The Projection Factors Affecting Sustainability on Infrastructure in Indonesia

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Abstract. Indonesia's rapid economic growth and accelerating urbanization have significantly increased the demand for sustainable infrastructure development. Yet, achieving true sustainability remains complex, influenced by intertwined environmental, economic, social, and governance factors. This study identifies and analyzes the key determinants shaping infrastructure sustainability in Indonesia, focusing on policy frameworks, financial mechanisms, technological innovation, and environmental challenges. By reviewing major infrastructure projects and their long-term outcomes, the research underscores the critical roles of government regulations, private sector engagement, and community participation in fostering resilient development. The analysis reveals that although Indonesia has made notable progress in integrating sustainability principles, persistent issues such as limited funding capacity, policy inconsistency, and environmental degradation continue to hinder optimal outcomes. Moreover, the study finds that underutilized or inefficiently managed urban spaces have contributed to a 15% reduction in the expected benefits of technological advancement by 2024. To overcome these barriers, the research emphasizes the necessity of integrated planning, cross-sectoral coordination, adoption of green technologies, and the strengthening of governance mechanisms. Collectively, these strategies are vital for ensuring that Indonesia's infrastructure development not only meets current needs but also supports long-term environmental integrity, economic resilience, and social equity in alignment with global sustainability goals.

1 Introduction

Indonesia stands at a critical juncture in its development trajectory, where rapid economic expansion and urbanization have intensified the demand for sustainable infrastructure. As one of the fastest-growing economies in Southeast Asia, Indonesia's infrastructure sector plays a pivotal role in shaping national competitiveness, social equity, and environmental stewardship. However, the pursuit of sustainability in infrastructure development is far from straightforward. It is shaped by a complex interplay of environmental, economic, social, and governance dimensions that influence project planning, execution, and long-term performance.

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In recent years, the Indonesian government has introduced a series of national policies and strategic frameworks to promote sustainable infrastructure ranging from green financing schemes and low-carbon initiatives to public–private partnerships that encourage innovation and efficiency. Despite these positive strides, the country continues to face persistent challenges such as inadequate funding, fragmented regulatory enforcement, policy inconsistencies, and growing environmental pressures linked to land use, energy consumption, and waste management.

Indonesia has made remarkable progress in advancing its infrastructure sector over the past few decades. This development encompasses a wide range of construction activities, including the establishment of transportation networks such as roads, bridges, and toll highways; public facilities like buildings, terminals, and stadiums; as well as essential utilities such as irrigation systems and electricity grids [1]. Collectively, these infrastructure initiatives represent a series of strategic efforts designed to enhance the nation's physical framework, promote economic growth, foster social inclusion, and ensure environmental sustainability. Given Indonesia's vast geographical expanse and the diversity of its regions from dense urban centers to remote rural areas—comprehensive infrastructure development serves as a crucial foundation for national integration. It enables the efficient movement of people and goods, facilitates trade and investment, and expands access to essential services such as education, healthcare, and clean water. More importantly, it acts as a driving force for regional equality, narrowing the development gap between the western and eastern parts of the country. Infrastructure Allocation from the State Budget (APBN) (in Trillion Rupiah) can be seen in Figure 1.

