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Capital Place, 7-8 Floor, Jl. Gatot Subroto Kav 18, Jakarta 12710, Indonesia
jipm@iigf.co.id | https://jipm.iigf.co.id | +62(0) 2157950550

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3. The abstract must be provided in Bahasa Indonesia and English, each not exceeding 250 words.
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PPP-Based Transport Infrastructure Development in Eastern Indonesia: A Case Study of Makassar–Parepare Railway

Fathurrahman[1], Vivian Alvianti[2]

[1] Urban Planning and Design Research Group, School of Architecture, Planning, and Policy Development, Institut Teknologi Bandung (ITB), Indonesia
[2] Urban and Regional Planning, Faculty of Infrastructure and Regional Technology, Institut Teknologi Sumatera (ITERA), Indonesia

Corresponding author:
Fathurrahman | athybyrahman@gmail.com

ABSTRACT

The Makassar–Parepare railway project is Indonesia's first Public-Private Partnership (PPP) initiative in the railway sector, with an investment value of IDR 1.1 trillion and operational costs of IDR 1.9 trillion. This study examines the relevance of Kingdon's Multiple Streams Framework in public administration, particularly in the implementation of large-scale transport infrastructure. Using a qualitative-interpretative case study based on literature synthesis, the research shows that Kingdon's framework is still relevant in explaining how policy decisions are shaped by contextual dynamics, actor interactions, and political opportunities. The findings highlight the important role of key actors in selecting governance models, as reflected in the partnership between the Ministry of Transportation and PT Celebes Railway Indonesia. This case demonstrates that governance choices influence agenda-setting and project implementation in infrastructure megaprojects. Overall, the study reveals that policy implementation is driven not only by the substance of policy problems but also by institutional interests, power relations, and strategic interactions among different actors.

Keywords: Infrastructure Policy; Kingdon's Model; Megaproject; PPP

ABSTRAK

Pembangunan jalur kereta api Makassar-Parepare merupakan proyek Kerja sama Pemerintah dengan Badan Usaha (KPBU) pertama di Indonesia pada sektor perkeretaapian, dengan nilai investasi sebesar Rp1,1 triliun dan biaya operasional sebesar Rp1,9 triliun. Penelitian ini mengkaji relevansi Multiple Streams Framework yang dikembangkan oleh Kingdon, khususnya pada proyek pengembangan infrastruktur transportasi berskala besar. Dengan menggunakan pendekatan studi kasus kualitatif-interpretatif berbasis sintesis pustaka, penelitian ini menunjukkan bahwa kerangka Kingdon masih relevan untuk menjelaskan bagaimana sebuah kebijakan dibentuk oleh dinamika kontekstual, interaksi antara aktor kunci, dan peluang politik. Temuan penelitian menegaskan pentingnya peran aktor kunci dalam pemilihan model tata kelola, sebagaimana terlihat pada kemitraan antara Kementerian Perhubungan dan PT Celebes Railway Indonesia. Kasus ini menunjukkan bahwa pilihan tata kelola berpengaruh terhadap penetapan agenda dan implementasi proyek megainfrastruktur. Secara keseluruhan, penelitian ini mengungkapkan bahwa implementasi kebijakan tidak hanya ditentukan oleh substansi kebijakan, tetapi juga oleh kepentingan kelembagaan, relasi kuasa, dan interaksi strategis dari beberapa aktor.

Kata Kunci: Kebijakan Infrastruktur; KPBU; Megaproyek; Model Kingdon

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INTRODUCTION

The construction of transportation infrastructure megaprojects presents numerous challenges. Although the government has proposed various solutions to address these issues, the associated governance challenges are equally complex (Taki Imrani & Champagne, 2023). To overcome infrastructure deficits and the need to modernize existing public systems, Public-Private Partnership (PPP)—known in Indonesia as *Kerja sama Pemerintah dengan Badan Usaha* (KPBU)—initiatives have expanded globally since the 1990s. Many countries, particularly developing nations, have launched investment programs through collaboration with domestic and foreign partners to promote development. The nature and structure of this collaboration, as well as the involvement of institutional bodies, depend on government regulations and guidelines (Pradhan et al., 2022).

PPP represents an important form of collaboration between government agencies and private entities. This collaboration aims to facilitate the design, financing, construction, and operation of various projects, including those related to social and economic infrastructure development. In facing these complexities, public entities are actively strengthening partnerships with private companies to support infrastructure project financing using the PPP approach, as highlighted by Amedanou (2023) and Pradhan et al. (2022). It is important to note that the specific arrangements of these partnerships can vary across countries, influenced by historical practices and by the distribution of responsibilities between the government and private institutions in providing services for the public interest (Viegas, 2010).

After a hiatus caused by the economic crisis in the late 1990s, the use of PPP re-emerged in 2005 with the introduction of a new policy framework under Presidential Decree No. 67 of 2005. This step was accompanied by the preparation of a catalog of projects proposed by the government, presented through the PPP Book or other designated lists (Wibowo, 2021). Through this initiative, the government seeks to improve the effectiveness and efficiency of infrastructure project execution and to create a more structured collaboration between public and private sectors to advance sustainable infrastructure development.

This article has two main objectives, i.e., to explain the emergence and formulation of the Makassar-Parepare railway development policy and to understand whether the choice of governance model is part of the solution to the problem by examining the PPP model. To achieve these objectives, the researcher developed an analytical framework based on Kingdon's Multiple Streams Framework and the PPP model.

In the context of this article, Eastern Indonesia (*Kawasan Timur Indonesia* or KTI) refers to the geographical region of Indonesia that administratively covers the eastern provinces, including Sulawesi, Maluku, Papua, and Nusa Tenggara. Historically, this region has faced more complex development challenges than the western region, such as limited basic infrastructure, low interregional connectivity, and economic and fiscal disparities. In the transportation sector, KTI often experiences isolation that affects population mobility and logistical efficiency, thereby requiring strategic and adaptive policy interventions.

KTI is positioned as a priority region for transportation infrastructure development, with the Makassar–Parepare railway project serving as a case study to examine the effectiveness of the PPP model. The project aims not only to improve regional connectivity in South Sulawesi but also to represent a new policy approach that combines innovative financing, collaborative governance, and institutional support to accelerate development in structurally limited areas. Thus, KTI in this article is not merely a geographical area but a symbol of the challenges and opportunities in inclusive infrastructure development in Indonesia.

The Makassar-Parepare railway development is the first project under the PPP scheme in the railway sector, with a capital expenditure (Capex) investment value of IDR 1.1 trillion and operational costs (Opex) of IDR 1.9 trillion. The project concession period lasts for 17 years (Minister of National Development Planning/Bappenas, 2023). Using the Availability Payment (AP) scheme, the project is intended to serve the South Sulawesi region, covering five regencies and cities: Maros, Pangkajene and Islands (Pangkep), Barru, Makassar, and Parepare. The project, which recently began operations on the 80-kilometer Maros-Barru route, has incurred a total budget of IDR 9.2 trillion (Rustam, 2023). This megaproject is interesting to examine from a governance perspective as it is a Strategic Priority Project in Sulawesi, implemented through a partnership between the Indonesian Ministry of Transportation and the implementing business entity, PT Celebes Railway Indonesia.

The development of the Makassar-Parepare railway line is an integral part of the broader Trans-Sulawesi railway network. The primary objectives of this initiative are twofold: *first,* to improve the transportation of goods and passengers in order to contribute to national connectivity; and *second,* to align with national railway development targets to reach a total length of 10,524 km by 2030. The scope of the PPP includes the construction of Segment F, the operation and maintenance of railway tracks and operational facilities for Segments B, C, D, and F, as well as the construction of two passenger stations in Segment F (Minister of National Development Planning/Bappenas, 2023).

Through this paper, the author seeks to highlight how the Makassar–Parepare Railway development policy emerged and was formulated within the Kingdon's Multiple Streams Framework, and to assess the extent to which the choice of the PPP governance model played a role in shaping the policy agenda for transportation infrastructure megaprojects in Indonesia. Taki Imrani and Champagne (2023) argue that without serious consideration of the choice of government model from the beginning of the decision-making process, it becomes much more difficult to align urban public transport policies of this scale within the government agenda. Based on these observations, the researcher argues that the choice of governance model for megaprojects is also a key factor in setting the policy agenda.

Following this introduction, the article is divided into four sections. The first section discusses the main theoretical concepts that form the theoretical framework of this article, particularly the PPP governance model. The second section presents the research strategy, which is based on case studies and documentary analysis. The third section presents the research findings on the role of the governance model selection during the agenda-setting phase of the railway megaproject. Finally, the last section discusses the conclusions drawn from this research.

This paper emphasizes that research linking PPP with theory-based policy analysis, particularly Kingdon's framework, remains limited. Thus, this article provides an academic contribution by integrating PPP governance analysis within a Kingdonian perspective to understand the agenda-setting process in transportation infrastructure megaprojects, particularly in the development of PPP projects in developing countries and in the context of infrastructure development planning in KTI.

LITERATURE REVIEW

This section discusses the central theme of this article, i.e., the concept of Public-Private Partnerships (PPP) as the preferred governance model for major urban public transport projects.

The Kingdon Model in the Context of Urban Public Transport

The Kingdon Model refers to the framework developed by John W. Kingdon to understand the policy-making process. This model is more commonly known as the Multiple Streams Framework (MSF) (Herweg et al., 2022). Kingdon's Multiple Streams framework is a widely used multi-theoretical approach that explains non-incremental policy change by synthesizing elements from structural and institutional theories (Smith, 2018). The MSF is built on the concepts of timing and ambiguity and their impact on the policy process (Herweg et al., 2022).

Kingdon (1984) proposes a way to understand public policy agenda-setting by examining direct and indirect processes within the fragmented political system of the United States. His explanation of how agenda-setting functions focuses on three categories of independent variables that interact to produce "windows of opportunity" for agenda-setting. The problem stream, the policy stream, and the political stream each have specific characteristics. These streams flow through different channels and remain relatively independent of one another until, at a particular point in time, policy windows open. Only at that moment do the streams intersect (Béland & Howlett, 2016).

Under certain conditions, policy windows can be used by specific actors within a policy subsystem to advance engagement with issues they consider important. As Kingdon (1984) observed, during agenda-setting, the separate streams of problems, policies, and politics come together at certain times. Solutions become coupled with problems, and both are coupled with favorable political forces. Only then does an issue become a recognized problem on the official or institutional agends, and the public policy process begins to address it (Béland & Howlett, 2016).

Kingdon (1984) suggested that the opening of a policy window may sometimes be triggered by seemingly unrelated external focusing events, such as crises, accidents, or the presence or absence of "policy entrepreneurs" both inside and outside government (Béland & Howlett, 2016). Policy entrepreneurs play a vital role in shaping these streams and their intersection by "coupling" policy problems and policy

solutions together with political opportunities. In this regard, policy entrepreneurs demonstrate the central role of agency within the MSF.

Based on the description of the MSF developed by Kingdon, the model can be schematically illustrated as an interaction among three main streams that operate relatively independently:

1. The problem stream reflects issues identified as public problems that need to be addressed.

2. The policy stream contains a collection of ideas, solutions, and policy alternatives developed by the policy community.

3. The political stream includes political dynamics, such as changes in government, pressure from interest groups, and public opinion.

These three streams flow in parallel and are not always interconnected. However, at certain moments, a crossover or convergence occurs, known as a policy window. This policy window refers to a point in time when an opportunity to set a policy agenda opens, allowing available solutions to be linked to recognized problems and supported by favorable political conditions. In this process, policy actors known as policy entrepreneurs play a crucial role in connecting the three streams. They act as catalysts who use momentum and opportunities to push a specific issue onto the government's official agenda.

Thus, the schema of Kingdon's model can be understood as a dynamic structure consisting of three independent streams that occasionally intersect through policy windows, with the active involvement of policy actors who help unify problems, solutions, and political support. This model emphasizes the importance of timing, opportunity, and agency in the public policy agenda-setting process, which shows that policy change is often non-incremental and influenced by complex contextual configurations.

Public-Private Partnership (PPP) Concept

In general, PPP is a contractual agreement between the public and private sectors that allow for greater private sector participation than conventional practices. The agreement generally involves government agencies contracting private companies to renovate, construct, operate, maintain, and/or manage specific facilities or systems. Although the public sector usually retains ownership of the facilities or systems, the private party is granted additional decision-making authority in determining how projects or tasks are completed (Dong et al., 2016).

PPP in infrastructure development, which is implemented in developed and developing countries, has produced diverse and successful outcomes. PPP significantly increases the value and effectiveness of projects across various sectors. These sectors range from transportation, such as highways, bridges, ports, airports, and railways, to utilities, including electricity, water supply, and waste disposal, as well as telecommunication networks, information technology services, and social infrastructure, such as schools, hotels, hospitals, prisons, and military facilities (Zhang, 2005). Although existing studies have discussed the successful application of PPP across various sectors, research has not yet fully explained its implementation in the context of developing countries with limited institutional capacity.

PPP can be viewed as an institutional approach suitable for addressing specific market failures by fostering fairness and shared responsibility in transactions between public and private entities through

collaborative efforts (Pongsiri, 2002; Wang et al., 2018). The inherent value of the PPP concept primarily lies in mutual benefit. Given that the government's role in such partnerships includes service provision, market oversight, the establishment of a clear regulatory framework is necessary. A strong framework enhances government benefits by ensuring that essential partnerships operate effectively and by optimizing available resources in line with broader policy objectives, ranging from social policy to environmental protection (Pongsiri, 2002).

The Concept of PPP in Indonesia

Formally, the development of cross-sectoral policies on PPP began in 1998 with the issuance of Presidential Decree Number 7 of 1998, which outlined regulations governing PPPs in infrastructure provision. Following the issuance of this initial framework, the implementation of PPP policies in Indonesia has undergone various changes.

To achieve the GDP growth targets and the medium-scenario infrastructure stock stipulated in the National Medium-Term Development Plan (RPJMN) 2020–2024, a total investment of IDR 6,445 trillion is required for infrastructure development, with an average of 6.2% of GDP. However, the government's financial capacity for infrastructure development is limited to IDR 2,385 trillion, covering only 37% of the total requirements for the 2020–2024 RPJMN period. Addressing this gap requires an innovative approach involving non-budgetary funds and the private sector, which are essential for financing the 63% of the infrastructure development needs (Minister of National Development Planning/Head of National Development Planning Agency, 2023).

Considering the budgetary limitations in driving Indonesia's economic transformation, the Government of Indonesia acknowledges the importance of private sector involvement in infrastructure provision. Therefore, to optimize public services while fostering close cooperation with the private sector, the government is promoting various efforts to overcome these budgetary constraints.

