



Integrating Sustainability Index Into Local Road Construction: A Strategic Approach to Sustainable Construction Management

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Abstract

The sustainability of local road construction projects plays a critical role in the achievement of long-term environmental, social, and economic development goals. This study aimed to assess the sustainability level of local road construction projects using a structured sustainability index. The research employed a mixed-methods approach, combining a comprehensive literature review, stakeholder engagement, and the Delphi technique to determine relevant sustainability indicators and assign appropriate weightings. The sustainability index was tested and validated by means of an expert evaluation and pilot application in selected local road projects. The findings indicate that environmental aspects tend to receive higher priority compared to social and economic aspects, mainly due to the increasing global emphasis on climate change and resource conservation. However, the study also highlights the importance of integrating social equity and local economic benefits to achieve a balanced sustainable development. The novelty of this research lies in its structured index framework tailored specifically for local road projects, supported by multi-stakeholder consensus, and its potential application in infrastructure planning and public procurement processes. This study contributes to the limited body of knowledge regarding sustainability assessments in local infrastructure development, especially in developing regions. The developed index offers a practical tool for local governments and stakeholders to incorporate sustainability principles into decision-making processes.

Keywords: Road Construction; Sustainability Index; Delphi Technique; Sustainable Construction Management.

1. Introduction

Road infrastructure plays an important role in supporting national development, economic growth, and the mobility of people and goods [1]. Roads serve as the backbone of the transportation network and are the main arteries for economic, social, and cultural interactions. With the global population projected to reach 9 billion by 2050, with 64.7% of that population living in urban areas [2], countries like Indonesia will face increasing challenges in providing safe, reliable, and sustainable transportation infrastructure. Local roads, especially those connecting cities and rural and urban areas, are crucial for ensuring that access to transportation is both equitable and inclusive.

However, the development of local road infrastructure often faces sustainability challenges due to non-environmentally friendly practices, such as the overexploitation of resources [3], the use of hazardous or non-renewable materials, and construction processes that consume a lot of energy [4] and generate greenhouse gas emissions [1]. This underscores the need for a more sustainable approach in all phases of road construction projects. One of the key challenges in managing road construction projects today is ensuring sustainability at all phases of their implementation. Many local road projects have yet to fully implement sustainability principles, resulting in negative environmental,

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social, and economic impacts. Therefore, sustainable construction management is increasingly becoming a strategic priority in road infrastructure development. In contrast to conventional management that focuses on time, cost, and quality, sustainable construction management integrates environmental protection, economic efficiency, and social equity throughout the life cycle of the project [5]. The transition to a sustainable infrastructure demands a holistic approach towards a project, from its planning, design, and procurement to its implementation and maintenance. Resource-intensive road infrastructure can contribute significantly to environmental degradation if it is not managed with sustainability in mind. In the context of sustainable construction management, the development of a sustainability index is crucial as a systematic measurement, monitoring, and decision-making tool. The index enables an objective, transparent, and actionable assessment to be made of the performance of a project. Currently, many local road projects lack practical instruments for assessing sustainability, making it difficult to evaluate and refine sustainable construction strategies.

Several studies have addressed the importance of sustainable construction practices for road infrastructure. For example, emphasized the need to integrate a life-cycle assessment when evaluating pavement sustainability [6], while highlighted the challenges in allocating a budget for local road maintenance based on sustainability considerations [3]. In addition, recent studies explored the use of green materials in road construction to reduce the environmental impact [7, 8]. The community and economic growth, protection of the environment, and minimization of the use of natural resources should be taken into consideration when building sustainable highways [9]. The sustainability requirements for a roadway project must be established and met during each step of its life cycle [10]. Highway sustainability must be approached with the understanding that transportation is required to meet human needs and that highways are a key component of the transportation infrastructure. In addition to managing the demands on the environment and natural resources, the development of sustainable highways should also focus on achieving access, rather than just mobility; moving people and goods, rather than just vehicles; and providing people with transportation options, such as secure and comfortable roads for walking, bicycling, and public transportation [11]. Road construction projects require a lot of energy and materials [12].

While there are various sustainability rating systems available such as GreenLITES [13], Greenroads [14], INVEST [15], and I-LAST [16], these systems are generally designed for freeways or large-scale projects, not for local roads in developing countries. Despite these advances, the assessment sustainability of local road construction, especially in developing countries, still lacks a specialized, accurate, and easy-to-use index that comprehensively integrates ecological, economic, and social dimensions.

