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Evaluation of The Performance of Green Road Construction Implementation on The KKT Kariangau – Sp. Tempadung Toll Road Project (IKN 3B) Using The Importance Performance Analysis (IPA) Method

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ABSTRACT
Nusantara Capital City (IKN), designated as Indonesia's new capital under Law Number 3 of 2022, is envisioned as a sustainable, eco-friendly forest city; consequently, strategic infrastructure such as the KKT Kariangau–Sp. Tempadung Toll Road (IKN Toll 3B) must strictly comply with green standards, yet empirical evaluation of its actual on-site construction performance remains highly limited. Implementing Green Road Construction is vital to reducing environmental impacts and strengthening sustainability commitments. This study evaluates its performance using the Importance Performance Analysis (IPA) method, based on responses from 42 participants comprising service users, providers, and supervising consultants. Results show an average importance score of 4.42 and a performance score of 4.17. Most indicators fall into Quadrant II (Maintain Performance), while energy-efficient lighting and excess material use fall into Quadrant I (Top Priority). Indicators related to energy, water, and materials are in Quadrant III (Low Priority), and none are in Quadrant IV. Overall, the implementation is satisfactory, with recommendations to enhance energy efficiency and material management to support sustainable toll road development in IKN further

Keywords: *Green Road Construction; Toll Road; Importance Performance Analysis (IPA); Sustainability; Nusantara Capital City (IKN).*

1. Introduction

As the main supporting city, Balikpapan plays a strategic role in advancing IKN's development. One form of this support is the construction of the KKT Kariangau–Sp. Tempadung Toll Road (IKN Toll 3B). Toll roads are believed to promote economic growth and equitable development [1][2][3]. However, toll road development can also have significant environmental impacts.

To mitigate negative impacts, the concept of Green Road Construction becomes relevant. Green roads are road construction practices that not only emphasize transportation functions but also consider environmental sustainability, resource efficiency, and resilience to climate change [4]. This concept emphasizes the balance between environmental, economic, and social aspects at every stage of construction, from planning to maintenance [5].

Implementing Green Road Construction is critical because toll roads generally leave a large ecological footprint [6][7][8]. This urgency is highly amplified in the context of the KKT Kariangau–Sp. Tempadung Toll Road (IKN Toll 3B) serves as a primary access route to Indonesia's new capital, which is explicitly mandated to pioneer a sustainable "Smart Forest City." Unlike standard highway projects, the construction of IKN Toll 3B cuts through environmentally sensitive zones in Kalimantan, introducing severe risks of tropical deforestation, wildlife habitat fragmentation, and heavy ecosystem disruption [9][10][11][12].

Failure to stringently execute green construction principles here would directly undermine the capital's grand design [13]. Furthermore, applying this concept supports Indonesia's commitment to achieving Net Zero Emissions by 2060 [14]. Conversely, without rigorous Green Road practices on

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this strategic site, the development may lead to severe environmental degradation, which would conflict with both national sustainability commitments and the Sustainable Development Goals (SDGs) [15].

2. Materials and Methods

This study employs the Importance-Performance Analysis (IPA) method. The research stages include data collection, comparative analysis, and interviews with project implementers. The research object is the implementation of Green Road Construction in the KKT Kariangau–Sp. The Tempadung Toll Road project (IKN Toll 3B) is analyzed through direct observation using a checklist and questionnaires.

2.1. Instruments and Data Collection

This study has two main variables: the performance level of Green Road Construction implementation and the level of satisfaction with its execution. These variables were selected because they are considered capable of illustrating the extent to which the Green Road Construction concept has been applied, as well as the level of stakeholder satisfaction in the toll road development. By analyzing these two variables, the study is expected to provide a comprehensive overview of the effectiveness of implementing Green Road Construction principles in the KKT Kariangau–Sp—Tempadung Toll Road project (IKN Toll 3B), as presented in Table 1.