PPP as an Alternative Financing Mechanism for Infrastructure Project Development

In the Indonesian context, PPP is defined as a type of financing cooperation between the government and business entities in infrastructure provision. Its objective is to provide flexibility for the government to partner with the private sector based on the principle of balanced risk allocation. The implementation of this scheme is regulated under Presidential Regulation Number 38 of 2015 (Arifin et al., 2024; Siagian, 2017).

In accordance with Presidential Regulation Number 38 of 2015, there are two distinct schemes for PPP project proposals: solicited and unsolicited. Solicited projects are initiated by the government, while unsolicited projects are initiated by the private sector.

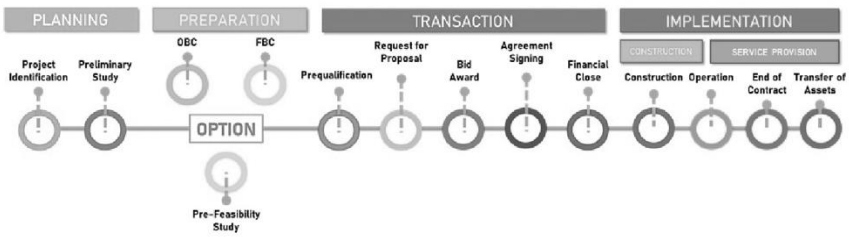

Figure 1. Project flow for government-initiated / solicited PPP proposals (Bappenas, 2023)

As stipulated in the Minister of National Development Planning Regulation Number 2/2020, the PPP project pipeline for solicited proposals consists of four main stages: planning, preparation, transaction, and implementation (Minister of National Development Planning/Head of National Development Planning Agency, 2023).

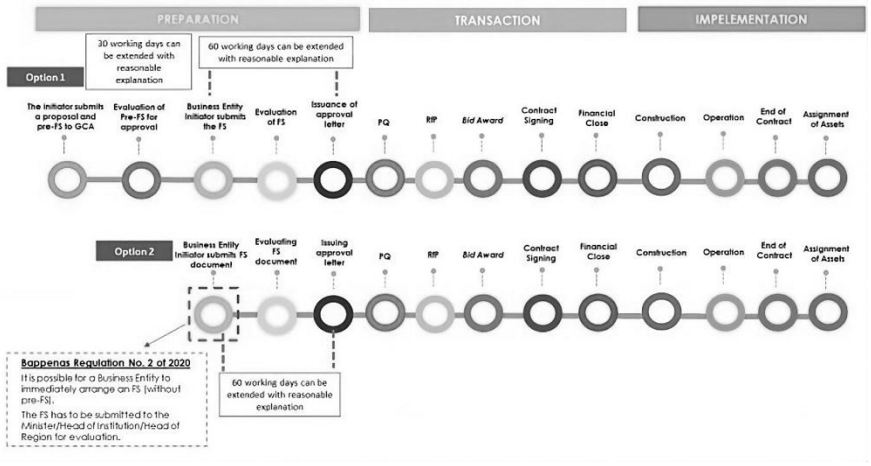

Figure 2. Project flow for private sector-initiated / unsolicited PPP proposals (Bappenas, 2023)

Unsolicited PPP proposals are initiated by the private sector or project proponents. The process for unsolicited projects involves three main stages: preparation, transaction, and implementation. The preparation stage is conducted by the private sector as the proposal initiator. In this article, we argue that policymakers' inclination toward the PPP governance model at the inception of transportation megaprojects shapes the selection of policy solutions.

DISCUSSION/ANALYSIS

Research Strategy

In this research, the researcher developed an analytical framework based on the Kingdon model within the concept of PPP. This research uses the Kingdon model as a framework to understand the factors that determine the convergence of three interconnected streams. This convergence is regarded as the opening of a "window of opportunity" to pursue policy solutions (Taki Imrani & Champagne, 2023). Based on the Kingdon-inspired framework, this analysis is structured around the behavior of policy actors and the flow of problems, solutions, and policy contexts, to which a governance stream is added. These streams help explain the creation of windows of opportunity in the process of setting the public policy agenda.

The methodology is based on a case study (Navalersuph & Charoenngam, 2021; Taki Imrani & Champagne, 2023) concerning the implementation of the Makassar–Parepare Railway Development Project, specifically Segment F, as well as the operation and maintenance (O&M) of railway tracks and operational facilities for Segments B, C, D, and F, and the construction of two passenger stations in Segment F. This megaproject is highly relevant to examine from a governance perspective because it is a Strategic Priority Project in the Sulawesi region, implemented through a partnership between the Ministry of Transportation of the Republic of Indonesia and the implementing business entity, PT Celebes Railway Indonesia (PT CRI). PT CRI's scope of work includes infrastructure construction for Segment F and the O&M of infrastructure for Segments B, C, D, and F of

the Makassar–Parepare line (Minister of National Development Planning/Bappenas, 2023).

The researcher employs a qualitative-interpretative analysis based primarily on document examination, as practiced by Taki Imrani and Champagne (2023). These documents include internal publications from public or private entities and media reviews. Additional sources, such as peer-reviewed articles, research papers, and analytical reports, contribute to a deeper understanding of the primary materials by helping interpret the data contained within them.

The period of 2002-2023 for literature search activities was selected by considering the growing discussions on the pressure faced by public authorities in addressing transportation challenges and regional disparities. This timeframe provides an opportunity to analyze project-related issues, including the stage at which the project first entered the policy agenda, particularly during the selection of the railway mode as a policy solution. Media reviews covering the 2014–2019 period focus on the physical realization of the Makassar–Parepare railway line.

During the above periods, the search covers implementation aspects and how the project was received by the public and other stakeholders. Meanwhile, the 2019–2023 timeframe concerns the PPP scheme and covers the operational phase of the Maros Station–Barru Garongkong Station route. The selection of this period is based on the significance of the shift toward private sector involvement in transportation infrastructure projects and the extent to which this shift influenced the sustainability and effectiveness of project implementation.

Regarding the role of the Kingdon model in the Makassar–Parepare railway PPP project, the researcher conducted analysis based on the Multiple Streams Framework (MSF), with the addition of one essential element: the governance stream. This framework is used to understand the convergence among the problem stream, policy solutions, political dynamics, and the governance model used in the project. Such convergence is understood as the opening of a policy window that allows an issue to enter the public policy agenda.

This study adopts a qualitative-interpretative approach using a case study method, in which the primary data sources consist of policy documents, institutional publications, and media reviews. To maintain the validity and reliability of the analysis, the researcher applies a pattern-matching technique between the empirical elements found in the documents and the components of the MSF. The analytical procedure is conducted through thematic coding of the document content, focusing on the identification of policy narratives, actor roles, stream dynamics, and governance structures. The document inclusion criteria include direct relevance to the Makassar–Parepare project, link with the PPP scheme, and contribution to the understanding of the policy agenda. Documents that are general, not project-specific, or do not contain interpretable policy information are excluded from the analysis.

As mentioned previously, the literature search period was established between 2002 and 2023. The period was filled by the evolution of policies and public discourse on infrastructure development in KTI. The period is divided into three phases: the initial transportation mode assessment phase (2002–2011), the project's physical realization phase (2014–2019), and the PPP implementation and service operation phase (2019–2023). Each phase is analyzed to identify patterns of interaction among the streams in the MSF and to examine how policy actors used windows of opportunity to advance the project agenda.

Through this approach, the resulting inferences are not merely declarative but are based on a systematic analytical process, so that they strengthen the validity and theoretical contribution and of the research findings.

Case Analysis

The Makassar–Parepare Railway PPP Project is implemented by PT Celebes Railway Indonesia (CRI). This project covers various scopes of work, primarily focusing on infrastructure construction for both Segment F (Tonasa) and the Garongkong segment. The project also includes ongoing responsibility for the operation and maintenance (O&M) of infrastructure for Segments B, C, D, and F (Tonasa). The estimated project cost is USD 138.58 million.

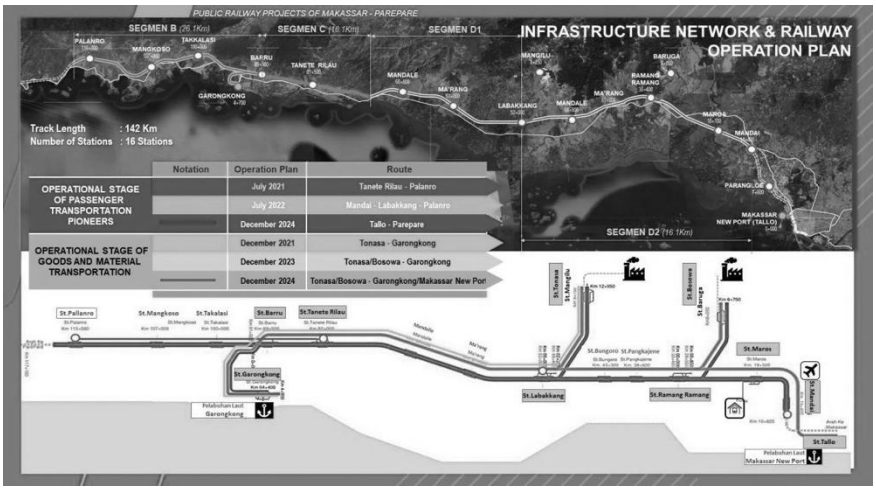

Figure 3. Makassar-Parepare Railway Line Project (PT CRI, 2020)

Policy Actors of the Makassar-Parepare Railway

The first policy actor is PT Celebes Railway Indonesia (CRI). PT CRI's services include the construction, operation, and maintenance of the Makassar–Parepare railway infrastructure under a PPP scheme between the Ministry of Transportation and the company (PT CRI, 2020). Established on February 6, 2019, CRI operates as a limited liability company with a shareholding structure consisting of four companies: PT PP (45%), PT Bumi Karsa (22.5%), PT CCCEI (22.5%), and PT Iroda Mitra (10%). PT CRI focuses on various activities, including infrastructure development for Segment F of the Makassar–Parepare railway line (PT CRI, 2020). CRI pioneered this scheme through the Makassar–Parepare Railway project, which encountered numerous challenges during the process, particularly in terms of financing (Adam et al., 2023; Ariana, 2024).

The second policy actor is the sixth president, Susilo Bambang Yudhoyono. The assessment of the Trans-Sulawesi railway line began as early as 2002, continued in 2004, and was pursued more systematically starting in 2011. In that year, the project was included in the 2011–2030 National Railway Master Plan prepared by the Directorate General of Railways of the Ministry of Transportation. The Susilo Bambang Yudhoyono administration showed strong commitment to preparing the Trans-Sulawesi railway because of its significant economic impacts on the community. The primary objective of this project was to boost the economy of South Sulawesi in particular and to connect regions or urban centers within the area (Hidayat, 2014).

The third policy actor is the seventh president, Joko Widodo (Jokowi). Jokowi's leadership emphasized national infrastructure development focusing on railway projects. One prominent initiative was the Makassar–Parepare railway project in South Sulawesi. The groundbreaking ceremony for this project took place on August 12, 2014, at the beginning of President Joko Widodo's term (Bureau of Communication and Public Information, 2014). The first step in implementation was the laying of the first rail on Friday, November 13, 2015, in Lalabata Village, Barru Regency. The limited operation of the Garongkong–Mangilu Station segment began on October 29, 2022. During this initial operational phase, occupancy rates reached 100% on weekends (Ubaidillah, 2022).

The total investment for the Makassar–Parepare railway project reached IDR 9.28 trillion, sourced from the State Budget (APBN), PPP financing, land acquisition conducted by the State Asset Management Agency (LMAN), and the Regional Budget (APBD). After a long process, the official inauguration of the Makassar–Parepare line for the Maros–Barru Intercity Train and the Maros Railway Depot was held on March 29, 2023, in Maros Regency, South Sulawesi (Setpres, 2023).

Factors Related to the Policy Framing of the Makassar-Parepare Railway

The author examines the implementation of the Makassar-Parepare Railway Project proposed by the Ministry of Transportation. To better understand this project and the governance model proposed by the Ministry, the author analyzes the pre-decision processes that enabled this policy to enter the agenda. The study applies Kingdon's framework by examining the problem, policy, and political streams.

1. Problem Stream

This project is part of the Trans-Sulawesi railway network, which is expected to generate economic benefits along the route in South Sulawesi. The Makassar–Parepare Railway was built to improve national connectivity and competitiveness (Bappenas, 2025). South Sulawesi has experienced economic growth above the national average, which indicates growth in various sectors, including transportation. The province has two major cities: Makassar and Parepare. Economically, Makassar serves as the largest distribution service hub due to its comparative geographical advantage in Eastern Indonesia, while Parepare plays an important role in supporting the functions of the capital city (Yusuf, 2022).

However, the construction of the Trans-Sulawesi railway from Makassar to Parepare has faced scrutiny for its slow progress and failure to meet the established targets (Mirsan, 2022). One contributing factor is the substantial investment required for the project (Tempo, 2017). The project requires significant financial resources, which has become a major obstacle. In addition, land acquisition performance is considered slow. Uncertainty in land procurement can lead to construction delays, hinder project progress, and ultimately affect the achievement of time targets (Redaksi Walai, 2022).

Furthermore, the Williamson Inequality Index of South Sulawesi increased to 0.568 in 2021 compared to the previous year. Although this indicates an increase in development performance, it also shows that equitable development among regencies/cities in South Sulawesi has not yet been optimally achieved. Currently, interregional accessibility in South Sulawesi still relies on provincial and interprovincial road-based public transportation. To promote more effective and

efficient accessibility, mass transportation infrastructure in the form of an intercity public railway network connecting Makassar and Parepare is required (South Sulawesi Provincial Government, 2016).

Figure 4. Project schedule of the Makassar-Parepare Railway (Minister of National Development Planning/Head of National Development Planning Agency, 2020)

	Model Tradisional	Model PPP	Model KPBU PT CRI
Perencanaan dan Pembiayaan			
Kewajiban Perencaan	Pemerintah	Pemerintah	PT CRI + Mitra
Sumber Pembiayaan	Utang Publik Baru	Subsidi federasi dan provinsi mencakup sebagian biaya (variabel)	PT CRI + Mitra (PT PII/IIGF, PT SMI, PT BSI)
Pelaksanaan			
Kewajiban konstruksi	Pemerintah	Konsorsium swasta	PT CRI + Mitra
Pengoperasian			
Pengoperasian Proyek	Pemerintah	Konsorsium swasta	PT CRI + Mitra
Kendali pemegang saham	Pemerintah	Konsorsium swasta	PT CRI + Mitra
Asset dalam neraca keuangan pemerintah	Ada	Ada	Ada
Kepemilikan aset	Pemerintah	Konsorsium swasta (35 tahun) kemudian dilanjutkan oleh pemerintah	Masa konsesi proyek ini berlangsung selama 17 Tahun

Figure 5. Comparison between PPP models at PT CRI with others models (Taki Imrani & Champagne, 2023)

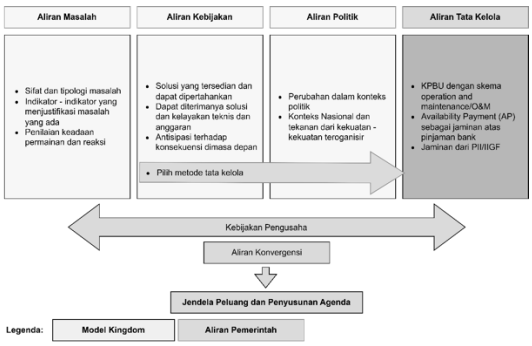

Figure 6. The Kingdon model revisited through the governance stream of the Makassar–Parepare Railway Project (Taki Imrani & Champagne, 2023)

In proposing new policies, Kingdon highlights the crucial role of stakeholders and public response. Consequently, policymakers use statistical data to illustrate the potential negative consequences if problems persist. This approach helps them position their preferred policy solutions as the best alternatives for mitigating those issues (Taki Imrani & Champagne, 2023).