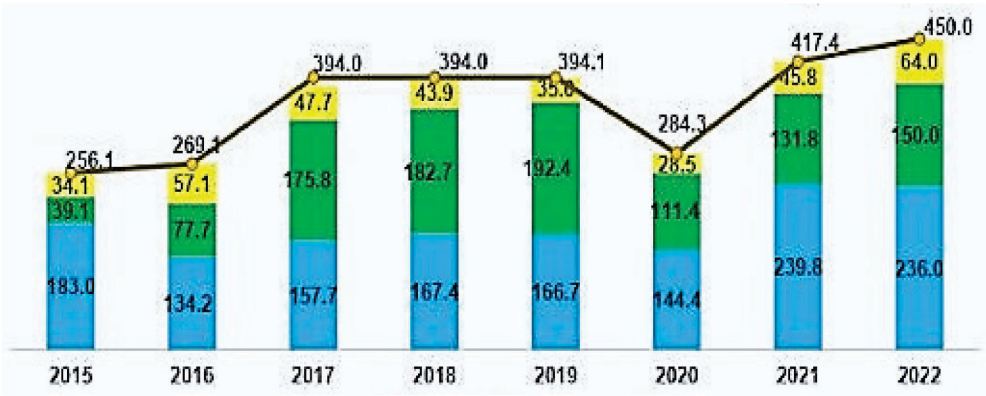

Fig. 1. Infrastructure Allocation based on the State Budget by the Ministry of Finance (www.detik.com accessed May 12, 2024)

However, in pursuing these ambitious goals, Indonesia faces the vital task of ensuring that development remains ecologically balanced and sustainable. Rapid construction without sufficient consideration of environmental impacts can lead to resource depletion, ecosystem degradation, and increased vulnerability to climate-related disasters. Therefore, embedding sustainability principles within infrastructure planning and execution is imperative. A sustainable infrastructure approach emphasizes the harmony between physical growth and environmental stewardship, integrating economic feasibility, social welfare, and ecological preservation into a unified development strategy. Furthermore, assessing the long-term environmental and economic consequences of infrastructure projects has become increasingly significant. Such evaluations not only guide policymakers in optimizing investment decisions but also influence the design and engineering outcomes of future

projects. Sustainable engineering practices, for instance, can help minimize carbon emissions, extend the lifespan of facilities, and enhance resource efficiency. By adopting forward-looking and environmentally responsible frameworks, Indonesia can ensure that its infrastructure not only meets present demands but also safeguards the well-being of future generations ultimately contributing to a more resilient, inclusive, and sustainable national development paradigm.

Infrastructure projects often face various challenges in realizing sustainable construction. Infrastructure projects can have significant environmental impacts, such as habitat destruction, pollution and resource depletion because the materials used are exploitative of non-renewable materials [2]. This statement was also emphasized by Agyekum et al., (2022) [3] who described the current infrastructure conditions as no longer in line with the goals of sustainable development that realize the achievement of the 17 pillars of the SDGs (Sustainable Development Goals). Examining the statements of previous researchers regarding the influence of eco- systems and the environment on the realization of the sustainability of all infrastruc- ture built is by emphasizing resources and compliance with the overall construction process. This is able to help achieve sustainable development with financial suitability in good design practices. A review of several previous studies underlines the influ- ence of resources and carbon emissions as an important part of sustainable construction [4-9]. Infrastructure development involves resource management and results in carbon emissions. In line with the increasing achievement of infrastructure develop- ment, the efficiency of both material and immaterial resources needs to be focused on. Minimizing waste is highly recommended in achieving construction sustainability. Chan et al., (2022) [10] stated that sustainable infrastructure has become increasingly popular in recent years because of its great potential to facilitate social, environmental and economic sustainable development. Facing the challenges of climate change and other social and economic development problems, the concept of sustainable devel- opment has been put forward to encourage the protection of ecological systems while encouraging community welfare and economic growth. Over the past few decades, the importance of sustainable development has been highlighted in various disci- plines, including infrastructure [11,15]. The statement also emphasizes that well- planned infrastructure projects can make a significant contribution to environmental, social and economic development in both rural and urban areas. The emotional and psychological factors associated with infrastructure change also encourage communi- ty engagement for sustainable development. Reducing emissions through strategies such as the use of low-carbon materials, efficient transportation and renewable energy sources can be a challenge. Saragi, (2023) [12] and Widyakusuma, (2023) [13] stated that the construction pro- fession is now faced with the task of understanding and translating strategic sustaina- bility goals into concrete actions at the project-specific level. This has proven to be a very challenging task. This process is exacerbated by the multidimensional perspec- tive of sustainability such as economy, society, environment, coupled with the lack of methodology and structured information at various levels of the hierarchy. Sustaina- ble construction in Indonesia faces several challenges, which come from a combina- tion of economic, social, and environmental factors. One example of the implementa- tion of the library building construction project carried out by several districts/cities, Green Open Spaces (RTH) that are not well maintained, road infrastructure whose service life has begun to decrease from the target. The mode of transportation for logistics transportation is increasingly limited with an emphasis on multifunctionality and the Over Dimension Over Loading (ODOL) trend which has fatal consequences for infrastructure, pedestrians that have changed function, parks and public spaces actually look deserted and the use of public spaces is not visible as expected. The aim of research is projecting factors that influence infrastructure sustainability.