This research addressed this gap by proposing the development of a sustainability index specifically designed for local road construction in Indonesia. The index integrates the triple bottom line approach, namely, planet (ecological), profit (economic), and people (social), to ensure that sustainable development goals are achieved without compromising any of the dimensions. The life-cycle thinking approach was also applied to evaluate the environmental impacts throughout the service life of the infrastructure.

The index not only aims to evaluate project performance but can also be used as a guide in planning, procurement, material selection, emission control, and energy management throughout the life cycle of a road. Thus, managerial decisions in construction projects can become more responsible and directed towards the long term. Furthermore, this research aligns with global and national policy directions in promoting inclusive and sustainable infrastructure. The developed index has the potential to improve sustainability governance and support responsible professional engineering practices. Road infrastructure must not only be technically functional but also a means to meet the needs of society without compromising the environment.

The structure of this article is organized as follows: Section 2 describes the research methodology, including criteria identification, expert validation, and weighting methods. Section 3 presents the results of the sustainability index development, while Section 4 discusses the findings and their implications for sustainable local road development. Finally, Section 5 concludes the study and provides recommendations for policymakers and future research directions.

2. Material and Methods

Many experts find the term “sustainable highways” ironic, given the large consumption of materials and their major effect on natural resources resulting from the use vehicles and the building of highways [17]. However, when one closely examines the triple bottom line ideas, one must recognize the social and financial advantages that highways offer, namely, accessibility, mobility, and the facilitation of the transport of goods and persons. In this regard, highways are essential for our infrastructure and are the mainstay of civilization [18].

This study is based on the Triple Bottom Line (TBL) sustainability theory, which positions environmental, social, and economic performance as the main conceptual dimensions in evaluating road infrastructure sustainability. This

framework emphasizes that road sustainability must be understood as a multidimensional system that reflects a balance between dimensions, rather than as a partial achievement of a particular aspect. The TBL principles are enriched through conceptual models developed in various established road sustainability assessment systems, which serve as theoretical representations of infrastructure sustainability practices. Furthermore, the development of sustainability indices is supported by expert consensus theory, which views the collective knowledge of experts as a valid source for establishing contextual criteria, as well as by multi-criteria decision-making theory, which provides a rational basis for mapping the relative importance of sustainability dimensions. The integration of these theoretical frameworks enables the development of a local road sustainability index that is conceptually coherent and scientifically accountable.

This research was conducted using a structured and systematic methodological framework consisting of three major phases. The first phase involved the identification of sustainability criteria through a comprehensive literature review on sustainability assessments for local road construction projects. Furthermore, a benchmarking of several established highway sustainability rating systems, such as GreenLITES, Greenroads, INVEST, and I-LAST, was conducted to understand the prevailing sustainability measurement practices, that have been subsequently adapted to the Indonesian local road context.

In the second phase, the Delphi technique was employed to obtain the consensus of experts on the most relevant sustainability criteria for local roads. The Delphi panel comprised sustainability experts, academics, practitioners, and stakeholders involved in road infrastructure development. This process was conducted through multiple rounds of questionnaires, starting with the initial identification and evaluation of criteria (Round 1), followed by their refinement and confirmation (Round 2) [19]. This process was supported by a statistical analysis, using the Mann-Whitney U test to detect differences between the expert groups, and the Wilcoxon signed-rank test to confirm the response stability, with $\Delta CV < 0.2$ and $p > 0.05$ as convergence indicators [20].

In the third phase, the analytical hierarchy process (AHP) was utilized to determine the relative weights of the finalized criteria based on the pairwise comparisons provided by the experts. The hierarchical structure included the main goal (local road sustainability), criteria (ecology, economy, and social), and sub-criteria derived from the Delphi panel. The consistency ratio was calculated to ensure logical consistency [21]. This integrated methodological framework, starting from the literature review for criteria identification, the Delphi technique for consensus building, AHP for weighting and prioritization, and statistical validation for robustness, ensured that the developed sustainability index was conceptually sound, stakeholder-approved, and practically applicable for evaluating the sustainability of local roads in Indonesia.

This three-phase approach, comprising a literature-based identification, expert consensus, and weighted prioritization, ensures that the resulting index was scientifically grounded, systematically structured, and practically useful. The output of this methodology was a sustainability index that can be applied to assess, monitor, and guide the planning and implementation of local road construction in a more sustainable direction.

2.1. Highway Sustainability Rating System

GreenLITES was created by the New York State Department of Transportation to identify best practices and assess their success by analyzing projects including sustainable solutions. Two certification schemes, one for project designs and another for operations, help evaluate highway building projects. The certification levels, such as certified, silver, gold, or evergreen, are determined by the overall credits accumulated [13].