The Makassar-Parepare Railway Project is an example of a project intended to support regional economic growth as well as to enhance the movement of goods and passengers (Yusuf, 2022). Several key aspects of this project include the following (Ministry of Finance, 2022):

- The project development uses a PPP scheme, with the Ministry of Transportation acting as the Government Contracting Agency (*Penanggung Jawab Proyek Kerja Sama* or PJPK), and a concession period of 17 years;

- The indicated investment value is IDR 1 trillion, and the project is expected to use an Availability Payment scheme. It is intended to promote national connectivity and stimulate regional economic growth

- Stakeholder involvement and public response are necessary to ensure that the project achieves both government and community objectives while minimizing potential negative impacts during the construction and operational phases. Therefore, the use of statistical data and a policy approach that prioritizes the most effective solutions is vital to achieving the objectives of this project.

2. Policy Stream

In Kingdon's model, to adopt a public policy, policymakers must navigate a series of stages involving policy identification, formulation, and adoption. A key aspect of this process is the ability of policymakers to justify their proposed solutions (Taki Imrani & Champagne, 2023). The Makassar-Parepare Railway project faces new challenges as it involves a new investment scheme. Innovative solutions are required, particularly in relation to financing, which may involve the establishment of new financial structures or the development of conventional models.

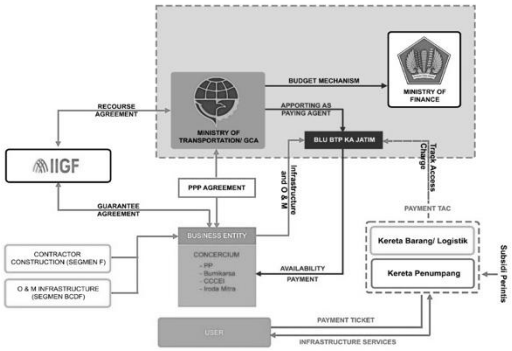

Figure 7. Project structure of the Makassar-Parepare Railway (Minister of National Development Planning/Head of National Development Planning Agency, 2025)

The Makassar–Parepare Railway project is a PPP financing-based project that involves CRI as the implementing business entity, together with PT Indonesia Infrastructure Finance (IIF), PT Sarana Multi Infrastruktur (SMI), and PT Bank Syariah Indonesia (BSI). In implementing the project, the Ministry of Transportation received support from the Ministry of Finance through the Project Development Facility (PDF), with PT Penjaminan Infrastruktur Indonesia (PII) assigned as the facility coordinator. The PDF facility covers various project stages, from the preparation of the Final Business Case to Financial Close (Adam et al., 2023). This project serves as an example of successful creative non-state budget financing in Indonesia and is expected to have a positive impact on the economy of South Sulawesi. In this context, several funding innovations emerged, particularly in relation to the banking sector (Adam et al., 2023).

The first innovation is the guarantee from PII, which provided an extra yet vital layer of security. This guarantee refers to risk protection given to the implementing business entity to complement government commitments, aiming to increase investor confidence and project bankability.

The second innovation is the Availability Payment (AP) scheme. In the context of the Makassar–Parepare Railway, AP is not a direct guarantee for bank loans but a scheme for periodic payments from the government to the implementing entity based on the availability of agreed infrastructure services. This scheme reflects a shift from traditional financing approaches that rely on direct user revenue, such as fares or ticket sales.

The third innovation is the accelerated payment. The project introduced an accelerated payment scheme that differs from standard payment schedules.

The Makassar–Parepare Railway project requires an investment of approximately USD 138.58 million and will be operated by the designated party under a 17-year concession agreement. This illustrates the scale of investment and the management period before possible changes in ownership or operation occur. The project demonstrates positive financial feasibility, with an Internal Rate of Return (IRR) of 11.76% and a Net Present Value (NPV) of approximately USD 3.46 million (Bappenas, 2023), which indicate the financial viability and profit potential of the investment.

3. Political Stream

The political context plays a vital role in both the problem and policy streams. Factors such as shifts in public opinion, government positions, and pressure from organized political forces influence policy dynamics (Taki Imrani & Champagne, 2023). Thus, understanding this political context is important to understand the flows of problems and policies comprehensively.

In the political stream, support from various institutional actors is a crucial factor in opening a policy window. The Makassar–Parepare Railway project gained support from the central government, provincial government, and regency/city governments

along the route. This support is reflected in the project's integration into the national development agenda and regional development planning.

Within the MSF, this configuration of political support strengthened policy momentum as it allows the project to enter the national transportation development priority agenda. The support of the Regional House of Representatives in the construction of the Makassar–Parepare Railway represents a legislative function that aligns national strategic policies with the real needs of local communities. Politically, this support is crucial because the project must be integrated into the Regional Long-Term Development Plan (*Rencana Pembangunan Jangka Panjang Daerah* or RPJPD) as part of South Sulawesi's macro-transportation vision and further detailed operationally in the its medium-term development plan. Without synchronization within these regional planning documents, the project would struggle to gain budgetary legitimacy through the Regional Budget, especially for supporting infrastructure such as station access roads, feeder transport, and Transit-Oriented Development (TOD) around stations.

Furthermore, the involvement of the Regional House of Representatives in the political stream ensures synergy between central planning through the National Medium-Term Development Plan (*Rencana Pembangunan Jangka Menengah Nasional* or RPJMN) and local interests in regencies such as Maros, Pangkep, and Barru. The legislative role in ratifying Regional Regulations on Spatial Planning (*Rencana Tata Ruang Wilayah* or RTRW) provides the primary legal basis for land acquisition, thereby minimizing regulatory obstacles at the ground level. By integrating this project into the RPJMD, the Regional House of Representatives helps guarantee development sustainability despite regional leadership transitions by ensuring that the railway provides measurable economic impacts for logistics connectivity and population mobility in South Sulawesi.

At the national level, the Directorate General of Railways acts as the policymaker and planner for rail-based transportation systems. However, the political stream at the national level functions as a general policy environment. Conversely, as the first PPP project in the railway sector, the Makassar–Parepare project has specific strategic characteristics. In this context, the political stream plays a more active and direct role because the project serves as a symbol of the success of the PPP scheme and as a national pilot project. Political will encouraged a more structured PPP design, including the use of AP and clear risk allocation through institutional support such as the PDF and PII.

The Choice of Governance Model

Following the three streams proposed by Kingdon, Taki Imrani and Champagne (2023) suggest adding the fourth stream: the choice of governance model during the agenda-setting phase. They argue that the PPP governance model plays a vital role in opening the window of opportunity for this megaproject. This model differs significantly from conventional models, in which the government bears full responsibility, and also differs from traditional PPP models in terms of its structured relationship with the government.

In the implementation of the Makassar–Parepare Railway, the central government, local governments, and various agencies engage in collaborative works. The adopted governance model includes cross-sectoral cooperation involving the Ministry of Transportation, the Directorate General of Railways, the Railway Engineering Bureau, and local governments, including South

Sulawesi Province, Makassar, Parepare, and Maros (BPKP, 2017).

The President of Indonesia highlighted this railway as a transportation option that not only facilitates mobility but also reduces logistics costs. By involving various ministries and local governments, the project demonstrates a holistic approach to infrastructure development. Under this model, cross-institutional governance oversees the project to ensure efficient execution and monitor the use of funds in order to enhance regional competitiveness.

Opening the Window of Opportunity

In Kingdon's framework, a "window of opportunity" occurs when the three, or in this case four, streams converge. In the Makassar–Parepare project, the policy window opened through the interaction and convergence of these streams. The project is expected to provide significant economic and social benefits, with an estimated social benefit value of IDR 2.51 trillion (Sardi, 2022).

Beyond its economic impact, the project is expected to drive regional growth through improved access, travel time savings, and logistical cost efficiency. It is also considered a contributor to the Sustainable Development Goals (SDGs), particularly in relation to decent work and economic growth (Yusuf, 2022). The presence of railway services is expected to stimulate the movement of people and goods, support regional tourism, create new jobs, and develop Micro, Small, and Medium Enterprises (MSMEs) around stations. Thus, the project aims to promote economic progress, to improve community welfare, and support environmental preservation. These aims reflect the government's strong commitment to realize sustainable development.

CONCLUSION

This research examines the relevance and utility of the MSF, as developed by Kingdon, in the context of public administration, specifically in relation to the implementation of transportation infrastructure megaprojects in Indonesia. This study focuses on the Makassar–Parepare Railway project as a case study, which serves as the first pilot project under the PPP scheme in the railway sector. Through a qualitative approach based on document analysis, this research finds that the central hypothesis of the Kingdon model tends to be confirmed: public policy is not always the result of a rational and inclusive deliberative process; rather, it is often opportunistic and influenced by political momentum, institutional windows, and the configuration of the actors involved.

One of the main theoretical contributions of this research is the expansion of the MSF model by proposing the governance stream as an additional element that influences policy agenda-setting. The governance stream refers to the choice of governance model used in the project, including financing schemes, risk allocation, and institutional structures. In the case of Makassar–Parepare, the selection of the PPP scheme with the AP mechanism and guarantee support from institutions such as PII and PDF proved to be key factors in opening the policy window. The convergence of the governance, problem, and political streams created conditions that allowed this project to be implemented more rapidly and efficiently than conventional approaches.

This research also highlights the critical role of actors in the policy decision-making process. Actors from various institutions, such as the Ministry of Transportation, the Ministry of Finance, the implementing business entity, and financial support institutions, exert significant influence in determining policy

direction and project design. The interactions, interests, and political power of each actor are decisive factors in choosing the governance model and implementation strategy. These findings reinforce the argument that, in the context of public administration, policy decisions are influenced not only by the substance of the problem but also by power dynamics and institutional configurations.

Conversely, this research identifies limitations in the autonomy of local governments in megaproject governance, despite the fact that they are the most affected parties and have a direct interest in the project's success. Local government involvement tends to be passive, limited to technical execution and impact management, without sufficient space in the planning and strategic decision-making processes. In addition, financial aspects are found to be the ultimate determinants of project feasibility and sustainability. Financing structures, risk guarantees, and payment mechanisms are crucial elements that affect investment decisions and successful implementation.

The policy implications of these findings suggest that the central government needs to provide more space for local governments in megaproject governance, including in planning, decision-making, and oversight. Furthermore, transparency in the AP scheme and government guarantees must be strengthened to enhance accountability and prevent political risks or potential corruption. The government must also ensure that the institutional designs and governance models used are capable of addressing local challenges and strengthening regional institutional capacity.

In the context of the political stream, political support from various institutional actors is a vital factor in opening policy windows. The Makassar–Parepare Railway project gained support from the central government, provincial government, and regency/city governments along the project route. This support is reflected in the project's integration into the national development agenda and regional development planning. Within the MSF, this configuration of political support strengthened policy momentum, enabling the project to enter the national transportation development priority agenda.

The limitation of this research lies in its document analysis-based methodological approach; therefore, the resulting interpretations may not fully reflect the empirical dynamics on the ground. As the consequence, further validation through in-depth interviews with key actors, as well as quantitative analysis of project and financing data, is highly recommended to strengthen these findings and broaden their generalizability.

To strengthen the result of this analysis, future researchers are suggested to compare this project with other PPPs in the transportation sector or other infrastructure sectors in Indonesia. They may also benchmark it against megaproject governance practices in other countries with similar institutional and political contexts.

ABOUT THE AUTHORS

Fathurrahman is a graduate of the Master's Program in Urban and Regional Planning at Institut Teknologi Bandung (ITB). He currently serves as a research fellow in the Urban Planning and Design Research Group, SAPPK ITB.

Vivian Alvianti is a graduate of the Master's Program in Urban and Regional Planning at Institut Teknologi Bandung (ITB). She currently serves as a lecturer in Urban and Regional Planning at Institut Teknologi Sumatera (ITERA).

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Dual Risk Guarantee Mechanism for Net-Zero City Financing in Indonesia

Rifky Pratama Wicaksono[1], Muhammad Rafi Bakri[2]

[1] Australian National University, Canberra, Australia
[2] The Audit Board of Indonesia, Jakarta, Indonesia

Corresponding author:
Rifky Pratama Wicaksono | rifky.wicaksono@anu.edu.au

ABSTRACT

The development of Net-Zero Cities (NZCs) in Indonesia faces significant obstacles due to complex financing mechanisms and inherent governance challenges in Public-Private Partnerships (PPPs). Although PPPs have become a strategic instrument for addressing the financing gap in green infrastructure, high fiscal risks, uncertain benefits, and weak intergovernmental coordination continue to hinder their effectiveness. In this context, PT Penjaminan Infrastruktur Indonesia (PT PII) plays a vital role in mitigating risks by providing government-backed guarantees for infrastructure PPPs. However, the effectiveness of this role depends on oversight mechanisms conducted by the Audit Board of Indonesia (BPK) as the state audit institution. This paper therefore introduces the concept of a dual risk guarantee mechanism, which combines PT PII's infrastructure guarantees with BPK's fiscal oversight. Through this scheme, the feasibility of NZC projects can be strengthened, fiscal risks can be more carefully monitored, and public investment governance can be improved. The study draws on document analysis and case-based studies of contemporary practices in Indonesia. The authors find that the acceleration of NZCs requires robust oversight, the establishment of contingency funding, optimization of gearing ratios, risk transparency, and stronger synergy of PT PII, BPK, the Ministry of Finance, and other stakeholders.