2 Research and Methodology

This study adopts a mixed-method approach, combining both qualitative and quantitative analyses to examine the key factors influencing the sustainability of infrastructure development in Indonesia. The methodology is structured into several key stages: data collection, data analysis, and interpretation, ensuring a comprehensive understanding of the economic, environmental, social, and governance aspects that shape infrastructure outcomes. The research employs a descriptive and analytical design. Descriptive methods are used to present an overview of infrastructure development trends and budget allocations in Indonesia from 2015 to 2022, while analytical methods are applied to assess relationships among policy frameworks, financial mechanisms, and sustainability indicators. This dual approach allows for the integration of numerical data and contextual insights. The study relies on both secondary and primary data sources:

a) Secondary Data were obtained from official reports, such as the Ministry of Public Works and Housing (PUPR), Ministry of Finance, Bappenas, and statistical data from Badan Pusat Statistik (BPS). Additional references include academic journals, policy documents, and previous research on sustainable infrastructure.
b) Primary Data were gathered through semi-structured interviews with key stakeholders, including government officials, private sector actors, and community representatives involved in major infrastructure projects.

Thematic analysis was conducted on policy documents, stakeholder interviews, and project reports to identify recurring themes related to sustainability, governance, and technological innovation. This step aimed to uncover institutional, financial, and environmental barriers affecting sustainable infrastructure implementation. This research was conducted in South Sula- wesi Province, this location was chosen because the development infrastructure is higher than other provinces. This research was conducted in November - December 2024. Figure 2 shows the location to conduct research.

Fig. 2. The map of Reseacrh Location

This research method uses a spatial method or GIS (Geographic Information System) analysis to map and analyze infrastructure distribution in South Sulawesi. The spatial method is a method for ob- taining observation information that is influenced by the effects of space or location. The influence of the spatial effect is presented in the form of location coordinates (longitude, latitude) or weighting. Spatial patterns have two types of data, namely they can be distinguished into patterns with a point and area approach [14-15]. The map shown shows land conditions in South Sulawesi Province, Indonesia, at a scale of 1:2,000,000 using the Transverse Mercator projection and WGS 1984 datum. This map contains various geographic and administrative information, including pro- vincial and district/city boundaries, roads, rivers, and coastlines.

The study applies a Sustainability Assessment Framework (SAF) that evaluates infrastructure performance across four dimensions. To ensure the reliability and validity of findings, the study employs data triangulation, comparing information from various sources (government reports, interviews, and literature). Expert reviews were also conducted with academic scholars and policy practitioners to confirm the accuracy of interpretations. The methodological framework integrates empirical data with contextual insights, ensuring that the analysis reflects both the measurable progress and the underlying systemic challenges of Indonesia's infrastructure sustainability journey.

3 Result and Discussion

Indonesia's commitment to infrastructure development has been evident through a significant increase in public investment over the last decade. The data derived from the State Budget (APBN) allocation between 2015 and 2022 demonstrate a clear upward trajectory in infrastructure spending, underscoring its central role in supporting economic growth and national connectivity. In 2015, infrastructure allocation stood at approximately Rp 256.1 trillion, which increased steadily to Rp 269.1 trillion in 2016. The most notable growth occurred between 2016 and 2017, when infrastructure investment rose sharply to Rp 394 trillion, reflecting a robust government focus on improving transportation networks, utilities, and rural connectivity. This trend maintained its pace until 2019, when allocations reached Rp 394.1 trillion, before experiencing a temporary contraction in 2020 to Rp 284.3 trillion due to the economic impacts of the COVID-19 pandemic. However, by 2021, the allocation had rebounded to Rp 417.4 trillion, and by 2022 it reached an all-time high of Rp 450 trillion.