Table 1. Research Variables

No.	Variable Type	Variable	Indicators	Source
1	Stakeholder Perception	Level of Importance (Importance) toward Green Road Construction aspects	– Environmentally Friendly Material – Waste Management – Energy Efficiency – Emission Reduction – Water Conservation – Green Technology	[16], [17], [18], [19].
2	Performance	Performance Level of Green Road Construction Implementation	– Environmentally Friendly Materials – Waste Management – Energy Efficiency – Emission Reduction – Water Conservation – Green Technology	

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Table 2. Respondent Characteristics Based on Their Role in the Project

Respondent Role	Number of Respondents (People)	Percentage (%)
Service User (Owner)	7	16,7
Service Provider (Contractor)	22	52,4
Supervisory Consultant	13	31
Total	**42**	**100**

3. Results and Discussions

3.1 Instrument Testing

a. Validity Test

This study used a questionnaire validity test in SPSS 22. The hypotheses for the test were :

H0: The questionnaire item is valid

H1: The questionnaire item is not valid

With 42 respondents, the degrees of freedom (df) = 40, and the r-table value at α = 5% is 0.304. The evaluation criteria are:

If r-count ≥ r-table, the questionnaire item is considered valid.

If r-count < r-table, the questionnaire item is considered invalid.

The results of the r-count calculations in SPSS are shown in Table 3.

Table 3. Validity Test of Performance and Importance Levels

No	Attribute	r Count		r Tabel	Status
		(Importance)	(Performance		
1	Implementation of environmental management systems in the toll road project.	0.854	0.820	0.3044	Valid
2	Environmental awareness training for toll road project workers.	0.829	0.817	0.3044	Valid
3	Control of environmental impacts, including dust, noise, and lighting, around the project site.	0.873	0.832	0.3044	Valid
4	Protection of habitats and ecosystems along the toll road alignment.	0.796	0.739	0.3044	Valid
5	Greening in the project area, environmentally friendly drainage systems, water infiltration, and flood prevention.	0.854	0.778	0.3044	Valid
6	Safe and aesthetically designed toll road geometric layout.	0.854	0.773	0.3044	Valid
7	Completeness of quality documents, project team coordination, and commitment to green construction.	0.858	0.480	0.3044	Valid
8	Energy and fuel savings, including the use of renewable energy.	0.873	0.633	0.3044	Valid
9	Efforts to reduce emissions from heavy equipment and asphalt paving processes.	0.843	0.800	0.3044	Valid
10	Recycling programs for toll road construction materials.	0.781	0.753	0.3044	Valid
11	Water management programs during project implementation.	0.769	0.742	0.3044	Valid
12	Reuse of old pavement materials.	0.716	0.729	0.3044	Valid

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No	Attribute	r Count		r Tabel	Status
		(Importance)	(Performance		
13	Application of MMGPS technology in the construction project.	0.873	0.633	0.3044	Valid
14	Balancing excavation and embankment volumes (cut & fill) to minimize environmental impacts.	0.873	0.802	0.3044	Valid
15	Utilization of local materials for toll road construction works.	0.703	0.747	0.3044	Valid
16	Energy savings for toll road lighting and effective use of surplus materials.	0.774	0.782	0.3044	Valid
17	Durable toll road pavement design (≥40 years service life).	0.769	0.790	0.3044	Valid

Based on a validity test using SPSS 22, the calculated r-value (r-count) was found to exceed the r-table value, indicating that all questionnaire items are valid and capable of measuring the research objectives appropriately.

b. Reliability Test

Research using questionnaires also requires a reliability test. This test was conducted using SPSS 22 with the Cronbach's Alpha technique as follows:

H0: the questionnaire items are reliable

H1: The questionnaire items are not reliable

The reliability value is determined from the Cronbach's Alpha result in the SPSS 22 output, as shown in Table 4 below.

Table 4. Cronbach's Alpha.

Cronbach's Alpha for Importance	Cronbach's Alpha for Performance
0.996	0.949

The reliability testing criterion in this study is as follows: if the Cronbach's Alpha value ≥ 0.6, then H0 is accepted, and the questionnaire is considered reliable; if the Cronbach's Alpha value < 0.6, then H0 is rejected, and the questionnaire is considered not reliable.

3.2 Results of Importance Performance Analysis (IPA)

a. Analysis of Attribute Conformity Level

The Importance Performance Analysis (IPA) was employed to compare the level of importance (importance) with the level of performance for each Green Road Construction indicator. The calculation includes the importance score (Hi), the performance score (Ki), and the alignment level (Tki%), which is formulated as Tki% = (Ki/Hi) × 100%. The Tki% value indicates the degree of alignment between respondents' expectations and the actual implementation in the field; the higher the value, the closer the performance aligns with expectations, whereas a lower value indicates areas requiring improvement. The IPA results for the 17 research indicators are presented in Table 5.