Keywords: Accountability; Guarantee Mechanism; Net Zero Cities; Public Finance Management

ABSTRAK

Pengembangan *Net-Zero Cities* (NZCs) di Indonesia menghadapi tantangan besar akibat kompleksitas mekanisme pembiayaan dan persoalan tata kelola yang melekat dalam skema KPBU. Meskipun KPBU telah menjadi instrumen strategis untuk mengatasi kesenjangan pembiayaan infrastruktur hijau, tingginya risiko fiskal, ketidakpastian manfaat, dan lemahnya koordinasi masih menghambat efektivitas skema tersebut. Dalam konteks ini, PT Penjaminan Infrastruktur Indonesia (PT PII) memegang peran penting dalam memitigasi risiko melalui penyediaan penjaminan pemerintah bagi KPBU di bidang infrastruktur. Namun, efektivitas peran tersebut bergantung pada mekanisme pengawasan Badan Pemeriksa Keuangan (BPK) sebagai lembaga audit negara. Oleh sebab itu, artikel ini memperkenalkan konsep *dual risk guarantee mechanism*, yaitu mekanisme yang mengombinasikan penjaminan infrastruktur oleh PT PII dengan pengawasan fiskal BPK. Melalui skema ini, kelayakan proyek NZCs dapat diperkuat, risiko fiskal dapat dikalibrasi lebih tepat, dan tata kelola investasi publik dapat ditingkatkan. Studi ini menggunakan analisis dokumen dan studi kasus terkini di Indonesia. Penelitian menunjukkan bahwa akselerasi NZCs memerlukan pengawasan yang kuat, pembentukan pendanaan kontinjensi, optimalisasi *gearing ratio*, transparansi risiko, serta sinergi yang kuat antara PT PII, BPK, Kementerian Keuangan, dan pemangku kepentingan terkait lainnya.

Kata Kunci: Akuntabilitas; Manajemen Keuangan Publik; Mekanisme Penjaminan; *Net Zero Cities*

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INTRODUCTION

The rapid urbanization of the Asia-Pacific region presents both challenges and opportunities for sustainable urban development (Osei-Kyei et al., 2020). The United Nations Secretary-General's Panel on Critical Energy Transition Minerals (2024) estimates that the global urban population will increase to 6.5 billion by 2050. While cities drive economic growth, they also contribute to overcrowding, environmental degradation, and infrastructure pressure, particularly in informal settlements (Abu-Rayash & Dincer, 2025). Given that urban areas account for more than 70% of Global Greenhouse Gas (GHG) emissions and consume more than 67% of the world's energy, urgent solutions are needed to enhance environmental sustainability and resource efficiency (Xu et al., 2024; Yang et al., 2024).

The concept of Net-Zero Cities (NZCs), or sustainable cities, has emerged as a transformative approach to urban development by integrating smart technologies, Artificial Intelligence (AI), and the Internet of Things (IoT) to optimize urban ecosystems (Antolín-López et al., 2024). With the advent of Industry 5.0, which prioritizes human-centered digital transformation, there is an opportunity to reimagine urban spaces as intelligent, connected, and regenerative systems. Kahachi et al. (2024) argue that cities should leverage information technology and digital systems to improve efficiency, sustainability, and resilience. NZCs that integrate innovative technologies can provide solutions to pressing urban issues, including energy, transportation, water, and communication networks (Soudeep et al., 2024). However, NZC initiatives must also remain inclusive and responsive to the needs of all citizens, including marginalized communities, to avoid further exacerbating socioeconomic disparities (Liu et al., 2024).

Despite this potential, a significant financing gap remains in the practical application of Industry 5.0 principles to NZC development, particularly in emerging economies such as Indonesia, where the integration of smart city frameworks with sustainability goals remains a major challenge (Goh et al., 2024; Hidayat et al., 2025). The government recognizes that investments in green infrastructure, such as urban forestry and vegetation, can contribute to the greening of smart cities. However, addressing this financing gap is challenging because such projects often involve substantial costs and uncertain long-term benefits.

One potential solution lies in strategic collaboration between the public and private sectors through Public-Private Partnerships (PPPs). The rapid global adoption of net-zero targets by both state and non-state

actors, particularly around major global climate negotiations, underscores the importance of institutional coordination mechanism in mobilizing climate mitigation action across sovereign and market-based actors (Green et al., 2025; Wozniak et al., 2025). Governments can use PPPs to pool resources, expertise, and innovation in addressing infrastructure financing constraints (Huang et al., 2019; Osei–Kyei et al., 2022). Through such collaboration, the public and private sectors can develop comprehensive strategies that integrate renewable energy sources, optimize energy use through smart grids, and implement scalable technological solutions. Cities such as Copenhagen have demonstrated the effectiveness of this approach in driving sustainability initiatives. Its real-time traffic management system, with sensor networks and AI to reduce congestion and emissions, is an example of strong public-private collaboration (Oyadeyi & Oyadeyi, 2025).

In Indonesia, the implementation of PPPs has become increasingly significant. The Ministry of Finance has indicated that, by 2025, there will be 35 ongoing PPP projects distributed across Indonesia, as shown in Figure 1. PPPs in Indonesia primarily focus on infrastructure procurement with substantial social and economic impacts, making them relevant to the development of NZC-related infrastructure.

Figure 1. Distribution of PPP Projects in 2025

The Indonesian government also supports infrastructure development by providing guarantees for PPP initiatives. Investors and infrastructure providers benefit from government-supported projects that may receive guarantees through PT Penjaminan Infrastruktur Indonesia (PT PII). Overall, there are 22 sectors that PT PII may guarantee, many of which are relevant to NZC-related infrastructure, as shown in Figure 2. As of October 2023, PT PII had provided guarantees for 50 projects with a total investment value of IDR 496 trillion, consisting of 33 PPP projects and 16 non-PPP projects. The 33 PPP projects covered six sectors, including road infrastructure, comprising 15 toll road projects and three non-toll road projects; four telecommunications projects; one electricity project; six drinking water projects; two transportation projects; and two energy conservation projects.

Figure 2. Sectors that PT PII could guarantee

However, the guarantee function performed by PT PII must be managed within its institutional capacity limits. Based on the Decree of the Minister of Finance of the Republic of Indonesia No. 460 of 2022 concerning the Determination of the Capability Limit or Gearing Ratio of the Infrastructure Guarantee Business Entity in Carrying Out Guarantee Activities, the capability limit of the Infrastructure Guarantee Business Entity (BUPI), namely PT PII, is set at a maximum of 12 times its equity. Maintaining this threshold is essential to ensure that PT PII does not assume an excessive guarantee burden. In this context, fiscal oversight by an independent external institution is necessary. In Indonesia, this oversight role is performed by the Audit Board of Indonesia (BPK).

This paper aims to examine how PT PII's infrastructure guarantee function and BPK's fiscal oversight role can jointly support the governance of NZC-related PPP financing in Indonesia. Rather than treating BPK as a financial guarantor, this paper positions BPK as an accountability institution whose audit and fiscal oversight functions can strengthen transparency, risk discipline, and public financial governance in infrastructure guarantee schemes. Accordingly, the proposed dual-layer risk governance mechanism refers to the combination of PT PII's project guarantee role and BPK's fiscal oversight role in managing the NZC-related PPP financing risks (Sunandar et al., 2024).

This paper specifically seeks to: *first,* explain the relevance of PPP guarantees to NZC financing in Indonesia; *second,* analyze the role and capacity constraints of PT PII in providing infrastructure guarantees; *third,* examine BPK's role in safeguarding fiscal accountability and transparency; and *fourth,* formulate a conceptual mechanism through which guarantee provision and fiscal oversight may jointly strengthen NZC-related infrastructure financing.

THEORETICAL FRAMEWORK

PT PII's Role in Supporting NZC-Related Infrastructure Financing

As a Special Mission Vehicle (SMV) under the Ministry of Finance, PT PII provides financial guarantees to mitigate risks associated with PPP projects. This role is intended to improve the bankability of infrastructure projects and increase their attractiveness to private sector investors. PT PII's financial capacity is reflected in its equity value, which stands at IDR 14.8 trillion. This capital enables PT PII to support projects up to 5.8 times its equity value through a gearing ratio scheme. The gearing ratio measures financial leverage and risk exposure; a higher ratio may indicate greater guarantee capacity, although it also requires careful monitoring to ensure that risk exposure remains within prudent limits.

NZC projects require comprehensive feasibility assessments to determine whether they are viable for government support, including support through PT PII's guarantee facilities. Such projects often involve substantial investment costs and may pose difficulties in quantifying long-term benefits, particularly when benefits relate to environmental sustainability, emissions reduction, resilience, and social inclusion. Through its evaluation framework, PT PII has established basic guidelines to assess whether the PPP scheme provides value for the government, particularly in infrastructure development (Iftitah & Wibowo, 2022). This framework is relevant to NZC-related infrastructure because the development of NZCs depends on investment in sectors such as renewable energy, public transportation, water systems, telecommunications, energy efficiency, and other urban infrastructure.

In managing guarantee exposure, PT PII uses several risk-sharing instruments, including re-guarantee and co-guarantee mechanisms. These instruments should be distinguished from the dual-layer risk governance mechanism proposed in this paper. Re-guarantee and co-guarantee mechanisms are financial instruments used to distribute or share guarantee risks among guarantors or reinsurers. By contrast, the proposed dual-layer risk governance mechanism refers to the combination of PT PII's guarantee function and BPK's fiscal oversight role. In this sense, BPK act as an accountability institution that strengthens transparency, risk discipline, and fiscal governance in infrastructure guarantee schemes.

Table 1. Comparison of re-guarantee and co-guarantee mechanisms

Aspect	Re-guarantee	Co-guarantee
Reason for using the guarantee strategy	Excess risk exposure	Limited funding capacity
Number of main guarantors	One	More than one
Dilution of control	No	Yes
Capital relief impact for the main guarantor	Yes	No
Party responsible for paying claims in case of default	Main guarantor	Main guarantor and partners
Specific scheme	Facultative and treaty	Direct and indirect

As shown in Table 1 above, a re-guarantee instrument, or reinsurance, occurs when a guarantor redistributes a portion of the accumulated risk exposure in its guarantee portfolio to one or more reinsurers. In exchange for assuming part of the risk, the primary guarantor pays a specified premium based on the magnitude of the risk transferred. Reinsurance provides capital relief to the primary guarantor and is commonly used when total risk exposure approaches a predetermined capacity limit.

In a re-guarantee arrangement, the primary guarantor remains the sole contracting party with the guaranteed entity, while the reinsurance agreement with the reinsurer is conducted separately from the original agreement. Consequently, in the event of default, the guaranteed entity receives the full claim payment from the primary guarantor, even though the claim payment may include a proportionate contribution from the reinsurer to the guarantor.

By contrast, a co-guarantee is a risk-sharing instrument conducted in collaboration with one or more guarantor partners for a specific project guarantee. This mechanism enables a guarantor to increase its guarantee capacity without requiring additional capital. Yet, a co-guarantee does not reduce the risk burden recorded in the financial statements. Instead, it mitigates risk exposure through a pre-agreed allocation of responsibility set out in the initial guarantee agreement, compared with a standalone guarantee.

In a co-guarantee agreement, a single contract is established among the primary guarantor, co-guarantor partners, the guaranteed entity, and the beneficiary. Upfront fees and premiums are agreed upon among the guarantors before being presented to the guaranteed entity. This arrangement allows the primary guarantor to manage risk exposure strategically by determining which projects require co-guarantee support and which can be guaranteed independently.

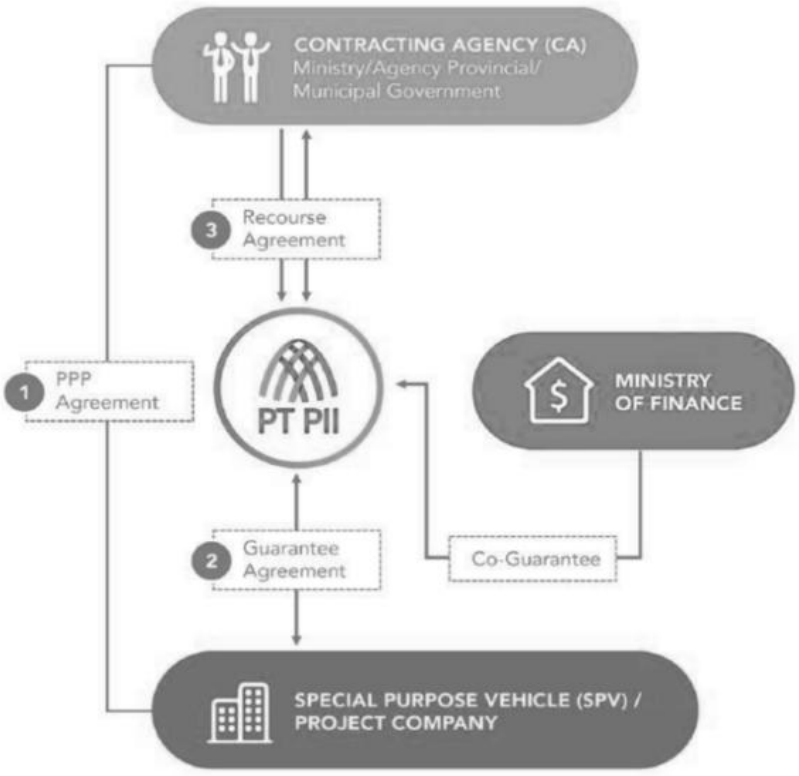

Figure 3. Business process of PT PII

As shown in Figure 3, PT PII executes a guarantee contract after all required procedures have been completed and the project has been deemed eligible for a guarantee. The contract is established with the party requesting the guarantee and may include a co-guarantee or re-guarantee agreement with another entity serving as a guarantor partner. At present, most of these arrangements are executed in coordination with the Ministry of Finance.

BPK's Oversight Role in Safeguarding Accountability and Transparency

The potential expansion of PT PII's guarantee capacity through the optimization of its gearing ratio may increase opportunities for infrastructure financing. However, this expansion is also accompanied by greater fiscal and financial risks. These risks may arise, for example, when a project-executing business entity is unable to generate sufficient revenue, thereby affecting its solvency and its ability to meet loan or guarantee-related obligations. From PT PII's perspective as a guarantor, inadequate assessment of fiscal capacity and project risk may create exposure to guarantee obligations if the business entity experiences financial distress.

Auditing, therefore, plays an important role in mitigating financial and governance risks in infrastructure guarantee schemes (Riyanda, 2020). In terms of NZC initiatives, audit institutions do not function as project guarantors. Rather, they provide assurance that funding mechanisms remain sustainable, accountable, and aligned with national development objectives. They may also help ensure that the infrastructure being financed contributes to green, sustainable, and resilient urban development.