Greenroads is a body of best practices for sustainability relevant to road building; it covers voluntary as well as necessary best practices. Although voluntary best practices improve sustainability beyond the minimum criteria, the required best practices must be fulfilled as a minimum standard [14].

IN-VEST, designed by the Federal Highway Administration, is a web-based self-evaluation tool intended to evaluate the viability of roadbuilding projects. It comprises 68 best practices linked to sustainability and references to other instruments such as GreenLITES and Greenroads [15].

I-LAST is made up of two main elements, namely a rating system and a guide created by the Illinois Department of Transportation to evaluate highway project sustainability. It covers more than 150 sustainable criteria. Three steps comprise the I-LAST scoring process: (1) selecting relevant criteria for a given project, (2) assessing the overall points attained, and (3) computing the final score by means of the percentage of achieved points in relation to the total available points [22]. The contents of a synopsis of every rating system are shown in Table 1.

Table 1. A summary of the highways sustainability rating system

	GreenLITES	Greenroads	INVEST	I-LAST
Owner	NYSDOT	Greenroads Foundation	FHWA	IDOT
Assessment stage	Design & Operational	Planning, and Construction	Planning, Construction, Operational, and Maintenance	Planning, and Construction
Point range	1-4 point	1-5 point	1-4 points	1-3 points
Total points	60 & up	108	250 (planning) 126 (Construction) 210 (Operational and Maintenance)	271
Predicate	Certified (15-29 points) Silver (30-44 points) Gold (45-59 points) Evergreen (60 & up points)	Certified (30-40% total points) Silver (40-50% total points) Gold (50-60% total points) Evergreen (>60% total points)	Bronze (≥30%) Silver (≥40%) Gold (≥50%) Platinum (≥60%)	Present of point met

2.2. Delphi Technique

To guarantee ongoing sustainability performance development, local road managers must set suitable goals and key performance indicators [23]. The determination of sustainability criteria and appropriate actions to facilitate sustainability is based on the principles of being environmentally friendly, socially equitable, and economically efficient in all phases of the local road pavement project life cycle. Furthermore, the determination of the local road sustainability index used the life-cycle assessment method and the Delphi technique, to reach a consensus among all local road stakeholders and sustainability experts [19].

A well-known and often used technique for reaching consensus among professionals in a given field is the Delphi technique. This approach is a structured group communication tool intended to match professional opinions on current affairs. It uses a methodical and interactive approach whereby professional insights are acquired by means of several rounds of surveys or interviews, with a minimum of two iterations including controlled feedback between rounds [20].

The Mann-Whitney U test was used to examine significant differences between the opinions of the groups of experts. The output determined how strongly the two expert groups agreed. Furthermore, the Wilcoxon signed rank test was used to inspect the stability of the answers between two consecutive Delphi rounds. This was carried out by measuring the difference in value in the coefficient of variation (CV) between the two Delphi rounds. A significant level (*p*) in the Wilcoxon signed rank test that is greater than 0.05 ($p > 0.05$) and a difference in CV between the two Delphi rounds of 0.2 or 20% ($\Delta CV < 0.2$) indicate the achievement of stability, and no further Delphi cycle is required [20].

2.3. Analytical Hierarchy Process

The most efficient step in the decision-making process is selecting the elements that are critical to the decision. Following their selection, these components are arranged in a hierarchical framework by the AHP, which starts with an overall aim and moves down through the criteria, sub-criteria, and options in consecutive tiers [24]. The AHP, enhanced by Saaty, is a highly recognized and extensively employed multi-criteria analysis methodology. It provides an intuitive way for users to ascertain the relative weight of several criteria or alternatives in relation to the specified criteria. However, policymakers or assessors can determine which criterion is more significant than another even in the absence of quantitative assessments.

Pairwise comparisons are consistently converted into a set of integers that indicate the relative importance of each criterion item. A scale of numbers indicating how much more significant or dominant one component is over another in relation to the criterion by which they are compared is used to make comparisons [21]. This scale is shown in Table 2.