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Table 5. Results of Importance-Performance Analysis (IPA) Calculation

No	Attribute	Importance Level (Hi)	Performance Level (Ki)	Alignment Level (Tki%)	Average Hi (Yi)	Average Ki (Xi)
1	Implementation of environmental management systems in the toll road project.	196	189	96,43	4,67	4,50
2	Environmental awareness training for toll road project workers.	192	182	94,79	4,57	4,33
3	Control of environmental impacts, including dust, noise, and lighting, around the project site.	193	177	91,71	4,60	4,21
4	Protection of habitats and ecosystems along the toll road alignment.	187	178	95,19	4,45	4,24
5	Greening in the project area, environmentally friendly drainage systems, water infiltration, and flood prevention.	196	181	92,35	4,67	4,31
6	Safe and aesthetically designed toll road geometric layout.	191	184	96,34	4,55	4,38
7	Completeness of quality documents, project team coordination, and commitment to green construction.	197	190	96,45	4,69	4,52
8	Energy and fuel savings, including the use of renewable energy.	181	172	95,03	4,31	4,10
9	Efforts to reduce emissions from heavy equipment and asphalt paving processes.	181	171	94,48	4,31	4,07
10	Recycling programs for toll road construction materials.	177	159	89,83	4,21	3,79
11	Water management programs during project implementation.	185	167	90,27	4,40	3,98
12	Reuse of old pavement materials.	162	154	95,06	3,86	3,67
13	Application of MMGPS technology in the construction project.	181	172	95,03	4,31	4,10
14	Balancing excavation and embankment volumes (cut & fill) to minimize environmental impacts.	182	174	95,60	4,33	4,14

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No	Attribute	Importance Level (Hi)	Performance Level (Ki)	Alignment Level (Tki%)	Average Hi (Yi)	Average Ki (Xi)
15	Utilization of local materials for toll road construction works.	175	171	97,71	4,17	4,07
16	Energy savings for toll road lighting and effective use of surplus materials.	185	176	95,14	4,40	4,19
17	Durable toll road pavement design (≥40 years service life).	195	182	93,33	4,64	4,33
Average				94,40	4,42	4,17

Based on the calculation results, the indicator with the highest alignment level is P2 (environmental awareness training for toll road project workers) at 98.47%. In comparison, the lowest alignment level is P9 (efforts to reduce emissions from heavy equipment and asphalt-laying processes) at 89.41%. Overall, the average alignment level across all indicators is 94.40%, placing it in the "very aligned" category. This indicates that the implementation of Green Road Construction on the KKT Kariangau–Sp. The Tempadung Toll Road project has been running well according to respondents' expectations. The high alignment level reflects the consistency between expectations and performance; the higher the value, the more optimal the program implementation [20].

b. Cartesian Diagram Analysis

The Cartesian diagram is used as a fundamental analytical tool in the Importance-Performance Analysis (IPA) framework to visually map the relationship between respondents' perceived importance and the actual performance of Green Road Construction. Based on this established methodology, this two-dimensional matrix is divided into four distinct quadrants. These quadrants are delineated by mutually perpendicular vertical and horizontal lines intersecting at the grand mean scores of both variables: the average performance score (Xi) on the X-axis and the average importance score (Yi) on the Y-axis. By plotting the calculated values of each indicator into this matrix, the complex data derived from stakeholder perceptions is transformed into a clear, understandable visual representation.

Through this spatial mapping, project management can easily identify and categorize whether a specific sustainability indicator falls into an area requiring urgent improvement, represents a successful effort that must be maintained, or indicates a potential over-allocation of resources that could be reallocated elsewhere. Consequently, the Cartesian diagram serves as more than a descriptive instrument; it is a strategic decision-making tool. It enables project implementers to systematically prioritize resource distribution and formulate targeted improvement strategies for Green Road Construction indicators in the KKT Kariangau–Sp. Tempadung Toll Road project. Ultimately, this ensures that the project's sustainability goals are met efficiently without compromising other technical aspects. The comprehensive results of this indicator mapping are presented in Figure 1.