A well-structured audit process can identify potential financial mismanagement, fraud risks, inefficiencies, and weaknesses in NZC-related infrastructure projects. For PT PII, as a government-backed risk guarantor, audit oversight helps ensure that its financial exposure remains manageable and does not create unforeseen fiscal liabilities. While PPPs facilitated by entities such as PT PII provide essential technical expertise and financial resources for infrastructure development, defining "sustainable investments" in such arrangements requires robust governance frameworks. These frameworks are necessary to prevent ambiguity between rules-based taxonomies and principles-based approaches, which may otherwise create opportunities for greenwashing (Cochran et al., 2025; Harrington-Abrams & Bower, 2025).

The 1945 Constitution of the Republic of Indonesia and Law Number 15 of 2004 mandate the Audit Board of Indonesia (BPK) as an independent audit institution responsible for auditing the management and accountability of state finances. As a Supreme Audit Institution, BPK is expected to ensure government accountability and transparency by assessing compliance with laws and regulations, while also considering justice and propriety (Albugis, 2016; Arum & Winarno, 2015; Koynja, 2017). In this capacity, BPK conducted an examination of PT PII to assess and conclude whether PT PII's management of revenue, expenditure, and investment complied with the laws, regulations, and guidelines applicable to the institution.

BPK applies a risk-based approach in its audit methodology by substantively assessing PT PII's guarantee activities in the infrastructure and other sectors mandated by the government (The Audit Board of

Indonesia, 2022). BPK also conducts financial and non-financial analyses based on the auditor's understanding of PT PII's risks and business processes, particularly compliance risks related to applicable laws and regulations. Audit oversight of infrastructure guarantee mechanisms is also relevant to climate-related infrastructure as it supports accountability through consistent disclosure standards and compliance frameworks. Such oversight may also contribute to the evaluation of climate action co-benefits, such as public health gains from reduced air pollution (Cooley et al., 2025).

BPK has identified several issues that, to a certain extent, may create potential fiscal liabilities. These include overexposure to high-risk infrastructure projects, inadequate transparency in guarantee issuance, and weaknesses of PT PII's monitoring process. As of the first semester of 2021, PT PII had provided guarantees for 34 projects, consisting of 29 PPP projects and six direct lending projects. In addition, there were 13 Project Development Facility (PDF) initiatives and 13 guarantees under the National Economic Recovery program.

Based on the Compliance Audit Report on PT PII's Revenue, Expenditure, and Investment for the period from 2019 to the first semester of 2021, BPK found that PT PII's accumulated gearing ratio reached 6.08 times its equity value, with guarantee exposure of IDR 72.9 trillion and equity of IDR 11.99 trillion. These figures were based on the financial statements for the first semester of the 2021 fiscal year, excluding projects under the National Economic Recovery program. According to Minister of Finance Regulation Number 95 of 2017, PT PII's gearing ratio was set at a maximum of ten times its equity value. This indicates that the guarantee capacity used by PT PII remained below the regulatory threshold. As a result, the potential benefits of guarantees for business entities had not yet reached the expected level. In addition, the relatively low level of guarantees resulted in limited profit margins from guarantee services and PDF, which constitute PT PII's core business, compared with revenue from other sources.

To enhance transparency and accountability in state financial management, BPK also conducted a review of the implementation of government fiscal transparency at the Ministry of Finance (BPK, 2024). On the basis of this report, BPK sought to perform its role as an independent institution that is capable of providing value-added audits, as expected under the INTOSAI-P 12 (International Organization of Supreme Audit Institutions, 2019).

Figure 4. The framework of INTOSAI-P 12

BPK's review report is used as a supporting document for the audit results of the Central Government Financial Statements (LKPP), which are submitted to the President, the House of Representatives (DPR), the Regional Representative Council (DPD), and. The review applies parameters based on the Fiscal Transparency Code (FTC) published by the International Monetary Fund (2019). The FTC consists of four main pillars: (1) Fiscal Reporting, (2) Fiscal

Forecasting and Budgeting, (3) Fiscal Risk Analysis and Management, and (4) Resource Revenue Management. Each pillar contains specific dimensions and criteria, which are assessed at four levels of practice: Basic, Good, Advanced, and Not Assessed.

As an SMV under the government's fiscal management framework, PT PII is one of the entities evaluated under the third pillar, namely Fiscal Risk Analysis and Management (The Audit Board of Indonesia, 2024). This pillar examines the analysis and management of state financial risks, as well as coordination processes in fiscal decision-making within the public sector. It consists of three dimensions: Risk Analysis and Disclosure, Risk Management, and Fiscal Coordination. Among the assessed criteria, four are particularly relevant to PT PII: 3.1.2. Specific Fiscal Risks, 3.2.1. Budget Contingencies, 3.2.3. Guarantees, and 3.2.4. Public-Private Partnerships.

Criterion 3.1.2 assesses whether the main risks to fiscal projections are disclosed qualitatively in a summary report that includes the estimated magnitude of the risks and their likelihood of occurrence. Criterion 3.2.1 concerns the allocation of contingency budgets, supported by clear utilization criteria and periodic reporting on budget realization. Criterion 3.2.3 examines whether all government guarantees, their beneficiaries, generated gross exposure, and the likelihood of claims are published at least annually. Meanwhile, Criterion 3.2.4 assesses the extent to which the government publishes all rights, obligations, other exposures, expected receipts, and payments arising from PPP contracts at least annually. It also evaluates the existence of regulations that limit the accumulation of obligations arising from PPP contracts.

The four transparency pillars are briefly illustrated in the following figure.

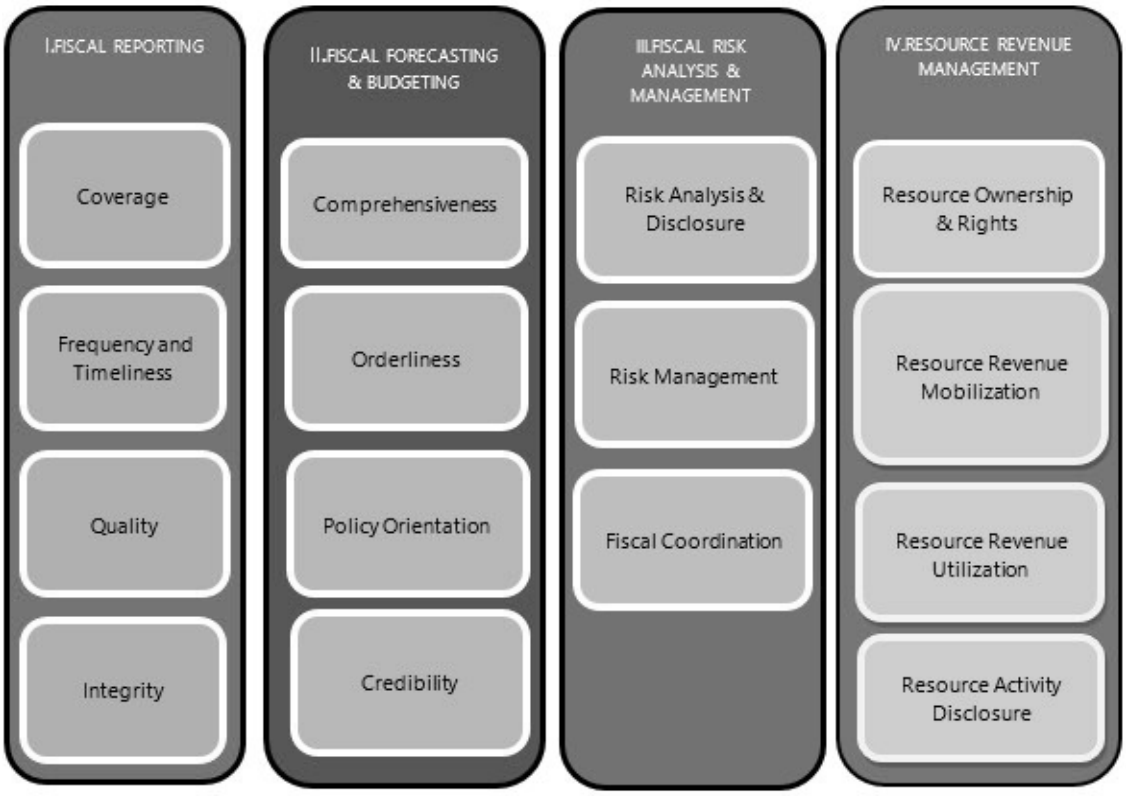

Figure 5. Fiscal transparency pillars (BPK Fiscal Transparency Report, 2024)

Although these four indicators were assessed at the Advanced level by BPK (2024), the review still highlighted several fiscal risks for PT PII in providing infrastructure guarantees. *First,* financial risk may arise if the project-executing business entity is unable to meet its financial obligations to the guarantor. *Second,* the maximum gearing ratio may pose a risk if it is not measured reliably, as this may affect the adequacy of PT PII's gearing ratio and increase exposure to co-guarantee risk with the Ministry of Finance. *Third,* recourse receivables owed to PT PII have not been clearly determined in terms of payment responsibility, particularly whether they should be paid by regional-owned enterprises (BUMD) or by regional heads as the government contracting agencies. This uncertainty may increase financial risk for PT PII.

In addition, based on BPK's 2024 review report, PT PII had not yet received an allocation for contingency obligations as the government considered the risk of default on guarantee obligations to be insignificant and highly unlikely. Nevertheless, BPK emphasized that the government still needs to monitor the development of PT PII's capital position to prevent increasing fiscal risk. The Ministry of Finance has periodically reported the position of government infrastructure guarantee obligations in the portfolio management report, which is accessible through the website of the Directorate General of Budget Financing and Risk Management (Direktorat Jenderal Pengelolaan Pembiayaan dan Risiko, 2024).

The results of BPK's compliance audit on PT PII and its fiscal transparency review, as part of the audit of the central government financial statements, indicate that BPK plays a substantial role in strengthening fiscal discipline and accountability in infrastructure guarantee schemes. Within the dual-layer risk governance mechanism proposed in this paper, BPK does not provide a financial guarantee or assume project risk. Instead, BPK provides independent fiscal oversight to help ensure that PT PII's guarantee obligations are still within reasonable limits. This check-and-balance function is important because the promotion of green transition through environmentally oriented infrastructure development must be accompanied by sound financial governance. Through such oversight, PT PII can maintain financial integrity and avoid providing guarantees beyond its institutional capacity. This mechanism demonstrates how BPK's role can go beyond formal compliance by contributing to broader improvements in public financial governance and sustainable infrastructure development.

ANALYSIS

Toward a Dual-Layer Risk Governance Mechanism for NZC Financing

The collaboration between BPK and PT PII in supporting infrastructure financing, particularly for NZC-related projects, involves two different but complementary functions: financial facilitation and fiscal oversight. As illustrated in Figure 6, PT PII, as a government-owned infrastructure guarantee institution, is responsible for providing guarantees for infrastructure projects, including those implemented through PPPs. This role includes supporting project preparation, improving financial viability, and increasing investor confidence, while also safeguarding public financial interests. By contrast, BPK does not function as a financial guarantor. Its role is to audit and oversee PT PII's financial operations to ensure compliance with national standards, legal frameworks, and principles of accountability in state financial management.

PT PII contributes to the financing and management of large-scale infrastructure projects, including those relevant to NZC development. This includes providing guarantees under various financial structures, such as direct lending schemes and PPP arrangements. To improve the financial viability of these projects, PT PII also provides support through instruments such as the PDF and guarantees against specific risks. These instruments aimed to make infrastructure projects more bankable by structuring them in a way that attracts investors while minimizing excessive fiscal exposure for the government. In this regard, PT PII's management of the gearing ratio, which regulates the relationship between guarantee exposure and equity, is a critical element of its risk management strategy. However, as noted in BPK's reports, the optimization of this ratio requires careful assessment to ensure that available guarantee capacity can be used effectively without creating excessive fiscal risk.

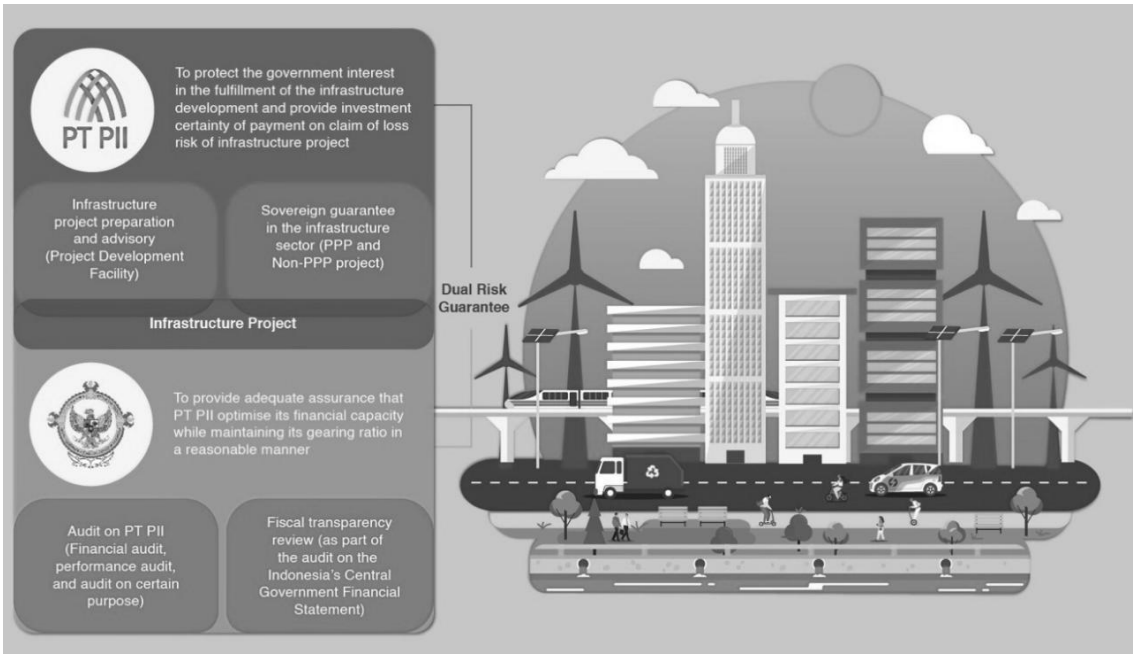

Figure 6. Dual-guarantee scheme

BPK's oversight function primarily focuses on ensuring that PT PII adheres to financial management standards and maintains transparency in its operations. BPK audits PT PII's revenue, expenditure, and investment activities, including matters related to the timeliness of guarantee fee payments and the adequacy of internal controls. For example, in its audit of PT PII's operations from 2019 to 2021, BPK identified several areas requiring attention, including delays in the payment of guarantee-related fees and the underutilization of PT PII's financial leverage through its gearing ratio. Such oversight helps ensure that PT PII remains financially sound and compliant with national regulations. This is particularly important for long-term infrastructure investments, including those aimed at supporting sustainable and low-carbon urban development. The relationship between BPK's financial audit function and PT PII's infrastructure guarantee function also extends to the broader assessment of public financial management. By evaluating the financial soundness of PT PII's investments and guarantees, BPK helps ensure that public funds are used effectively and that

guarantee obligations do not create unmanaged fiscal liabilities. BPK's role includes examining PT PII's management of fiscal resources, including capital provided through government investment, which has been a significant source of support for PT PII's operations. For example, in 2020, the government allocated an additional IDR 1.57 trillion in capital to PT PII for the sake of supporting infrastructure development projects under the National Economic Recovery (*Pemulihan Ekonomi Nasional*, or PEN) initiative.