This steady increase reveals the Indonesian government's sustained prioritization of infrastructure as a driver of national transformation. Infrastructure investments were distributed among three primary sources of funding: the Central Government (Pusat), Transfers to Regions and Village Funds (TKDD), and Financing (Pembiayaan). Over the observed period, the central government's contribution remained the largest, averaging about 60–65% of total allocation, while regional transfers and financing mechanisms shared the remaining proportion. These findings highlight not only fiscal expansion but also a strategic reallocation of funds toward long-term national development priorities, aligning infrastructure programs with Indonesia's vision of sustainable, inclusive, and regionally balanced growth. The analysis of funding allocation patterns reveals a growing emphasis on decentralized development. As Indonesia comprises over 17,000 islands with diverse geographical conditions, the government recognized the importance of distributing infrastructure investment beyond Java and major metropolitan areas.

Between 2015 and 2022, allocations through TKDD (Transfers to Regions and Village Funds) increased steadily, indicating a deliberate policy shift toward empowering regional governments in planning and executing local infrastructure projects. In 2015, TKDD allocations for infrastructure stood at Rp 39.1 trillion, growing to Rp 77.7 trillion in 2016, and reaching Rp 192.4 trillion by 2019. This decentralization process sought to close the

infrastructure gap between developed western Indonesia and the less developed eastern provinces, particularly in Sulawesi, Kalimantan, and Papua.

Despite this positive trend, disparities remain evident. Regions with limited fiscal capacity or technical expertise often struggle to manage infrastructure projects efficiently. Delays in project implementation, inadequate maintenance, and poor integration between national and regional planning mechanisms remain common. Moreover, the uneven spatial distribution of investments has sometimes perpetuated imbalances in access to transportation, electricity, and digital infrastructure. Thus, while regional allocation has improved, sustainable development outcomes require further strengthening of local governance structures, improved intergovernmental coordination, and enhanced capacity building for regional planning units. These measures would ensure that decentralization effectively translates into equitable and sustainable development outcomes across Indonesia.

Government policy plays a decisive role in shaping the sustainability of infrastructure development. Over the years, Indonesia has implemented a series of policies aimed at improving investment efficiency, environmental management, and public accountability. The National Medium-Term Development Plan (RPJMN), together with supporting policies from the Ministry of Finance and the Ministry of Public Works and Housing (PUPR), outlines strategic priorities for infrastructure expansion and sustainability integration.

The introduction of Public–Private Partnership (PPP) frameworks, Infrastructure Guarantee Funds, and green financing mechanisms has been instrumental in mobilizing additional resources beyond the state budget. These frameworks are designed to attract private sector participation while maintaining public oversight. However, challenges remain in ensuring that private investment aligns with sustainability standards and long-term environmental goals.

Governance mechanisms also determine the success or failure of sustainable infrastructure programs. Transparent procurement systems, efficient project monitoring, and effective anti-corruption measures are vital to maintaining accountability. Yet, instances of regulatory overlap, bureaucratic inefficiency, and fragmented institutional responsibilities continue to hinder optimal performance.

Another critical factor is policy consistency. Frequent changes in administrative structures and project priorities across political cycles often disrupt the continuity of long-term infrastructure programs. Therefore, institutional resilience and policy stability must be reinforced through legal frameworks and cross-sectoral coordination. Strengthening governance in this way ensures that infrastructure development is not only robust but also adaptable and sustainable. Technological innovation represents one of the most transformative forces in the sustainability of infrastructure development. In Indonesia, digital transformation and green technology adoption have gradually been integrated into major projects, although the pace remains uneven.

