each row to determine the relative importance of each criterion. It is calculated by this equation:

$$GM_i = (\Pi_{j=i}^{n} a_{ij})^{1/n} \qquad (1)$$

a_{ij} = *Pairwise comparison value between element i and element j*
n = *Total number of elements*

This step is used to simplify the values from multiple pairwise comparison into a single representative value for each criterion.

4. Calculating priority values

The geometric mean results are normalized using this equation to determine priority values:

$$w_i = \frac{GM_i}{\sum_{i=1}^{n} GM_i} \qquad (2)$$

w_i = *Normalized weight or priority value of criterion i*
GM_i = *Geometric mean i criterion*

The resulting vector represents the priority weight that indicates the relative importance of each criterion toward overall goal.

5. Consistency check

To ensure the logical consistency of the judgements, the maximum eigenvalue (λ_{max}), consistency index (CI), and consistency ratio (CR) are calculated using this equation:

$$CI = \frac{\lambda_{max} - n}{n - 1} \qquad (3)$$

$$CR = \frac{CI}{RI} \qquad (4)$$

CI = *Consistency index; matrix is sufficiently consistent if CI <0.1*
n = *Number of criteria*
λ_{max} = *Specifies the largest correct number of the matrix*
CR = *Consistency ratio, consistency value*
RI = *Table value based on the number criteria, so called random index*

6. Final prioritization

Indicators were ranked based on their calculated priority weights. The third stage examined the applicability of the indicators through a pilot project by conduction an interview with the project manager. The project manager had nearly 10 years of experience in construction projects, 8 years in building management, and 3 years in green building. This stage was carried out to evaluate the feasibility of implementing the proposed indicators. Respondents were asked to score each indicator on a Likert scale ranging from 1 (least applicable) to 5 (most applicable), and to provide qualitative insights regarding barriers, opportunities, and potential improvements.

Finally, the data were analyzed by combining the quantitative scores with qualitative comments from respondents. This process enabled the identification of indicators that were considered highly applicable in practice, as well as those facing significant implementation challenges. The results provided an initial validation of the framework and highlighted areas requiring policy support and contextual adaptation.

D. RESULT AND DISCUSSION

1. Identification and collection of sustainable action indicators

Sustainable action indicators were identified through a structured literature review focusing on sustainability in the construction phase. Literature was collected using the Publish or Perish application with the Google Scholar database, employing keywords such as:

sustainable, action, behaviour, practices, contractors, indicators. Only papers published in the past five years (2020–2024) were included. The selected papers were analyzed based on their background, research questions, discussion, and results. Relevant factors extracted from the reviewed literature were grouped according to their thematic similarities to formulate the sustainable action indicators. Any factor that could not be grouped was categorized as an unclassified indicator. The identified indicators were categorized into five main groups: environmental, social, economic, management (lean), and unclassified. The detailed classification is shown in Table 2, Table 3, Table 4, Table 5 and Table 6.

2. Prioritization of sustainable action indicators using AHP

The next step was to prioritize the indicators using the AHP method. This was implemented through a structured questionnaire distributed to experts including project managers, site managers, supervisors, and HSE officers. AHP is a multi-criteria decision-making tool used to rank alternatives based on a set of defined criteria.

***Table 2.** Environmental indicators*

No	Environmental Indicators	Description	Sources
1	Efficient construction waste management	Minimizing environmental impact through waste reduction, reuse, and recycling practices	Alnsour, et al., (2022); Moradi & Kahkonen (2022)
2	Use of environmentally friendly materials	Selecting low-impact materials, such as recycled or eco-labeled products	Alnsour, et al., (2022)
3	Use of renewable or energy-efficient resources	Utilizing renewable energy (e.g., solar power) or energy-saving technologies during construction	Rajabi, et al., (2022); Moradi & Kähkönen, (2022)
4	Prevention of environmental contamination around the project site	Implementing dust control, water protection, and air pollution prevention strategies	Apanavičienė, et al., (2020); Moradi & Kähkönen, (2022)
5	Adaptation to potential disasters in the project area	Designing with disaster risk considerations (floods, earthquakes, etc.) to enhance resilience	Moradi & Kähkönen, (2022)