The complexity of managing large-scale infrastructure projects, particularly those related to net-zero targets, requires strong coordination among PT PII, BPK, the Ministry of Finance, local governments, and other relevant stakeholders. Despite PT PII's considerable involvement in PPP projects, BPK has noted that PT PII has not fully optimized the potential market for infrastructure guarantees. Limited coordination between PT PII and other financial entities, such as the Directorate General of Budget Financing and Risk Management (DJPPR), may hinder the effective deployment of resources and reduce the potential financial benefits of guarantee services. Therefore, strengthening institutional coordination is essential to ensure that guarantee instruments can support NZC-related infrastructure without weakening fiscal prudence.

The practices of Dual-Layer Risk Governance Approach

Several projects illustrate the relevance of dual-layer risk governance approach. One example is the development of the Patuha Geothermal Power Plant (PLTP Patuha), a renewable energy project designed to supply electricity by utilizing geothermal resources. This project involved collaboration with the Asian Development Bank (ADB) and carried a total investment value of USD 469.2 million. Initiated in August 2020, the project is expected to mature over a period of 20 years. BPK conducted an audit on this project and recommended that PT PII maintain a gearing ratio of 0.07, with a maximum guarantee amount of IDR 827 billion.

Another example is the Hydropower Programme, a project valued at IDR 6.9 trillion and aimed at improving electrification rates across Central and Eastern Indonesia. The programme uses hydropower technology to convert water into electricity, which offers environmental advantages by producing lower levels of pollution compared to several other power generation technologies. Following its audit, BPK recommended that PT PII limit the gearing ratio for this project to 0.06 in order to mitigate excessive financial burdens.

These examples show that BPK's role should be understood as fiscal oversight rather than project guarantee provision. The value of BPK's involvement lies not in making PPP projects directly more attractive to investors, but in strengthening the credibility, transparency, and accountability of the guarantee system (Genda et al., 2024). In NZC-related infrastructure financing, this oversight is important because green and sustainable projects often involve long investment horizons, uncertain benefits, and complex risk allocation. PT PII's guarantee function can improve the bankability of such projects, while BPK's oversight can help ensure that guarantee exposure remains within prudent fiscal limits.

Accordingly, the proposed dual-layer risk governance mechanism does not add BPK as another guarantor in the financial sense. Instead, it conceptualizes a complementary relationship between PT PII's ex-ante

guarantee function and BPK's ex-post audit and fiscal oversight function. PT PII supports project financing by mitigating selected risks and improving investor confidence, whereas BPK safeguards public financial accountability by reviewing whether guarantee obligations, fiscal risks, and related disclosures are properly managed. This arrangement can support the development of NZC-related infrastructure by balancing two objectives: accelerating sustainable infrastructure investment and maintaining fiscal discipline.

In the future, the partnership between BPK and PT PII is still very important for Indonesia's infrastructure development agenda, particularly in relation to sustainable cities. BPK's audit activities help ensure that PT PII's guarantee operations are transparent, accountable, and compliant with legal frameworks. Meanwhile, PT PII's role in structuring and guaranteeing infrastructure projects remains essential for attracting private investment to support NZC-related infrastructure. Both institutions need to address existing weaknesses, particularly in coordination, risk disclosure, contingency planning, and gearing ratio optimization. The long-term success of these efforts will depend on PT PII's ability to meet the growing demand for sustainable infrastructure while managing risks, keeping investor confidence, and operating within a robust public financial governance framework.

CONCLUSION

This paper has examined the role of PT PII's infrastructure guarantee function and BPK's fiscal oversight role in supporting the governance of NZC-related PPP financing in Indonesia. The findings suggest that the development of NZCs requires not only access to private investment and bankable infrastructure projects, but also strong fiscal governance to ensure that guarantee obligations remain transparent, accountable, and financially sustainable. In this context, PT PII plays an important role in improving the bankability of infrastructure projects through government-backed guarantees, while BPK contributes by strengthening accountability, transparency, and fiscal risk oversight.

The proposed dual-layer risk governance mechanism should be understood as a combination of two complementary roles. PT PII provides project-related guarantees to mitigate selected risks and attract private sector participation, whereas BPK provides independent oversight to ensure that such guarantees are managed within prudent fiscal limits. This mechanism does not position BPK as a financial guarantor or as an institution assuming project risk. Rather, BPK's role lies in providing assurance through audit, review, and fiscal transparency assessment. This clarification is important to avoid conceptual confusion between guarantee provision and audit oversight.

The analysis also shows that several issues require further attention, including the optimization of PT PII's gearing ratio, the need for contingency funding for guarantee obligations, stronger disclosure of fiscal risks, and improved coordination among PT PII, BPK, the Ministry of Finance, DJPPR, local governments, and other stakeholders. These measures are particularly important for NZC-related infrastructure because such projects often involve substantial costs, long-term benefits, and complex risk allocation. Strengthening coordination and fiscal oversight can help ensure that the expansion of infrastructure guarantees supports Indonesia's environmental and economic goals without creating excessive fiscal exposure.

This paper is conceptual in nature and does not quantify the administrative costs, time implications, or investor responses associated with the proposed mechanism. Future research should therefore examine the practical feasibility of this approach through empirical studies that involve local governments, investors, PT PII, BPK, and other relevant stakeholders. Further research may also compare Indonesia's infrastructure guarantee and fiscal oversight arrangements with similar mechanisms in other countries. Despite these limitations, this paper argues that a dual-layer risk governance approach can provide a more balanced framework for accelerating NZC-related infrastructure investment while maintaining public financial accountability.

ABOUT THE AUTHORS

Rifky Pratama Wicaksono is a graduate student of the Crawford School of Public Policy at Australian National University (ANU). For further correspondence: rifky.wicaksono@anu.edu.au.

Muhammad Rafi Bakri is a Research Analyst for the Senior Advisor of the Audit Board of the Republic of Indonesia (*Badan Pemeriksa Keuangan,* or BPK). For further correspondence: muhammad.bakri@bpk.go.id.

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Policy and Regulatory Readiness of Industrial Carbon Capture and Storage (CCS) in Indonesia

Lenny Hidayat[1], M. Ilham Ramadhan[1], Cholisa Amalia[1], Michael Timothy Tasliman[2]

[1] Greenwise Consulting, Jakarta, Indonesia
[2] Independent Consultant, Batam, Indonesia

Corresponding author:
Lenny Hidayat | lennyhidayat@greenwise.co.id

ABSTRACT

Carbon Capture and Storage (CCS) is increasingly discussed as a policy option for decarbonizing hard-to-abate industries and supporting Environmental, Social, and Governance (ESG) implementation. In Indonesia, recent regulatory progress—especially Presidential Regulation No. 14 of 2024—has created an initial legal basis for CCS, but industrial deployment still depends on the coherence of policy, regulatory, and licensing arrangements across multiple sectors. This study examines the policy and regulatory readiness of industrial CCS in Indonesia through a qualitative, document-based analysis of laws, regulations, policy documents, peer-reviewed literature, and stakeholder consultations. The assessment is operationalized through eight readiness indicators: policy alignment, regulatory clarity, institutional coordination, licensing integration, environmental integrity, social safeguards, governance accountability, and Monitoring, Reporting, and Verification (MRV) readiness. The findings show that Indonesia has made important progress in establishing a legal foundation for CCS, yet readiness remains partial. The authority is fragmented across energy, environment, industry, licensing, transport, and sustainable-finance domains; long-term liability and post-closure stewardship remain insufficiently specified; and the integration of social safeguards and ESG-linked governance requirements is still limited. The article argues that industrial CCS can support the pillar of ESG, but only if Indonesia strengthens coordination, clarifies liability, streamlines licensing, and aligns CCS governance with ESG-oriented policy and reporting expectations.

Keywords: Carbon Capture and Storage; ESG; Industrial Decarbonization

ABSTRAK

Carbon Capture and Storage (CCS) semakin dipandang sebagai opsi kebijakan untuk mendekarbonisasi industri yang sulit diturunkan emisinya sekaligus mendukung implementasi *Environmental, Social, and Governance* (ESG). Di Indonesia, kemajuan regulasi—terutama melalui Peraturan Presiden No. 14 Tahun 2024—telah memberikan landasan awal bagi CCS, namun penerapan CCS industri masih bergantung pada koherensi pengaturan kebijakan, regulasi, dan perizinan lintas sektor. Penelitian ini menelaah kesiapan kebijakan dan regulasi CCS industri di Indonesia melalui analisis kualitatif berbasis dokumen atas peraturan perundang-undangan, dokumen kebijakan, literatur ilmiah, dan konsultasi dengan pemangku kepentingan. Penilaian dioperasionalisasi melalui delapan indikator: keselarasan kebijakan, kejelasan regulasi, koordinasi kelembagaan, integrasi perizinan, integritas lingkungan, perlindungan sosial, akuntabilitas tata kelola, serta kesiapan *Monitoring, Reporting, and Verification* (MRV). Hasil analisis menunjukkan bahwa Indonesia telah membuat kemajuan penting dalam membangun landasan hukum CCS, namun tingkat kesiapan masih parsial. Kewenangan masih terfragmentasi di ranah energi, lingkungan, industri, perizinan, transportasi, dan keuangan berkelanjutan; pengaturan mengenai tanggung jawab jangka panjang dan pascatutup belum cukup jelas; serta integrasi perlindungan sosial dan persyaratan tata kelola berbasis ESG masih terbatas. Artikel ini menunjukkan bahwa CCS industri dapat mendukung pilar lingkungan dalam ESG, tetapi hanya bila Indonesia memperkuat koordinasi, memperjelas tanggung jawab, menyederhanakan perizinan, dan menyelaraskan tata kelola CCS dengan ekspektasi kebijakan serta pelaporan berbasis ESG.

Kata Kunci: Dekarbonisasi Industri; ESG; Penangkapan dan Penyimpanan Karbon

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INTRODUCTION

Industrial decarbonization has become a central policy challenge because a large share of emissions from cement, steel, refining, petrochemicals, and other hard-to-abate sectors cannot be eliminated through energy efficiency and electrification alone. In this context, Carbon Capture and Storage (CCS) is increasingly treated not merely as a technical add-on, but as part of an industrial governance strategy that can help manage residual emissions when integrated into credible policy, regulatory, and investment frameworks (Mathur et al., 2022; McLaughlin et al., 2023; Global CCS Institute, 2023). The significance of CCS, therefore, depends not only on capture technology or storage potential, but also on whether a country can allocate responsibility, manage long-term risks, and build confidence among affected communities, investors, and regulators (Alizadeh et al., 2024; Aslam, 2024; Osazuwa-Peters & Hurlbert, 2020).

Indonesia has become an important case in this debate. The country has substantial storage potential and a strategic interest in developing decarbonization pathways for energy-intensive sectors, while also seeking to maintain industrial competitiveness and align its climate agenda with broader sustainable development objectives (Hidayat et al., 2025). Presidential Regulation No. 14 of 2024 has provided an important umbrella framework for CCS activities, especially by clarifying the possibility of storage development and cross-border arrangements. Yet, the existence of an umbrella regulation does not, in itself, mean that implementation is institutionally ready. The practical readiness of CCS depends on whether capture, transport, storage, environmental approval, shipping, investment governance, and long-term stewardship can be governed coherently across the Indonesian legal system.

This question is especially important when CCS is viewed through an Environmental, Social, and Governance (ESG) lens. In ESG terms, the relevance of CCS cannot be reduced to emission reduction alone (Haryani & Anjani, 2023). The environmental pillar requires credible Monitoring, Reporting, and Verification (MRV), robust safeguards against leakage, and clarity on permanence (Keating et al., 2017). The social pillar requires consultation, risk communication, community protection, and accessible grievance mechanisms. The governance pillar requires institutional clarity, accountability, licensing predictability, and credible rules on liability and post-closure responsibility (Costa et al., 2021; Setiawan & Cuppen, 2013; Swennenhuis et al., 2024). A country may, therefore, have technical storage potential but still face low ESG readiness if governance arrangements are still fragmented.

The Indonesian debate has so far focused strongly on storage potential, oil and gas applications, and the strategic opportunities created by new regulation. This literature is valuable, but it leaves a more specific policy gap: whether Indonesia's current regulatory architecture is aligned, coordinated, and operational to support industrial CCS as an ESG-relevant infrastructure strategy.

This article addresses the aforementioned gap by examining readiness at the level of policy design, regulation, licensing, safeguards, and institutional coordination. The central argument is that Indonesia has moved from policy signaling to an initial legal foundation, but readiness remains partial because implementation still relies on multiple sectoral regimes with different mandates, procedures, and accountability logics.

For terminological consistency, this article uses CCS as the main term throughout the analysis. References to CCUS are retained only when they appear in official Indonesian regulatory language or in the wording of a cited source. This choice is deliberate. The main focus of the article is long-term storage governance and its implications for ESG implementation, rather than the full range of carbon utilization pathways. By using CCS consistently, the article avoids conceptual slippage between storage-focused regulation and broader decarbonization narratives.

The contribution of this article is threefold. *First,* it links CCS, ESG, and policy readiness within a single analytical lens for Indonesia. *Second,* it translates the broad notion of policy and regulatory readiness into operational indicators that can be applied systematically. *Third,* it shows that the key readiness problem in Indonesia is not the complete absence of law, but the mismatch between an emerging umbrella framework and the sectoral rules that still govern licensing, environmental approval, transport, monitoring, and long-term accountability (Ikeda & Tsuji, 2017). This approach makes it possible to move beyond descriptive regulatory mapping toward a more policy-relevant assessment of implementation risk.

THEORETICAL FRAMEWORK

CCS, ESG, and Policy Readiness

The literature on CCS governance shows that deployment succeeds when legal systems do more than authorize projects in principle. They must also define rights and obligations across the project life cycle, specify how environmental and safety risks will be managed, and allocate responsibility over long time horizons (Frattini et al., 2024; Romasheva & Ilinova, 2019; Aslam, 2024). In practice, readiness is a multidimensional condition, which includes whether policy objectives are aligned, regulatory requirements are clear, institutions can coordinate, and the licensing pathway is coherent to make implementation predictable for both regulators and project developers.