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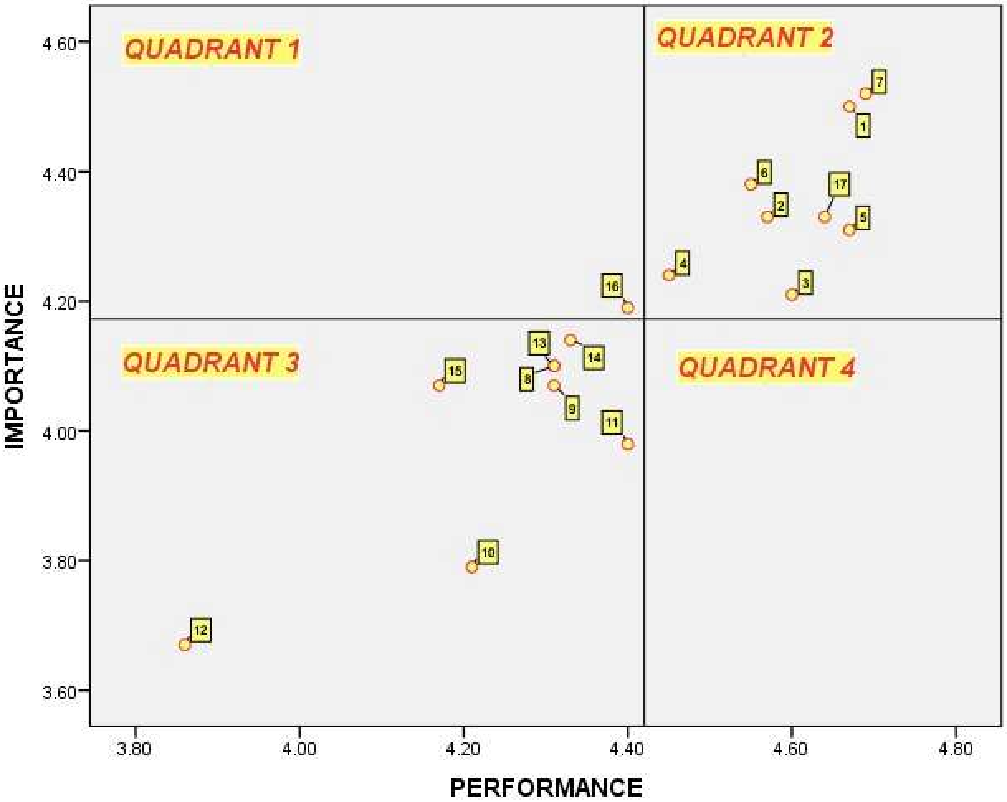

Figure 1. Cartesian Diagram of Importance-Performance Analysis (IPA)

Description:

1. Implementation of environmental management systems in the toll road project.
2. Environmental awareness training for toll road project workers.
3. Control of environmental impacts such as dust, noise, and lighting around the project site.
4. Protection of habitats and ecosystems along the toll road alignment.
5. Greening in the project area, environmentally friendly drainage systems, water infiltration, and flood prevention.
6. Safe and aesthetically designed toll road geometric layout.
7. Completeness of quality documents, project team coordination, and commitment to green construction.
8. Energy and fuel savings, including the use of renewable energy.
9. Efforts to reduce emissions from heavy equipment and asphalt paving processes.
10. Recycling programs for toll road construction materials.
11. Water management programs during project implementation.
12. Reuse of old pavement materials.
13. Application of MMGPS technology in the construction project.
14. Balancing excavation and embankment volumes (cut & fill) to minimize environmental impacts.
15. Utilization of local materials for toll road construction works.
16. Energy savings for toll road lighting and effective use of surplus materials.
17. Durable toll road pavement design (≥40 years service life).

c. Interpretasi Kuadran Diagram Kartesius

Quadrant I (Main Priority)

This quadrant contains indicators with high importance but low performance. In this study, the indicator in Quadrant I is P16 (energy-saving toll road lighting and effective use of excess materials).

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This shows a gap between respondents' expectations and actual implementation. The implication is that project implementers should focus more on energy efficiency and the optimal use of excess materials to prevent waste. Improving these aspects is expected to enhance Green Road Construction's effectiveness and support project sustainability. These technical improvements can be further strengthened by integrating renewable energy technologies and optimizing Green Open Spaces (RTH) as carbon-absorbing infrastructure, which have been proven essential to sustainable infrastructure development [21], [22]. Furthermore, optimizing these priority indicators is a common challenge in green road implementation, as similarly evaluated in the Green Highway project on the Semarang-Demak Toll Road section [23].