Between 2015 and 2022, the adoption of modern construction technologies—such as Building Information Modeling (BIM), smart sensors, and prefabrication systems—has enhanced efficiency and reduced waste in several large-scale projects, including toll roads, bridges, and urban transport systems. Despite these advances, the study's findings reveal that underutilized urban spaces and inefficiencies in technology integration have reduced potential technological gains by approximately 15% as of 2024. This indicates that while innovation is present, it has not yet been optimized across sectors.

Moreover, the application of green infrastructure principles, such as energy-efficient design, water-sensitive urban planning, and eco-friendly materials, remains concentrated in urban projects, while rural and regional initiatives often rely on conventional methods. To promote broader technological adoption, institutional incentives and capacity-building programs are needed to enhance local expertise and integrate sustainability-oriented technologies in all project stages—from design and construction to operation and

maintenance. The government's focus on **digital infrastructure**—including fiber optic networks and satellite-based connectivity—has also played a significant role in supporting sustainable development. Expanding digital access enables data-driven monitoring systems, supports e-governance, and enhances transparency in project implementation. Thus, technology not only contributes to efficiency but also acts as a governance tool that strengthens sustainability outcomes.

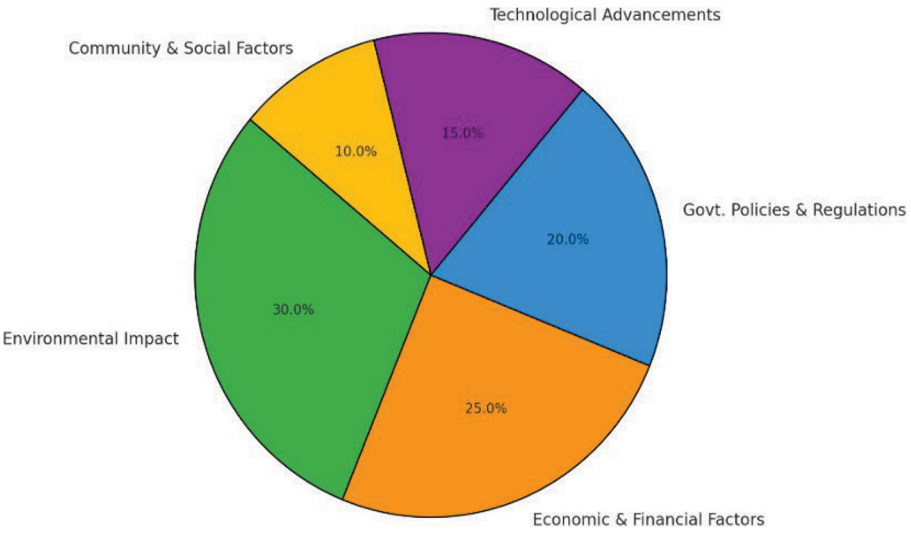

Fig.3. The percentage of factors affecting infrastructure in Indonesia

Infrastructure development inevitably interacts with natural ecosystems and human communities. Therefore, sustainability cannot be achieved without careful attention to environmental protection and social inclusion. The findings show that Indonesia has made significant progress in integrating Environmental Impact Assessments (AMDAL) and Strategic Environmental Assessments (KLHS) into project planning. However, the degree of compliance and enforcement varies across regions. In some cases, environmental assessments are treated as administrative formalities rather than essential planning tools, leading to ecological degradation such as deforestation, soil erosion, and water contamination. Furthermore, infrastructure projects often require land acquisition, which can generate social tension when local communities are inadequately consulted or compensated. Inclusive planning, participatory decision-making, and community empowerment are therefore essential to ensure that infrastructure benefits are distributed fairly and that affected populations are actively involved in the development process.

From a sustainability perspective, successful infrastructure should enhance not only physical connectivity but also social cohesion, resilience, and equity. Projects that incorporate local labor, promote livelihood opportunities, and respect cultural values tend to generate more lasting benefits. Hence, environmental and social sustainability are interdependent dimensions that must be integrated into every phase of infrastructure planning and execution.