Table 2. The fundamental scale of the absolute numbers

Intensity of importance	Definition	Explanation
1	Equal significance	Both activities help equally to reach the objective
2	Weak or moderate	This value points to the need of a compromise
3	Moderate significance	Experience and judgment slightly point one activity over the other
4	Moderate plus	This value requires a compromise
5	Strong significance	Experience and judgment greatly support one activity over another
6	Strong plus	This value points to a necessity for compromise
7	Extremely strong or demonstrated importance	One activity is strongly preferred over another; with solid evidence supporting dominance in practice
8	Very, very strong	This value suggests the need of a compromise
9	Extremely significance	The evidence in favor of one activity over another is of the highest level of certainty
Reciprocals of the top mentioned	If activity <i>i</i> is assigned one of the non-zero value above, then <i>j</i> is assigned the reciprocal value when compared to <i>i</i>	This assumption makes sense and logic

3. Results

In this paper, two Delphi rounds were conducted involving 70 independent respondents, including road pavement experts and sustainability experts comprising government, academic, and community groups. A stakeholder analysis was used to identify and select those experts, who had the influence and interest (importance), as well as the capacity and competence to be respondents [25]. The requirements to be fulfilled by the respondents in the Delphi technique as recommended by Giannarou & Zervas [19], included (1) having knowledge and experience of pavement and local road management, (2) being willing to participate by providing opinions or input, (3) having sufficient time to participate, and (4) having effective communication skills.

The first questionnaire for the Delphi study was designed with reference to several existing highway sustainability rating systems. From four separate highway sustainability models, key elements and pertinent indicators were identified and combined into a single comprehensive list. In the questionnaire, indicators covering elements of pavement design, maintenance, and construction execution were included and taken into consideration.

A new questionnaire, which was designed to closely reflect Round 1, was developed for Round 2 of the Delphi study. Once again, professionals were invited to evaluate the relevance of the indicators applied in defining and evaluating local road sustainability. However, this round included an overview of the results from the Round 1. Key statistical data, including the median score for each component, interquartile range, and percentage of responses rating components at or ≥ 4 , were presented as summarized in the table below. A quick overview was also provided to help explain why the experts thought particular indicators were crucial. Following the recommendations from Round 1, the experts were asked to assess the significance of the newly included components.

A p of $0.872 > 0.05$ was obtained in the Wilcoxon signed-rank test, indicating no difference in the responses from the Round 1 and 2. Moreover, the statistical analysis showed that the difference in CV between the rounds was in the range of 0.00-0.02, which was ≤ 0.2 or 20%, meaning also that there was stability [20]. Both these analyses showed that the answers provided by the respondents were stable. Therefore, no further Delphi rounds were required.

The work plan and research methods for developing the local road infrastructure sustainability index are presented in Figure 1.

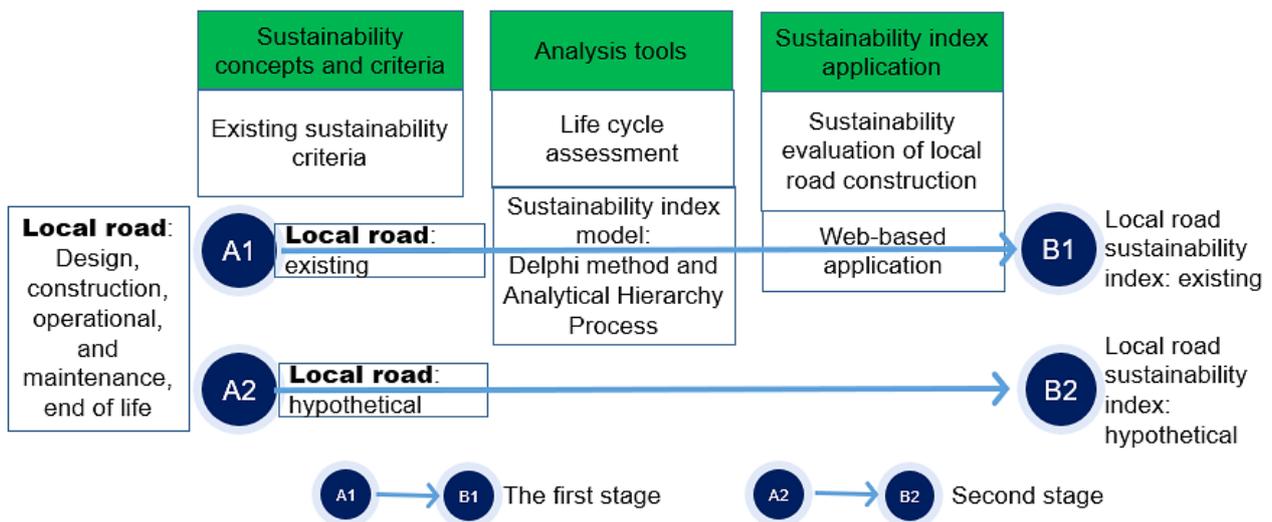


Figure 1. Framework for developing the sustainability index

Figure 1 describes the work plan and research methods. In the first stage, the research was conducted using the sustainability indicators on existing local roads, and the basic framework of the sustainability index was also developed. In the second stage, a sustainability index was modelled, compiled, and applied to measure existing and hypothetical roads.