Quadrant II (Maintain Performance)

Indicators in this quadrant are considered highly important by respondents and have been well implemented, including P1, P2, P3, P4, P5, P6, P7, and P17. This success must be maintained through consistent quality standards and environmentally oriented planning. The high performance in habitat protection (P4) and geometric design (P6) in this project is consistent with the Pekanbaru-Dumai Toll Road study, which successfully integrated elephant underpasses and CSP technology to accommodate local wildlife and operational safety [24]. Furthermore, while this project demonstrates excellent environmental management (P1) and impact control (P3), a comparative study of the Kunciran-Serpong Toll Road indicates that these aspects often face persistent challenges in mitigating noise and emissions despite meeting regulatory standards [25]. Therefore, the current performance in these indicators must be sustained to ensure long-term sustainability.

Quadrant III (Low Priority)

This quadrant contains indicators with low importance and low performance, including energy savings (P8), emission reduction (P9), material recycling (P10), water management (P11), and utilization of local/reused materials (P12, P15), among others. Although respondents considered these aspects non-urgent, they remain highly relevant for long-term sustainability. The necessity of energy (P8) and water efficiency (P11) is supported by eco-green architectural principles, which emphasize that optimizing natural resources is a critical step in mitigating broader environmental issues like global warming and resource waste [26]. Furthermore, integrating these aspects through a Green Lean Construction approach has been proven to significantly reduce material waste (P10), water, and energy consumption, ultimately providing long-term benefits in cost and process efficiency despite initial investment challenges [27]. Therefore, if resources allow, gradual improvements in these indicators should be implemented to align the project with comprehensive sustainable principles fully.

Quadrant IV (Possible Overkill)

This quadrant usually contains indicators with low importance but high performance. In this study, no indicators were found in Quadrant IV, indicating that the project's resource allocation is already proportional and avoids unnecessary waste.

This optimal allocation aligns perfectly with the principles of Lean Construction, which aims to eliminate non-value-added activities and optimize the use of materials, labor, and time to enhance operational efficiency [28]. Effective resource management is essential because, as demonstrated in other construction studies, suboptimal management of human and equipment resources can significantly hinder overall project productivity [29].

Furthermore, by not over-allocating efforts to less important aspects, the project implementers can redirect their focus and resources toward truly critical priorities. This includes strict adherence to Standard Operating Procedures (SOP) and safety management to prevent human errors, which are frequently identified as major risks in complex infrastructure projects [30]. Therefore, the absence of indicators in this quadrant reflects a highly efficient, safe, and well-targeted project implementation strategy.

4. Conclusions

This study successfully evaluated the implementation of Green Road Construction on the KKT Kariangau–Sp. Tempadung Toll Road project (IKN Toll 3B) through the Importance-Performance Analysis (IPA) framework. Methodological instrument testing using SPSS 22 confirmed that all 17

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research attributes are empirically valid, with r-count values significantly exceeding the r-table threshold ($0.854 \text{ to } 0.703 > 0.3044$), while demonstrating exceptional internal consistency with a Cronbach's Alpha of 0.996 for importance and 0.949 for performance. The empirical findings from the IPA model revealed a high level of overall technical compliance, with a grand average alignment level reaching 94.40%, categorizing the project's green execution as "very aligned" with stakeholder expectations based on a grand mean importance score of 4.42 and a performance score of 4.17.

Spatial mapping on the Cartesian diagram classified the sustainability indicators into three operational areas, where indicator P16, regarding energy savings for toll road lighting and the effective use of surplus materials, uniquely fell into Quadrant I as a top priority, highlighting a critical low-performance gap that mandates immediate technical intervention. Conversely, the project's core technical strengths, including environmental management systems, habitat protection, and durable pavement design (attributes P1, P2, P3, P4, P5, P6, P7, and P17), were successfully mapped into Quadrant II, indicating that their high performance must be strictly sustained. Resource recycling, emission reduction, and local material-use indicators (P8, P9, P10, P11, P12, and P15) were located in Quadrant III as low-priority, long-term, gradual enhancements. In contrast, the complete absence of indicators in Quadrant IV resulted in a highly efficient, well-proportioned resource allocation aligned with lean construction principles.

Based on these findings, several strategic recommendations are proposed to enhance both on-site execution and future academic research. Practical project management must urgently prioritize technical improvements for Quadrant I by focusing on energy-efficient lighting infrastructure and maximizing Green Open Spaces (RTH) to optimize carbon absorption. From a methodological perspective, future studies should expand the respondent pool to include a broader multi-stakeholder spectrum and integrate the IPA matrix with multi-criteria decision-making (MCDM) models to generate deeper engineering insights. Finally, comparative evaluations across various ongoing toll road projects in Indonesia should be conducted to establish scalable, national best practices for sustainable green highway development.

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