***Table 3.** Social indicators*

No	Social Indicators	Description	Sources
1	Occupational Health and Safety (OHS) practices	Applying safety standards and procedures to ensure worker protection	Alnsour, et al., (2022); Rajabi, et al., (2022)
2	Worker comfort and safety during construction	Providing safe and adequate worker facilities (toilets, rest areas, etc.)	Rajabi, et al., (2022); Moradi & Kähkönen, (2022)
3	Local stakeholder engagement	Involving community and local authorities in planning and implementation	Stanitsas & Kirytopoulos (2021)
4	Involvement of local labor and economy	Hiring local workers and sourcing materials locally to support the local economy	Moradi & Kähkönen, (2022)
5	Preservation of local culture	Ensuring construction respects and preserves local cultural values	Moradi & Kähkönen, (2022)

Table 4. *Economic indicators*

No	Economic Indicators	Description	Sources
1	Efficient use of energy and resources to reduce costs	Optimizing resource use to minimize waste and expenses	Rajabi, et al., (2022)
2	Client satisfaction	Measuring success based on the project owner's satisfaction with quality, time, and cost.	Moradi & Kähkönen, (2022)
3	Comprehensive Life Cycle Cost (LCC) consideration	Analyzing total costs over the asset's lifecycle to ensure investment value.	Moradi & Kähkönen, (2022)

Table 5. *Management (lean) indicators*

No	Management Indicators	Description	Sources
1	Just-in-Time (JIT) system for material management	Procuring materials exactly when needed to avoid excess inventory	Alnsour, et al., (2022)
2	Efficiency in project execution (time, resources)	Reducing waste through better scheduling and resource management	Stanitsas & Kirytopoulos (2021)
3	Monitoring and reporting of sustainability performance on-site	Regularly tracking sustainability metrics (energy, waste, etc.)	Stanitsas & Kirytopoulos (2021)

Table 6. *Unclassified indicators*

No	Unclassified Indicators	Description	Sources
1	Alignment with local work culture	Adjusting project practices to local norms and cultural expectations to prevent social conflict	Alnsour, et al., (2022)

The steps include:

a. *Pairwise comparison*
   Each criterion and alternative is compared using a scale from 1 to 9. The sample of pairwise comparison matrix described in Table 7.
b. *Determining priority weights*
   Relative weights for each criterion are calculated based on aggregated expert judgments. An example of the priority weights is shown by Table 8.
c. *Calculating priority values*
   The eigen vectors for each matrix element are normalized and averaged to obtain final priority values. These are shown in Table 9.
d. *Consistency check*
   CR $\leq$ 0.10 indicates acceptable consistency. In this study, λmax = 5.17, CI = 0.04, and CR = 0.03, which confirms consistency.
e. *Final prioritization*
   Indicators were ranked based on their calculated priority weights. The results are summarized in Table 10.

Table 7. *Sample pairwise comparison matrix*

Criteria	Environment	Social	Economic	Management/ Lean	Culture
Environment	1.00	8.00	8.00	0.13	7.00
Social	0.13	1.00	6.00	0.11	0.25
Economic	0.13	0.17	1.00	0.14	6.00
Management/Lean	8.00	9.00	7.00	1.00	8.00
Culture	0.14	4.00	0.17	0.13	1.00

Table 8. *Weight calculation*

Criteria	Environment	Social	Economic	Management/ Lean	Culture
Environment	1.0000	1.7029	1.2587	1.4598	3.7227
Social	0.5872	1.0000	1.5714	2.0671	2.3121
Economic	0.7945	0.6364	1.0000	1.4675	3.8115
Management/Lean	0.6850	0.4838	0.6814	1.0000	3.7020
Culture	0.2686	0.4325	0.2624	0.2701	1.0000
Total	3.3354	4.2555	4.7738	6.2646	14.5483

Table 9. *Priority values*

Criteria	Environment	Social	Economic	Management/ Lean	Culture
Environment	0.299814	0.400154	0.263657	0.233023	0.255884
Social	0.176065	0.234989	0.329171	0.329969	0.158923
Economic	0.238202	0.149540	0.209475	0.234261	0.261990
Management/Lean	0.205382	0.113680	0.142739	0.159628	0.254466
Culture	0.080537	0.101636	0.054959	0.043119	0.068737
Eigen Vector	-	-	-	-	1.000000

Table 10. *Final prioritization of indicators*

Main Indicator	Priority Rank	Sub-Indicator
Environment	1	Prevention of environmental contamination around the project
	2	Use of environmentally friendly materials
	3	Adaptation to potential natural disasters in the project area
	4	Efficient management of construction waste
	5	Use of renewable energy / energy efficiency
Social	1	Implementation of Occupational Health and Safety (OHS) practices
	2	Worker comfort and safety during construction
	3	Participation and involvement of local stakeholders
	4	Involvement of local labor and contribution to the local economy
	5	Preservation of local culture
Economic	1	Customer satisfaction
	2	Efficient use of energy and resources to reduce costs
	3	Consideration of comprehensive life cycle cost (LCC) analysis
Management/ Lean	1	Efficiency in project execution processes (time and resources)
	2	Implementation of just-in-time systems for material management
	3	Monitoring and reporting of sustainability performance on site
Culture	1	Alignment with local work culture