It was discovered that there was no statistically significant difference in the answers provided by the government and community respondents, which comprised lecturers or researchers. This was confirmed by the results of the Mann-

Whitney U test [26], which showed that the asymptotic significance was $p = 0.000$, which < 0.05 , and the Z-statistic were -0.315 and -0.394 for Round 1 and 2, respectively, which were also $<$ the Z table of 1.96 (two-way test with $\alpha = 5\%$). The test further indicated that the initial hypothesis was accepted, namely, that there was no significant difference between the answers provided by both groups of respondents. Therefore, the Delphi technique was concluded in the Round 2.

The measurement of expert agreement was determined in this study by meeting the three combinations of values stated as follows: (1) interquartile range ≤ 1 , (2) the percentage of 'agree' and 'strongly agree' answers $\geq 75\%$, and (3) standard deviation ≤ 1 [27]. The sustainability index for the design, construction, and maintenance phases and their weights, the results of the Delphi analysis, and the AHP are presented in Tables 3, 4, and 5.

Based on the results of the Delphi analysis, the experts agreed on a sustainable road rating level based on the number of indicator weights applied. The rating was represented or expressed by the number of stars that met a certain number of points, namely 4, 3, 2, and 1-star ratings. The range of total weights for this level was $100-85$, $84.9-37.6$, $37.5-9.8$, and 9.7 . The ratings can be implemented if the road plan meets the rating requirements, namely fulfilling the pre-feasibility study and environmental impact analysis.

Table 3. Sustainability index at design phase

ID	Sustainability index at design phase	Weight
D.1	Communicating the road project plan to the community	0.6
D.2	Involving the community in determining the need for facilities	0.6
D.3	Involve the community in the planning and implementation of road works	0.6
D.4	Construction waste recycling activity planning	4.3
D.5	Dust reduction planning due to construction activities	1.8
D.6	Tree protection planning around the project	1.8
D.7	Designing pavement 40 years for the base layer and less than 40 years for the surface layer	9.0
D.8	Pedestrian pavement design using unheated materials	7.6
D.9	Pedestrian pavement design that maintains the function of the sidewalk	7.8
D.10	Design using recycled materials	3.6
D.11	. Design using local materials	5.4
D.12	Minimum use of 90% of excavated soil material for embankment needs in site	3.2
D.13	Use construction equipment that meets emission thresholds	4.0
D.14	Provide access to parking or rest areas	1.5
D.15	Plan shade facilities in the parking area	1.5
D.16	Provide road access for vehicles and pedestrians to other modes of transport	1.5
D.17	Provide public transport/bus stops equipped with pedestrian access from/to the pedestrian path	1.5
D.18	Equipping pedestrian paths with shade	0.9
D.19	Designing new pedestrian paths by taking into account aspects of ease of maintenance	0.9
D.20	Provide a pedestrian bridge/zebra cross that is connected to the pedestrian path	0.9
D.21	Repair or rehabilitate existing pedestrian paths	0.9
D.22	Providing "street furniture" that considers aspects of ease of maintenance and low cost	0.5
D.23	Designing road geometries to ensure the safety and comfort of road users and can reduce energy use.	0.4
D.24	Design road equipment facilities that are easy to maintain	0.4
D.25	Improving plant functions related to environmental safety and harmonization	0.8

Table 4. Sustainability index at construction phase

ID	Sustainability index at construction phase	Weight
C.1	Organizing outreach for construction workers to increase environmental awareness and insight and identify the best practical methods to minimize impacts on the environment	5.0
C.2	Prevent environmental disruption due to eroded soil sedimentation, provide slope drainage and sediment traps	0.9
C.3	Prevent environmental disruption due to high water discharge by creating drainage channels and water storage ponds	0.9
C.4	The contractor has an environmental management system certificate	1.9
C.5	Replacing trees that had to be cut down due to construction	1.7
C.6	Provide warning signs for nearby animals	0.6
C.7	Controlling surface water during construction	1.8
C.8	Providing a surface planted with plants outside the road as water absorption/holding	1.8
C.9	Prevent rubbish from entering road drainage channels	0.9
C.10	Providing channel inspection and maintenance facilities	0.9
C.11	Accommodate surface water originating from the environment by providing water storage ponds	1.8
C.12	Designing traffic management during construction	1.1
C.13	Place trees to reduce noise	0.5
C.14	Use of road equipment facilities for traffic control during construction	0.8
C.15	Use of materials close to the project location	0.8
C.16	Conduct safety audits at the pre-construction stage	1.1
C.17	Conduct audits at the construction implementation stage	1.1
C.18	Conduct audits at post-construction stages	1.1
C.19	Repair/rehabilitate existing pedestrian paths	0.9
C.20	Coordination of design and construction implementation teams	3.6
C.21	The contractor has a quality management system (QMS) certificate	3.2
C.22	Quality assurance of construction implementation by contractors	3.1