This article treats policy and regulatory readiness as the extent to which a jurisdiction can govern industrial CCS in a way that is legally coherent, administratively workable, environmentally credible, and socially accountable. This definition is important because a purely descriptive inventory of laws cannot answer the more critical question of whether the regulatory architecture is capable of supporting real projects. In a fragmented setting, multiple rules may exist while responsibility remains blurred at the interfaces between sectors.

An ESG perspective sharpens this point. If CCS is promoted as part of a sustainable industrial transition, policy readiness must be assessed against the practical requirements of each ESG pillar. Environmental integrity

depends on MRV, storage stewardship, and enforceable standards for permanence. Social legitimacy depends on meaningful consultation, public communication, health and safety protections, and grievance pathways. Governance credibility depends on clear mandates, transparent decision-making, stable liability allocation, and regulatory consistency across agencies. In other words, CCS readiness is also ESG readiness when the technology is positioned as part of sustainable finance, industrial transition, or responsible infrastructure development (Costa et al., 2021).

Indicators of Industrial CCS Readiness

To operationalize the assessment of industrial CCS readiness, this study uses eight indicators. Policy alignment examines whether CCS is linked coherently to industrial decarbonization, climate commitments, and sustainable development policy. Regulatory clarity assesses whether the main obligations, approvals, and responsibilities are defined in a sufficiently explicit manner. Institutional coordination looks at whether lead and supporting roles are clearly arranged across ministries and agencies. Licensing integration considers whether the sequence of permits and approvals is understandable and manageable. Environmental integrity evaluates whether MRV, site stewardship, and environmental safeguards are credible. Social safeguards assess consultation, benefit-risk communication, and community protection. Governance accountability examines long-term liability, transparency, and responsibility. MRV readiness evaluates the strength of monitoring and reporting architecture across the project life cycle.

Table 1. Operational indicators for assessing industrial CCS readiness

Indicator	Question	Main ESG Relevance
Policy alignment	Is CCS clearly linked to decarbonization and industrial policy?	Improves strategic consistency and reduces policy uncertainty
Regulatory clarity	Are duties, approvals, and responsibilities explicitly defined?	Supports compliance and accountability
Institutional coordination	Are lead and supporting agencies clearly arranged?	Strengthens governance credibility
Licensing integration	Is the permit sequence transparent and manageable?	Reduces transaction costs and delay risk
Environmental integrity	Are MRV, permanence, and stewardship safeguards credible?	Supports the environmental pillar
Social safeguards	Are consultation, risk communication, and grievance channels provided?	Supports legitimacy and the social pillar
Governance accountability	Is long-term responsibility clearly allocated?	Determines who bears risk over time
MRV readiness	Can monitoring and reporting function across the full project life cycle?	Links performance to disclosure and assurance

These indicators are used qualitatively rather than numerically. The aim of the indicators is not to construct a rigid index, but to provide a transparent basis for determining whether Indonesia's readiness is adequate, partial, or absent in each dimension. This approach allows the analysis to identify where legal provisions exist but remain incomplete, where mandates overlap, and where ESG implications arise, even when the underlying issue appears at first glance to be merely regulatory or administrative. This distinction

is important in the Indonesian context, where implementation challenges are concentrated at institutional boundaries rather than in a single missing law.

METHODOLOGY

This study uses a qualitative, document-based policy and regulatory analysis. The unit of analysis is the governance architecture shaping industrial CCS in Indonesia, rather than an individual project. A qualitative design is appropriate because the research is related to analyzing legal coherence, institutional mandates, permitting arrangements, and ESG-related governance expectations that cannot be understood through technical or financial metrics alone. The analysis is descriptive-analytical as it describes the relevant policy and legal architecture while also evaluating whether that architecture is operationally ready to support industrial CCS.

The evidence base consists primarily of secondary materials. These include binding legal instruments, implementing regulations, official government publications, policy statements, comparative reports on CCS governance, and peer-reviewed academic literature on CCS, infrastructure governance, and ESG. Documents were selected using four criteria: direct relevance to industrial CCS or ESG governance; legal or policy authority; continuing applicability; and usefulness for tracing how responsibilities are distributed across capture, transport, storage, monitoring, licensing, and long-term stewardship. This selection logic was designed to avoid treating all documentary sources as equally probative and to keep the analysis focused on operational governance questions.

Analytically, the study combines comparative legal reading with thematic coding. Each source was read against the eight readiness indicators introduced above. The coding was guided by three practical questions: what is regulated; which institution is responsible; and what implementation issues remain unresolved at the interface with another part of the governance system. The results were then interpreted qualitatively as indicating adequate readiness, partial readiness, or absent readiness. This method enables the researchers to distinguish industrial CCS readiness as mere legal presence or genuine implementation preparedness.

Limited stakeholder consultations with government and policy stakeholders working on industry, environment, energy, and climate governance were used only for contextual validation of the regulatory reading. These consultations were non-attributable and were not treated as stand-alone primary interview data. Their role was to check whether the document-based interpretation reasonably reflected implementation realities, particularly with respect to sequencing, coordination difficulties, and areas of uncertainty. Validation was therefore pursued through triangulation across legal texts, policy documents, academic literature, and contextual stakeholder inputs.

The study has two main limitations. *First,* it does not attempt to provide a project-level technical or economic assessment. *Second,* because the analysis focuses on governance readiness, it cannot resolve all engineering questions relevant to storage performance or commercial viability. Even so, this scope is appropriate for the article's objective: to evaluate whether Indonesia's current policy and regulatory architecture is sufficiently ready to support industrial CCS as an ESG-relevant infrastructure strategy.

FINDINGS

The analysis shows that Indonesia's readiness for industrial CCS is best understood as partial rather than absent. The country now has an important umbrella basis for CCS through Presidential Regulation No. 14 of 2024, and this matters because it signals that CCS is no longer treated as a purely speculative policy option. At the same time,

implementation authority remains distributed across older sectoral regimes. As a result, Indonesia has moved beyond policy signaling but has not yet reached a fully integrated governance model. The practical consequence is that most readiness gaps emerge not from a total lack of rules, but from the interfaces between legal instruments, institutions, and approval processes.

A central finding is that the legal architecture remains segmented across the CCS value chain. Subsurface issues and storage development are strongly connected to the oil and gas regime; environmental approval is governed through the environmental protection framework; business licensing is linked to the OSS risk-based architecture; maritime movement and port handling of carbon are tied to shipping law; and cross-border elements implicate international agreement procedures. This segmentation is understandable because CCS cuts across several administrative domains. However, it also means that no single institutional pathway yet governs industrial CCS from capture to post-closure stewardship. This is the most prominent problem concerning Indonesia's readiness.

Table 2. Regulatory mapping, readiness gaps, and ESG implications across the CCS value chain

Stage	Main instruments	Key institutions	Readiness gap	ESG implication
Capture and conditioning	Industrial rules, environmental approval, OSS licensing	Industry authority, KLHK, licensing authority	Cross-sector sequencing is not yet fully integrated	Environmental claims may outpace governance clarity
Domestic transport	Technical transport and infrastructure rules	Energy and technical regulators	Responsibility shifts across stages remain complex	Governance risk may arise from fragmented authority
Maritime transport and terminals	Shipping and port regulations plus sector permits	Transport and port authorities	No single CCS-specific pathway covers all interfaces	Safety and community communication may be uneven
Injection and storage	Presidential Regulation No. 14 of 2024 and subsurface sector rules	ESDM and technical authorities	Long-term liability and post-closure rules remain incomplete	Governance credibility and investor confidence are affected
MRV and long-term stewardship	Environmental monitoring and technical oversight rules	KLHK, technical regulators, and operators	Lifecycle MRV integration is still partial	Environmental integrity and ESG disclosure remain incomplete

The fragmentation becomes most visible at transition points in the value chain. A capture facility may satisfy industrial and environmental requirements, yet uncertainty can arise when the project moves into transport regulation, offshore or interregional shipment, or injection and long-term storage responsibilities. Similarly, an umbrella regulation may recognize storage development in principle, while implementation still depends on environmental approval, business licensing, transport permissions, and technical standards issued under separate legal regimes. In governance terms, this creates a coordination burden for project developers and regulators without a formally defined mechanism for resolving overlap quickly and consistently.

This condition weakens policy alignment. CCS is increasingly discussed as part of climate and industrial transition policy, but the policy signal has not yet been translated into a fully articulated cross-sector application pathway. As a result, industrial actors may understand the strategic direction of policy but still face uncertainty over which regulatory sequence applies to specific project configurations. Thus, policy readiness is stronger at the level of ambition than at the level of implementation. This gap matters because industrial investment decisions depend less on rhetorical support and more on whether regulatory obligations can be predicted in a legally defensible way.

Regulatory clarity is also partial. Presidential Regulation No. 14 of 2024 improves the legal basis for CCS and helps reduce earlier uncertainty over whether storage activities can be recognized within Indonesian policy. However, clarity remains incomplete with respect to long-term liability, monitoring duration, post-closure stewardship, and the allocation of responsibility between operators and the state. These issues are vital because, in the context of CCS governance, they determine who bears risk after injection, what financial safeguards are required, and how environmental credibility is maintained over time (Aslam, 2024; Romasheva & Ilinova, 2019). Without further specification, the system is still vulnerable to governance ambiguity.

Institutional coordination is one of the clearest readiness bottlenecks. The sectoral distribution of authority means that energy, environment, industry, licensing, transport, and potentially sustainable-finance authorities all have a stake in CCS implementation. Yet the current arrangement still depends heavily on ad hoc coordination rather than a formally defined inter-ministerial governance mechanism. This creates at least three risks. *First,* different agencies may interpret project boundaries and approval requirements differently. *Second,* project developers may face duplication in documentation and review. *Third,* regulators may lack a shared framework for linking technical compliance to ESG-relevant outcomes, such as community safeguards, monitoring transparency, and long-term accountability.

Licensing integration remains similarly incomplete. Indonesia has had an important risk-based business licensing framework, but CCS is unusual because it spans industrial operations, subsurface governance, transport infrastructure, environmental approval, and potentially maritime or cross-border movement. In that setting, a generic licensing architecture is not enough (Setiawan et al., 2025). It needs a clear pathway showing lead agencies, review sequences, documentary requirements, and decision points from capture through storage. In the absence of such integration, the burden of navigating the system shifts to project proponents, increasing transaction costs and implementation risks even where formal legal authority exists.

The ESG implications of these findings are direct. For the environmental pillar, an incomplete MRV architecture and unclear post-injection stewardship can weaken confidence that stored carbon will be monitored credibly and that environmental risks will remain controllable over time. For the social pillar, fragmented permitting and weakly articulated consultation expectations can lead to limited communication with affected communities, unclear grievance channels, and lower public trust. For the governance pillar, ambiguity over long-term liability and overlapping authority can undermine accountability, reduce bankability, and weaken the credibility of CCS as a sustainable transition instrument. The central point is that regulatory incompleteness is also an ESG problem, not merely a legal one.

These gaps affect stakeholder groups differently. Industrial actors face uncertainty over project sequencing, compliance costs, and future liability exposure. Investors face policy and governance risks because unclear responsibility and incomplete safeguards

reduce the predictability needed for long-lived infrastructure. Communities face the risk of insufficient consultation, limited transparency regarding storage risks, and unclear channels for recourse. Regulators face the burden of coordinating across fragmented mandates without always having explicit procedural tools to do so. This distribution of risk helps explain why readiness must be evaluated beyond a descriptive inventory of laws. What matters is how governance gaps translate into practical consequences for implementation.

The above findings indicate that Indonesia's readiness profile is mixed. Policy alignment is emerging but not yet fully institutionalized. Regulatory clarity has improved through recent reforms but remains incomplete on long-term issues. Institutional coordination and licensing integration remain the weakest dimensions. Environmental integrity, social safeguards, and governance accountability are partially supported but not yet embedded in a unified CCS implementation pathway. MRV readiness is recognized as necessary, yet it requires more explicit operationalization across the project life cycle. The overall conclusion of the findings section is therefore clear: Indonesia has an initial legal foundation for industrial CCS, but it does not yet have a fully operational governance system for ESG-aligned deployment.

A useful way to interpret this result is to distinguish between formal readiness and operational readiness. Indonesia is moving toward formal readiness because key legal recognition now exists and CCS is no longer outside the policy conversation. Operational readiness, however, remains weaker because the chain of approvals, obligations, and accountabilities has not yet been translated into a single implementation logic that can be applied consistently across project types. This distinction helps explain why the current framework may appear more advanced when examined from the perspective of policy announcement than when examined from the perspective of project execution.

The same distinction is relevant to regulators. Where legal recognition arrives before procedural integration, regulators may have authority in principle but lack a shared operating protocol for complex cases that span multiple agencies. This can generate conservative decision-making, repeated requests for clarification, and uneven interpretation across sectors or project stages. For industrial actors, these governance frictions are not minor procedural issues; they directly affect project timing, costs, and perceived risks. For this reason, the maturity of Indonesia's CCS framework should be judged not only by the presence of legal instruments, but also by the degree to which institutions can apply them in a coordinated, transparent, and predictable way.

DISCUSSION

The Indonesian case shows why readiness cannot be inferred from the existence of a new regulation alone. Presidential Regulation No. 14 of 2024 is significant because it establishes legal recognition and policy direction, but the more difficult governance work lies in aligning sectoral regimes that were not originally designed around the full CCS life cycle. This is why the principal challenge is structural rather than technical. Indonesia's regulatory arrangement currently combines an umbrella policy logic with sector-specific implementation rules. Unless these layers are connected more explicitly, CCS will continue to face uncertainty at the precise points where projects must move from policy aspiration to legal execution.

This finding also helps explain why the article moves beyond description. A descriptive reading might conclude that Indonesia already possesses enough legal instruments to begin implementation. An analytical reading, however, leads to a more qualified conclusion: the system is ready in principle, but only partially ready in operation. The difference matters because ESG-oriented infrastructure requires a governance architecture capable of delivering

accountability, not merely authorization. Incomplete coordination can become a governance risk. Incomplete MRV can become an environmental integrity risk. Incomplete consultation can become a social legitimacy risk. Readiness gaps therefore cut across all three ESG pillars.

The analytical value of this approach lies in making regulatory sequencing visible as an ESG issue. In many infrastructure debates, ESG is discussed after legal design has already been settled, as if it were a separate layer of reporting or investor communication. The Indonesian CCS case suggests the opposite. If the legal sequence itself is fragmented, ESG performance will also be fragmented as environmental monitoring, social safeguards, and governance accountability are embedded in different agencies and procedures. A readiness analysis therefore provides a bridge between regulatory design and ESG performance rather than treating them as separate fields.

This point is particularly relevant for industrial transition policy. Industries considering CCS need evidence that climate alignment, regulatory compliance, and ESG expectations can be met through one coherent governance pathway. If each pillar is handled separately—environment in one process, licensing in another, consultation in another, and long-term liability in yet another—the result is not only administrative inefficiency but also a weaker transition narrative. Integrated readiness matters because it helps transform CCS from a narrowly technical compliance option into a credible component of responsible industrial strategy.