Based on the results of the indicator prioritization using the AHP (Table 10), environmental indicators received the highest priority weights. This indicates that experts consider preventing environmental contamination, using eco-friendly materials, adapting to disaster risks, managing construction waste, and utilizing renewable energy as the most critical aspects in achieving sustainable construction.

Within the environmental dimension, the indicator preventing contamination of the project's surrounding environment ranked the highest, reflecting strong awareness of the negative impacts of construction activities on nearby ecosystems. In the *social dimension, occupational health and safety (OHS) practices were prioritized, highlighting the importance of worker protection. In the economic dimension, client satisfaction emerged as the top priority. According to Homthong, et al., (2024), construction project success is measured not only by technical outcomes but also by client satisfaction, which can enhance a contractor's chances of securing future projects.*

From the management/lean perspective, process efficiency was considered most important. The use of AHP proved effective in capturing the subjective judgments of respondents (including project managers, site managers, supervisors, and HSE officers) and converting them into quantitative information to support decision-making.

3. *Applicability of sustainable action indicators*

The final phase involved a preliminary pilot study to assess the relevance and applicability of the literature-derived indicators in actual construction settings. This stage also identified potential challenges and refined the research instrument for subsequent broader application. Table 11 summarizes the applicability assessment of sustainable action indicators based on the pilot project interviews. The findings indicate a wide variation across dimensions, with higher scores for indicators closely related to safety, cost, and efficiency (e.g., safety, owner satisfaction, time and resource efficiency, and sustainability monitoring), and lower scores for those requiring systemic change or long-term perspectives (e.g., use of eco-friendly materials, life cycle costing, and cultural heritage preservation).

The pilot project revealed varying degrees of applicability for the proposed sustainable action indicators when assessed against real-world construction practices. Environmental indicators were generally perceived as challenging to implement, particularly waste management and the use of eco-friendly materials, which were constrained by cost and limited availability. While pollution prevention measures such as wastewater treatment facilities were considered feasible, more advanced initiatives like renewable energy adoption or life cycle-oriented design were seen as less practical without strong regulatory and financial support.

In contrast, social indicators especially occupational health and safety, worker welfare, and the use of local labor were recognized as highly relevant and achievable in practice. Stakeholders emphasized that safety and comfort directly influence productivity and worker retention, aligning these indicators with both ethical and economic imperatives. However, stakeholder participation was rated low, reflecting limited involvement of local authorities in construction projects. Meanwhile, the preservation of local culture was considered not directly relevant to project implementation. On the other hand, the adjustment to local work culture, particularly in terms of communication and interaction, was rated highly applicable. This indicates that cultural adaptation plays an important role as a supporting factor for effective collaboration in the field.

Economic indicators showed a similar dichotomy. Owner satisfaction emerged as the most implementable measure, commonly evaluated through the conventional metrics of time, cost, and quality performance. Yet, the adoption of life cycle cost (LCC) analysis was perceived as unrealistic, since contractors tend to focus narrowly on the construction phase rather than long-term operational considerations.

Table 11. *The result of pilot project*

Dimension	Indicator	Score (1–5)	Key Challenges
Environment	*Waste management*	*3*	*Cost of material reuse, limited disposal facilities, space availability*
	Eco-friendly materials	*2*	*Higher cost, limited availability*
	Renewable/energy efficiency	*3*	*High initial cost, weather dependency (e.g., solar panels)*
	Pollution prevention	*4*	*Need for specific facilities (IPAL)*
	Disaster adaptation	*3*	*Usually addressed in design, not construction*
Social	*Occupational health & safety (K3)*	*5*	*Maintaining consistency*
	Worker comfort & safety	*4*	*Working conditions*
	Stakeholder participation	*2*	*Low local government involvement*
	Local labor & products	*4*	*Material availability varies by region*
	Cultural heritage preservation	*1*	*Perceived irrelevant to project delivery*
Economic	*Energy & material efficiency*	*3*	*High initial investment*
	Owner satisfaction	*5*	—
	Life Cycle Cost (LCC)	*1*	*Contractors focus only on construction stage*
Management/ Lean	*Just-in-time system*	*4*	*Suitable only for fast-moving materials*
	Time & resource efficiency	*5*	*Need for better scheduling*
	Sustainability monitoring	*5*	*Requires data collction routines*