Table 5. Sustainability index at maintenance phase

ID	Sustainability index at maintenance phase	Weight
M.1	Reducing the use of fossil fuels in maintenance implementation by 15% to 25%.	3.1
M.2	Use of recycled materials or materials that are more environmentally friendly	3.1

4. Discussion

Several studies from different countries have emphasized the importance of developing sustainability rating systems tailored to the local context. Park & Ahn [28] successfully built a green road rating system in South Korea, focusing on environmental impacts and utilizing a web-based certification manual, demonstrating the need for context-specific systems in different regions. Similarly, Szpotowicz & Toth [29] conducted a comprehensive comparison of sustainable road rating systems in Hungary, using the technique for order of preference by similarity to ideal solution (TOPSIS) method to determine the most suitable framework for local applications. These findings support the approach used in this study, which adopted a multi-criteria evaluation tailored to local Indonesian road projects. Further reinforcing this perspective, Mehraban et al. [30] highlighted gaps and challenges in existing sustainability rating systems around the world, emphasizing that environmental aspects often dominate, while social and governance components are often underrepresented. This is in line with the findings of Del Rosario et al. [31], who conducted a systematic review of triple-bottom-line based assessment methods and recommended a balanced integration of environmental, social and economic dimensions in road sustainability assessments.

The current study followed this recommendation by combining stakeholder consensus, via the Delphi technique, and analytical weighting, via the AHP, to ensure a comprehensive coverage of sustainability dimensions. In addition, Lee et al. [32] showed that the use of recycled materials can significantly improve the environmental and economic scores in highway sustainability assessments, which underscores the practical benefits of sustainable material selection. Complementing this, Aifa et al. [33] emphasized the important role of pavement material and technology choices in improving sustainability performance, particularly in green highway rating systems. The inclusion of these considerations in the index developed for Indonesian local roads not only strengthens its practical applicability but also aligns with international best practices. This study therefore contributes to ongoing global efforts to establish a more context-sensitive and comprehensive sustainability rating system for road infrastructure.

The results of this study further show that the sustainability of local roads has not been prioritized in many projects in Indonesia, mainly due to the limited dissemination of sustainability criteria at the technical level, the lack of integration of environmental issues during construction, and the absence of mandatory policies. These findings are consistent with similar challenges faced in developing countries, such as rural road construction in India, where regulatory gaps and lack of awareness among local implementers have been cited as key barriers. In addition, Opeyemi et al. [34] noted that the lack of institutional integration and stakeholder engagement hinders sustainable infrastructure development in some African countries. This comparison underscores that such challenges are not unique to Indonesia but are a common development problem in many developing regions. The sustainability index scores obtained in this study ranged between 17.7-28.0 (Table 6), reflecting significant variations in sustainability practices among the projects studied. Interestingly, projects with flexible pavements did not consistently achieve higher sustainability scores than rigid pavement projects, indicating that pavement type alone does not determine sustainability outcomes (see Figure 2).

In contrast, proactive stakeholder engagement and early integration of sustainability principles in project planning have a more substantial influence on the final score. This observation was also supported by Kapatsa et al. [35], who emphasized that sustainability in transport infrastructure should be addressed from the early planning stages and requires active collaboration across sectors. Compared to previous models, such as those by Meiboudi et al. [36] for Iranian highways and Ahgel et al. [37] for Southeast Asian regional roads, the model proposed in this study provides a more contextualized framework for Indonesian local roads, specifically by addressing gaps in governance and policy integration. The robustness and relevance of the model were strengthened by methodological rigor through the combined use of the Delphi technique and AHP. While international models tend to prioritize environmental indicators [30], this study proposes a balanced, three-pronged approach tailored to Indonesia's unique socio-economic and regulatory context.