The result shows in Figure 3 that environmental sit in 30% of the total amount ef- fects towards sustainability followed by economic and financial factors for 25%. The most affected factors are downgrade y only 15% meanwhile it much needed to reach the sustainability. It is the technological advancement factors, which rely on the sus- tainability target by 2050. A

sustainable approach in infrastructure development di- rectly influences economic, environmental, technological, policy, and social factors. By focusing on long-term resilience and innovation, infrastructure can support eco- nomic growth, protect the environment, and improve the quality of life. After map- ping the factors, Figure 4 shows the result of coverage area and built areas. To move toward a more sustainable infrastructure paradigm, Indonesia must focus on strategic reforms that align national priorities with global sustainability standards.

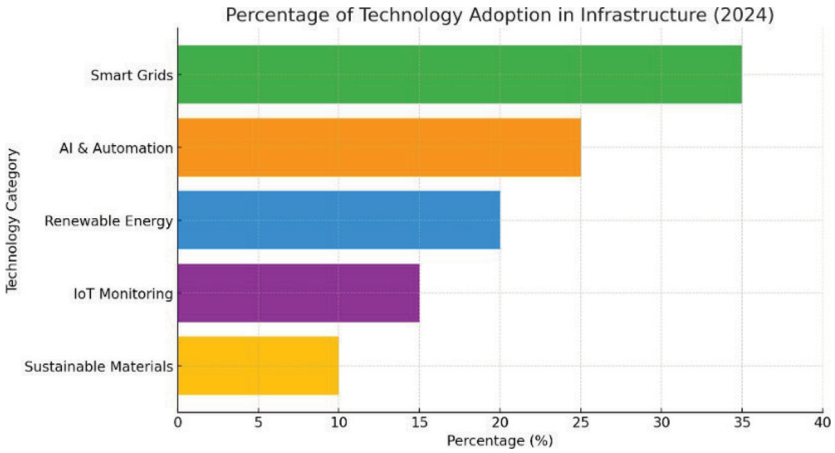

Fig. 4. The percentage of Technology Adoption in Infrastructure in 2024

The adoption of technology in infrastructure directly influences sustainability by improving efficiency, reducing environmental impact, and enhancing resilience. The higher the percentage of technology adoption, the greater the sustainability benefits. Figure 5 shows that the most adopted is Smart Grid followed by the AI and Automa- tion. The higher the percentage of technology adoption, the greater the sustainability impact in infrastructure. Smart technology leads to lower carbon emissions, increased efficiency, improved resilience, and cost savings. Investing in AI, IoT, GIS, and re- newable energy is critical for sustainable urban development. Infrastructure planning should adopt a systems-based approach that links transportation, energy, housing, and environmental management. Spatial integration ensures that new projects complement existing assets and minimize redundancy. The establishment of green bonds, sustainability-linked loans, and blended finance mechanisms can attract investment while promoting environmental responsibility. Public–private collaboration should incorporate clear sustainability benchmarks and performance indicators. Digital transformation and green innovation should be embedded into all project stages. Government incentives—such as tax benefits, research grants, and pilot programs—can accelerate technology adoption and stimulate private sector engagement.

Enhancing coordination between central and local governments through unified data systems, standardized procedures, and capacity-building programs will reduce fragmentation and improve accountability. Sustainable infrastructure must benefit people directly. Programs that engage local communities in project planning and maintenance increase ownership, reduce conflict, and ensure social sustainability. A robust sustainability assessment framework must be applied consistently to evaluate long-term impacts. This includes life-cycle analysis, climate resilience indicators, and transparent reporting mechanisms. By implementing these strategies, Indonesia can transition from infrastructure expansion to infrastructure transformation, ensuring that growth is inclusive, efficient, and environmentally responsible.