Table 12. *Research result*

Stages	Result
Stage 1: Literature review	*Based on the literature review, the identified sustainability indicators were categorized into five main groups: environmental, social, economic, management (lean), and unclassified*
Stage 2: Prioritization	*Based on the AHP prioritization results, environmental indicator ranked first, followed by the social, economic, management, and cultural indicators.*
Stage 3: Testing and validation	*Based on the pilot project results, the implementation of sustainable action indicators varied across dimensions. Social and management indicators such as occupational health and safety, time and resource efficiency and sustainability monitoring were the easiest to implement. In contrast, environmental indicators, particularly life cycle cost and the use of eco-friendly materials were found to be the most difficult to apply in practice.*

The summary of the research was presented in Table 12. This table illustrates the results of research stage. The first stage, a literature review identified five indicators: environmental, social, economic, managerial, and unclassified. In the second stage, the ranking results indicated that the environmental indicators was the most important, followed by social, economic, management, and unclassified indicators. The last stage testing and validation with project managers showed that social and management indicators such as safety, time and resource efficiency, and sustainability monitoring were the easiest *to implement. In contrast, environmental and economic indicators which require high cost such as the availability and use of environmentally friendly materials and life cycle cost were perceived as the most difficult to implement.*

From management indicators demonstrated the highest level of acceptance. Practices such as just-in-time material delivery, resource efficiency, and continuous monitoring were deemed feasible, primarily because they are closely tied to project productivity and cost efficiency. These findings suggest that indicators with immediate and tangible benefits to project execution are more likely to be adopted, while those requiring systemic changes, substantial investments, or policy-level enforcement remain less feasible.

Overall, the pilot project confirmed that the proposed indicators are not equally applicable in practice. Indicators linked to cost savings, efficiency, safety, and work culture gained strong support, whereas those demanding higher upfront investment or broader institutional alignment faced significant barriers. This implies that the successful implementation of sustainable construction in emerging economies like Indonesia requires not only technical readiness but also enabling policies, incentives, and contextual adaptation to local industry conditions.

E. CONCLUSION

This study reveals that sustainability in construction projects in Indonesia encompasses four interrelated dimensions: environmental, social, economic, and management. Using the AHP method based on the perceptions of construction professionals, the results indicate that environmental indicators are the highest priority, with prevention of environmental pollution during construction emerging as the most critical sub-indicator. This finding is consistent with previous studies presented in Tables 2-6, particularly Alnsour, et al. (2022) and Moradi & Kahkonen, (2022) who emphasized waste management and pollution prevention as primary environmental concerns in sustainable construction.

This is followed by social indicators focusing on OHS, economic indicators emphasizing client satisfaction and energy efficiency, and management indicators highlighting project execution efficiency and the implementation of just-in-time systems. These results are aligned with Rajabi, et al., (2022) and Stanitsas & Kirytopoulos., (2021) which also identified safety, efficiency, and stakeholder involvement as key factors supporting sustainable construction management.

The pilot project further confirmed that the applicability of sustainable indicators varies considerably in practice. Indicators closely linked to immediate project outcomes such as OHS, client satisfaction, time and resource efficiency, and sustainability monitoring were perceived as highly feasible and relevant to current industry practices. Conversely, indicators requiring substantial upfront investment or broader systemic change such as the adoption of eco-friendly materials, renewable energy, and LCC analysis faced significant barriers to implementation. Similar constraints were reported in previous studies (Rajabi, et al., 2022; Alnsour, et al., 2022), which highlighted cost and material availability as major challenges in implementing environmental and economic sustainability.

Notably, adaptation to local work culture was found to be feasible and important in supporting project *collaboration, whereas cultural heritage preservation was not seen as directly relevant to construction operations.*

The practical implication of this study is the need for policymakers, contractors, and other stakeholders to adopt and adapt these prioritized indicators throughout the planning, execution, and evaluation stages of construction projects. Emphasizing environmental and social dimensions, while aligning them with the realities of industry practice, can enhance not only project performance but also accountability and the overall competitiveness of the construction sector. Furthermore, these results provide a foundation for developing context-specific policies, project execution standards, and sustainability performance assessment tools that balance theoretical priorities with practical feasibility in national construction practices.

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