Table 6. Sustainability index at case study project

Case study	Brief on the project	Index
A	Hos Cokro Road. This project is a rigid pavement project, with total length 1,1 km and total width 7 m. The owner of the project is Public works and spatial Planning Agency, Sragen	17.7
B	Carikan-Bulakan Road. This project is a rigid pavement project, with total length 1,3 km and total width 7 m. The owner of the project is Public works and spatial Planning Agency, Sukoharjo	18..7
C	Tegalan-Mangkuyudan Road. This project is a rigid pavement project, with total length 0.7 km and total width 7 m. The owner of the project is Public works and spatial Planning Agency, Sukoharjo	17.9
D	Kartini Road. This project is a rigid pavement project, with total length 1.46 km and total width 6 m. The owner of the project is Public works and spatial Planning Agency Sragen	17.7
E	Sukowati Road. This project is a flexible pavement project, with total length 3,6 km and total width 8 m. The owner of the project is Public works and spatial Planning Agency Sragen	19.5
F	Tengklik-Jarum Road. This project is a flexible pavement project, with total length 1,5 km and total width 15.6 m. The owner of the project is Public works and spatial Planning Agency Sukoharjo	18.3
G	Sugihan-Paluhombo ring road. This project is a rigid pavement project, with total length 3 km and total width 7 m. The owner of the project is Public works and spatial Planning Agency Sukoharjo	28.0
H	Gondang ring road. This project is a rigid pavement project, with total length 2.025 km and total width 5 m. The owner of the project is Public works and spatial Planning Agency Sragen	26.3
I	Sambireo-Sambi road. This project is a rigid pavement project, with total length 1.229 km and total width 5 m. The owner of the project is Public works and spatial Planning Agency Sragen	17.9
J	Gedongan-Mayarejo road. This project is a rigid pavement project, with total length 2.920 km and total width 4.5 m. The owner of the project is Public works and spatial Planning Agency Sragen	18.4
K	Pucung-Gemolong road. This project is a rigid pavement project, with total length 2.408 km and total width 4 m. The owner of the project is Public works and spatial Planning Agency Sragen	17.7
L	Mondaka-Pare road. This project is a rigid pavement project, with total length 2.266 km and total width 5 m. The owner of the project is Public works and spatial Planning Agency Sragen	18.6
M	Agus S alim road. This project is a rigid pavement project, with total length 2.027 km and total width 6 m. The owner of the project is Public works and spatial Planning Agency Sragen	18.8
N	Kedawung-Jambangan road. This project is a rigid pavement project, with total length 3,476 km and total width 6 m. The owner of the project is Public works and spatial Planning Agency Sragen	28.0
O	Made-Jatikusumo road. This project is a rigid pavement project, with total length 3,352 km and total width 4.5 m. The owner of the project is Public works and spatial Planning Agency Sragen	27.2
P	Prayunan-Gesi road. This project is a rigid pavement project, with total length 3,448 km and total width 5m. The owner of the project is Public works and spatial Planning Agency Sragen	17.7
Q	Gemolong Kragilan road. This project is a flexible pavement project, with total length 3 km and total width 5 m. The owner of the project is Public works and spatial Planning Agency Sragen	19.4
R	Enar-Banyuurip road. This project is a rigid pavement project, with total length 4.697 km and total width 5 m. The owner of the project is Public works and spatial Planning Agency Sragen	18.3
S	Gentan-Banaran road. This project is a rigid pavement project, with total length 2.409 km and total width 4.5 m. The owner of the project is Public works and spatial Planning Agency Sragen	28.0
T	Beloran-Alun alun road. This project is a flexible pavement project, with total length 1.482 km and total width 8.4 m. The owner of the project is Public works and spatial Planning Agency Sragen	26.3