Applying the Sustainability Assessment Framework (SAF) used in this study, Indonesia's infrastructure performance can be analyzed through four interconnected dimensions:

a) Environmental Sustainability: Progress has been made in incorporating environmental assessments, but enforcement remains inconsistent. Future projects must emphasize renewable materials, energy efficiency, and climate adaptation.
b) Economic Sustainability: Investments have increased substantially, yet funding diversification is required to reduce dependency on the state budget. Long-term cost-benefit analysis should guide project selection.
c) Social Sustainability: Infrastructure has improved access to services and reduced regional disparities, but community participation and social safeguards require greater institutional support.
d) Governance Sustainability: Stronger institutional coordination, transparency, and continuity across political cycles are necessary to ensure policy coherence and accountability.

These dimensions collectively determine Indonesia's capacity to achieve sustainable infrastructure outcomes. Integrating them into a unified planning framework will create a robust foundation for long-term national resilience. Overall, the results indicate that Indonesia is on a strong trajectory toward sustainable infrastructure but remains at a transitional stage where traditional growth-oriented models coexist with emerging sustainability frameworks. Continued policy innovation, institutional reform, and cross-sector collaboration are required to ensure that infrastructure serves not only as an engine of economic progress but also as a catalyst for environmental protection, technological advancement, and social well-being.

By embracing a holistic sustainability approach, Indonesia can build infrastructure that stands not merely as physical structures but as enduring instruments of equitable and resilient national development.

4 Conclusion

The findings of this study demonstrate that the sustainability of infrastructure development in Indonesia is the result of a complex interplay between financial, policy, technological, environmental, and social factors. Over the 2015–2022 period, infrastructure investments have shown consistent growth, reflecting the government's strong commitment to achieving equitable and inclusive national development. However, this progress also reveals the persistent gap between economic expansion and sustainable practice, particularly in environmental protection, regional equity, and institutional coordination. The study confirms that government budget allocations—particularly through the central APBN, transfers to regions, and financing mechanisms—have significantly contributed to strengthening Indonesia's physical infrastructure. Nevertheless, the uneven distribution of funds across regions highlights continuing disparities in development outcomes. Java and Sumatra remain dominant in infrastructure investment, while eastern regions such as Papua, Maluku, and Nusa Tenggara continue to lag behind in both scale and impact. Achieving infrastructure sustainability therefore requires not only financial growth but also equitable regional distribution supported by stronger governance.

Technological advancement has emerged as a key determinant of sustainability, with digital innovation, renewable energy, and green construction materials offering transformative potential. Yet the study finds that only about 15% of the technological potential has been effectively utilized in major infrastructure projects by 2024. This indicates that Indonesia must invest more strategically in research, digital infrastructure, and capacity building for engineers and planners. Establishing stronger partnerships between universities, industries, and government institutions will be crucial to bridge this gap. Environmental

sustainability remains the most critical challenge. The rapid pace of urbanization and industrialization has increased pressures on natural ecosystems, leading to deforestation, resource depletion, and greenhouse gas emissions.

From a governance perspective, the effectiveness of institutional coordination determines the overall performance of infrastructure sustainability. Strong leadership at both the national and regional levels, combined with transparent mechanisms and public accountability, will enhance trust and attract private sector participation. Strengthening the role of local governments and fostering interagency collaboration are essential to ensuring that sustainability principles are embedded into all operational levels. In conclusion, the sustainability of infrastructure development in Indonesia cannot rely solely on financial expansion or physical output. It must be grounded in an integrated framework that balances economic efficiency, environmental responsibility, social inclusion, and institutional integrity. The findings suggest that Indonesia's progress toward sustainable infrastructure will depend on three strategic pillars: (1) integrated planning and policy coherence, (2) technological innovation and capacity building, and (3) participatory and transparent governance.

Future development must also be aligned with global sustainability goals, particularly the Sustainable Development Goals (SDGs), to position Indonesia as a regional leader in sustainable infrastructure. By strengthening collaboration among government agencies, the private sector, academia, and local communities, Indonesia can create infrastructure systems that not only support economic growth but also ensure long-term resilience and environmental harmony.

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