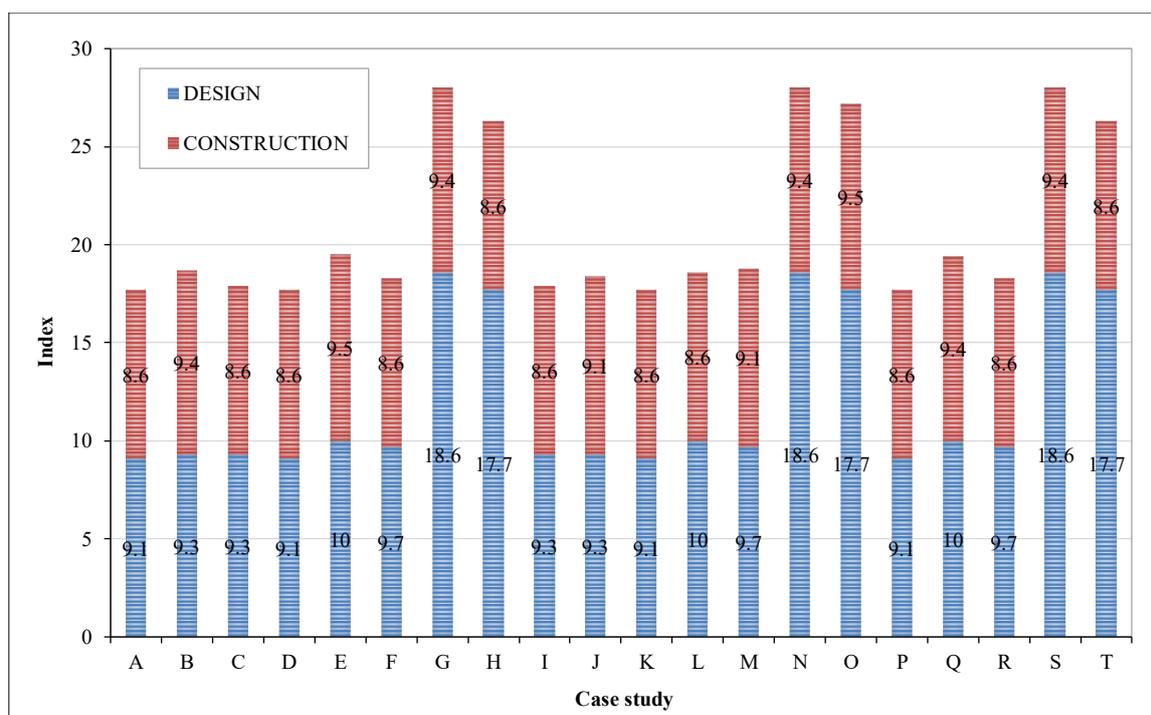


Figure 2. The result of local road sustainability index assessment

Several local road projects have undergone local road sustainability assessments. Based on the assessments, it was found that sustainability criteria have not been widely applied at the design and construction stages for various reasons, including: sustainability criteria have not been socialized to the technical level of implementers, construction activities have not paid attention to ecosystem balance, more attention has been paid to addressing infrastructure delivery issues, and there is no policy requiring local road operators to apply sustainability criteria. This can be addressed at the early stage of the project, i.e. the project initiation stage, where sustainability criteria are planned and established in policy.

The main contributions of this study are the development of a set of criteria to create a sustainability rating system for local road construction projects, making efforts as a first step towards establishing a unique certification system for sustainable roads, and the development of guidelines for assessing sustainability performance at different stages of road construction projects. The development of a sustainability index for local road construction projects can also serve as a rating system to help engineers perform their work professionally, especially if it is developed with knowledge management and artificial intelligence, as described by Altaie & Dishar [38].

5. Conclusion

In this study, a sustainability assessment framework was specifically designed for local road construction projects in Indonesia. The framework was formulated through a comprehensive process involving the Delphi technique to reach consensus among experts and stakeholders, followed by the AHP to determine the relative importance of each sustainability criterion. The sustainability index generated from this framework was tested on several ongoing road projects, providing valuable insights into the current status of the implementation of sustainability in local infrastructure development. The results revealed that sustainability principles have not been fully integrated into the planning and implementation of local road projects. Several barriers were identified, including the limited dissemination of sustainability criteria to technical implementers, a lack of attention to environmental balance, an overriding focus on meeting infrastructural needs, and the absence of mandatory policies to enforce sustainability practices. These challenges mirror the problems being faced in other developing countries, emphasizing the need for systematic reforms and stronger policy integration.

One of the main contributions of this research is the contextualization of a sustainability assessment framework for Indonesian conditions to address governance gaps and ensure the applicability of the proposed model to local practices. The framework incorporates a three-pronged approach targeted at environmental, social, and economic aspects to ensure that sustainability is addressed comprehensively. In addition, the study lays the foundation for the development of a sustainability certification system specific to local road construction projects in Indonesia. Future work should focus on strengthening this framework by integrating digital monitoring systems, improving stakeholder participation mechanisms, and benchmarking with similar frameworks in other developing countries. These efforts will help ensure that sustainability principles are embedded not only at the policy level but also in the practical day-to-day operations of infrastructure development in Indonesia.

6. Declarations

6.1. Author Contributions

Conceptualization, F.S.H. and S.S.; methodology, F.S.H. and S.S.; validation, F.S.H. and S.S.; formal analysis, F.S.H.; investigation, F.S.H.; resources, F.S.H. and S.S.; data curation, F.S.H.; writing—original draft preparation, F.S.H.; writing—review and editing, F.S.H. and S.S.; visualization, F.S.H.; supervision, S.S.; project administration, F.S.H.; funding acquisition, F.S.H. All authors have read and agreed to the published version of the manuscript.

6.2. Data Availability Statement

The data presented in this study are available in the article.

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6.4. Conflicts of Interest

The authors declare no conflict of interest.

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