The implications for industrial actors and investors are especially important. CCS projects are long-lived and capital-intensive. They require confidence not only in technical feasibility, but also in future responsibility, compliance burdens, regulatory sequencing, and disclosure expectations (Pasha et al., 2025). Where long-term liability remains insufficiently specified, capital providers may price additional governance risk into projects or delay participation altogether. Where licensing remains fragmented, developers may face sequencing delays and higher transaction costs. This means that regulatory quality is part of project bankability, not a separate administrative concern (Osazuwa-Peters & Hurlbert, 2020; Costa et al., 2021).

The social dimension is equally significant. CCS often encounters public concern not because communities reject decarbonization as such, but because long-term storage, local safety, transparency, and accountability are difficult to understand and assess from outside expert communities. Thus, Indonesian policy needs to treat consultation as more than a procedural formality. Effective social safeguards require timely disclosure, understandable risk communication, and pathways for affected stakeholders to raise concerns before, during, and after project approval. Without these safeguards, CCS may be perceived as a technocratic project that serves industrial and policy interests while externalizing uncertainty to communities (Setiawan & Cuppen, 2013; Abdullah et al., 2021).

Several actionable implications follow from this analysis. *First,* Indonesia should establish an inter-ministerial CCS coordination body with a clear legal basis involving ESDM, KLHK, the Ministry of Industry, the Ministry of Finance, OJK, and the relevant licensing or investment authority. The purpose of such a body would not be to replace sectoral mandates, but to coordinate sequencing, resolve overlap, align MRV and ESG expectations, and provide a focal point for implementation decisions that cross ministerial boundaries. This measure directly addresses the current coordination gap that makes fragmented authority difficult to manage in practice.

Second, the government should develop a cross-ministerial CCS-ESG roadmap. Such a roadmap should explain when and under what conditions industrial CCS can be

recognized as an ESG-supporting activity, what constitutes acceptable environmental integrity, what social safeguards are required, and how governance accountability should be demonstrated. A shared roadmap would provide a common policy signal for project developers, regulators, financiers, and affected stakeholders. It would also reduce the current disconnect between climate policy ambition, industrial policy, and the governance expectations associated with sustainable finance and ESG-oriented investment.

Third, Indonesia should issue more detailed implementing rules on long-term liability, monitoring duration, post-closure transfer of responsibility, and financial security mechanisms for storage sites. These issues are central to governance credibility because they determine how risk is allocated over time and whether operators can demonstrate that they are not shifting unresolved stewardship burdens to the public. Clearer rules on closure plans, guarantee instruments, and monitoring obligations would improve both regulatory predictability and ESG credibility. They would also help define what constitutes responsible CCS deployment rather than mere legal permissibility.

Fourth, licensing reform should focus on transparency and integration. A practical near-term measure would be a joint guidance document or integrated permitting map that sets out required approvals, lead agencies, review sequences, documentary standards, and decision points for industrial CCS projects. Such a tool would not eliminate sectoral regulation, but it would reduce uncertainty for both developers and regulators by making the process visible and manageable. This is especially important in a risk-based licensing environment, where clarity of pathway is often as important as the formal existence of authority.

Finally, social safeguards should be treated as part of readiness rather than as a late-stage add-on. Consultation requirements, public information standards, and grievance mechanisms should be articulated more clearly in the governance framework for CCS projects. Doing so would strengthen the social pillar of ESG while also improving governance credibility. For Indonesia, this is not only a matter of public acceptance. It is also a matter of whether industrial CCS can be presented credibly as part of a just and accountable decarbonization strategy.

CONCLUSION

This article argues that Indonesia's policy and regulatory readiness for industrial CCS is partial: stronger than before, but not yet fully operational. The country has an important umbrella basis for CCS, yet implementation still depends on multiple sectoral regimes governing subsurface activity, environmental approval, licensing, transport, and long-term stewardship. The readiness challenge lies in fragmentation at the interfaces between these regimes, not in the total absence of law.

Viewed through an ESG lens, these readiness gaps matter because they affect all three pillars simultaneously. Incomplete MRV and stewardship rules weaken environmental integrity. Weakly articulated consultation and grievance pathways reduce social legitimacy. Unclear liability and overlapping authority undermine governance credibility. Industrial CCS can be a meaningful support instrument for ESG implementation in Indonesia, but only if the country moves from basic legal recognition toward a more coordinated and accountable governance architecture.

The practical priorities are clear: establish an inter-ministerial coordination mechanism, adopt a cross-ministerial CCS-ESG roadmap, clarify long-term liability and post-closure responsibility, integrate licensing pathways transparently, and strengthen consultation and safeguard requirements. If these steps are taken, Indonesia will be better positioned to convert its emerging CCS framework into a credible system for ESG-aligned industrial transition. Othewise, CCS may be strategically attractive but operationally underprepared.

ABOUT THE AUTHORS

Lenny Hidayat is the Founder of Greenwise Consulting and has over 20 years of experience in public policy, organizational development, ESG, sustainability, and climate finance. She can be reached at lennyhidayat@greenwise.co.id.

M. Ilham Ramadhan is an Associate at Greenwise Consulting with over 5 years of experience in construction management, infrastructure development, PPPs, and sustainability initiatives. He can be reached at ilham@greenwise.co.id.

Cholisa Amalia is a Junior Associate at Greenwise Consulting with over 3 years of experience in GHG accounting, ESG, and sustainability initiatives. She can be reached at cholisa@greenwise.co.id

Michael Timothy Tasliman is an independent Researcher. His interests include turning market insights into strategic growth opportunities. He can be reached at michaeltasliman@gmail.com

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Indonesian Government's Policy in Managing Chinese Foreign Direct Investment for Sustainable Transport Development

Haniyah Nurafifah[1], Virtuous Setyaka[1], Diah Anggraini Austin[1]

[1] Universitas Andalas, Padang, Indonesia

Corresponding author:
Haniyah Nurafifah | Haniyahafifffah@gmail.com

ABSTRACT

Foreign Direct Investment (FDI) is one of the funding sources, alongside the State Budget (APBN), that can be used to support national development. This study aims to analyze the policies implemented by the Indonesian government to achieve adequate infrastructure development in accordance with the SDGs agenda, particularly transportation infrastructure that supports global sustainability by utilizing Chinese FDI as one of its funding sources. This study employs a qualitative approach with a descriptive research design. Primary data were obtained through interviews with the Ministry of Investment and Downstream Industry, while secondary data were collected from reports, journals, articles, and relevant websites. Using Theodore H. Moran's concept of FDI and Development, this study analyzes how Indonesian government policies seek to achieve structural benefits in managing Chinese FDI in the transportation sector to support sustainable development. The findings show that the four main indicators of FDI and Development—transparency of payments, improvement of economic patterns, enhancement of the local business climate, and promotion of investment—have been implemented fairly well. Chinese FDI has contributed to technological transfer, skill upgrading, supporting industries, and improved investor confidence in Indonesia's sustainable transportation development.

Keywords: Chinese Investment; FDI; SDGs; Transportation Infrastructure;

ABSTRAK

Foreign Direct Investment (FDI) merupakan salah satu sumber pendanaan, selain Anggaran Pendapatan dan Belanja Negara (APBN), yang dapat dimanfaatkan untuk mendukung pembangunan nasional. Penelitian ini bertujuan untuk menganalisis kebijakan yang diterapkan oleh pemerintah Indonesia dalam mewujudkan pembangunan infrastruktur yang memadai sesuai dengan agenda *Sustainable Development Goals* (SDGs), khususnya infrastruktur transportasi yang mendukung keberlanjutan global dengan memanfaatkan FDI Tiongkok sebagai salah satu sumber pendanaannya. Penelitian ini menggunakan pendekatan kualitatif dengan desain penelitian deskriptif. Data primer diperoleh melalui wawancara dengan Kementerian Investasi dan Hilirisasi, sedangkan data sekunder dikumpulkan dari laporan, jurnal, artikel, dan situs web yang relevan. Dengan menggunakan konsep *FDI and Development* dari Theodore H. Moran, penelitian ini menganalisis bagaimana kebijakan pemerintah Indonesia diarahkan untuk memperoleh manfaat struktural dalam pengelolaan FDI Tiongkok di sektor transportasi guna mendukung pembangunan berkelanjutan. Hasil penelitian menunjukkan bahwa empat indikator utama dalam konsep *FDI and Development*—transparansi pembayaran, perbaikan pola ekonomi, peningkatan iklim bisnis lokal, dan promosi investasi—telah diimplementasikan dengan cukup baik. FDI Tiongkok telah berkontribusi pada transfer teknologi, peningkatan keterampilan, pengembangan industri pendukung, serta peningkatan kepercayaan investor terhadap pembangunan transportasi berkelanjutan di Indonesia.

Kata Kunci: FDI; Infrastruktur Transportasi; Investasi Tiongkok; SDGs.

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INTRODUCTION

To direct and manage the flow of foreign investment into a country effectively, government policy is the most important tool, especially in channeling such capital into specific projects that are consistent with the country's development priorities (Lu & Biglaiser, 2020). In the case of Indonesia, the need for infrastructure is closely aligned with sustainability goals. As the UN Environment Program (UNEP) explains, sustainable infrastructure refers to the planning, construction, and operation of infrastructure systems that improve resource efficiency, use low-carbon technologies, provide social and economic benefits, and support environmental protection (UNEP, 2025).

One of the key features of sustainable infrastructure is its orientation on meeting present needs without compromising the ability of future generations to meet their own. This principle is reflected in Presidential Regulation No. 59 of 2017 concerning the Implementation of Sustainable Development Goals and is further strengthened through the 2020–2024 National Mid-Term Development Plan, which highlights sustainable infrastructure as a pathway to sustainable economic growth.

The *Anggaran Pembiayaan Belanja Negara* (APBN) has limited capacity to finance these ambitious projects on its own without inflows of foreign capital in the form of Foreign Direct Investment (FDI) (Indah & Istifadah, 2020). Broader regulatory and institutional mechanisms have therefore been introduced by the Indonesian government to channel this type of investment more effectively. These include the Online Single Submission (OSS) system for simplifying licensing procedures, sectoral restrictions through the Positive Investment List that prioritizes strategic industries, and fiscal incentives such as tax holidays granted to projects with meaningful sustainability value (Palguna et al., 2024).

The above mechanisms should not simply function as tools to attract investors, but also as instruments to direct investment toward projects aligned with national priorities. With its policy orientation toward welcoming foreign investment, Indonesia has found opportunities to collaborate, particularly with China, through the Belt and Road Initiative. Chinese foreign direct investment (FDI) in Indonesia reached USD 8.22 billion in 2022 across several sectors. The management of FDI inflows is necessary and is carried out by the Ministry of Investment, or *Badan Koordinator Penanaman Modal* (BKPM), in collaboration with the relevant institutions and sectors.

Thus, Indonesia's challenge is not only to attract foreign capital but also to ensure that it is fully aligned with long-term sustainability goals. This issue is also relevant to broader

international debates on FDI governance. Foreign investment in the transport and energy sectors has also been debated in Kenya and Brazil, where media and political dialogue have focused on the tension between economic benefits and environmental and social responsibilities (Fall et al., 2024). Such comparative experiences reinforce the need for comprehensive policy frameworks that leverage FDI for sustainable development rather than undermine it. This places Indonesia's case within a broader global narrative of how developing economies can effectively navigate international capital flows. As a central actor, the Indonesian government needs to ensure that foreign capital is not only managed but also strategically attracted to support long-term sustainability goals and realize the benefits of FDI for infrastructure development.

THEORETICAL FRAMEWORK

Institutional Liberalism

Institutional Liberalism, also known as Neoliberal Institutionalism, is regarded as an updated version of classical liberal theory applied to international politics. Keohane (1989) describes it as an International Relations approach that highlights global institutions as a crucial dimension of cooperation among states, given that international relations are largely anarchic by nature. Like Realists, Institutional Liberals recognize states as the principal unit of analysis, namely sovereign entities pursuing national interests. They similarly acknowledge the absence of a central authority that is willing and able to regulate state behavior, yet they argue that rational states can cooperate around mutual interests.

Realists argue that cooperation is constrained by anarchy, whereas Institutional Liberals argue that cooperation is possible and can endure because of established international institutions and regimes. These institutions provide a structure for interaction, set expectations, reduce unpredictability, and encourage compliance. Institutional Liberalism also posits that shared interests between states can result in win-win scenarios because some goals cannot be achieved unilaterally. Although Institutional Liberals recognize that hegemonic powers help sustain institutions, they also believe that institutions can function even without the direct dominance of hegemons. This perspective emphasizes the increasing interdependence of states in the economic, security, and environmental spheres, which creates opportunities for collective action across borders to address shared problems (Keohane, 1989).

Foreign Direct Investment (FDI)

Inquiries into how host countries manage foreign investors, investment promotion, domestic content requirements, and export performance standards reconstruct the measures set by their competitors (Moran, 1998), which reflects another version of Keohane's ideas. In contrast to Realism, Moran argues that the unit of analysis remains the state, but state behavior is also influenced by interaction with international institutions, an assumption that echoes Institutional Liberalism. He demonstrates the growing importance of FDI in developing and transition economies, where, over the last 15 years or so, there has been a shift from suspicion toward Multi-National Enterprises (MNEs) to a more pragmatic engagement with them in the development process.

FDI is defined as the inflow of foreign direct investment into a host country and is generally considered a long-term investment by multinational firms operating in foreign sectors within the host economy (Moran, 1998). Moran identifies several direct advantages of FDI, including clearer firm policies, secure property rights, reduced

bureaucracy, and the efficient allocation of investment to key economic sectors such as manufacturing and technology (Moran, 1998). Moreover, he stresses that the gains from FDI can be maximized by developing linkages between foreign firms and local industries and labor markets in order to create multiplier effects, such as employment generation, technology transfer, and skills development.

Moran (1998) also argues that directing FDI toward social impact depends on policy, and that managing the risks associated with it is essential to realizing the potential development benefits of FDI. However, Moran (1998) believes that immediate economic gains are not sufficient; structural gains are required for long-term sustainability. He focuses on host-country policies that use FDI as a tool for structural transformation. According to him, the consequences of FDI, both positive and negative, largely depend on the host government's policy framework. These consequences are also reinforced by industrialized countries, multilateral financial institutions, labor organizations, Non-Governmental Organizations (NGOs), civil society, and corporate social responsibility.

Structural Benefits of FDI

In the second generation of research, Moran (1998) further elaborates on four indicators through which FDI can improve sustainable development outcomes.

The *first* is Transparency of Payment, which relates to policies that establish transparent and publicly accessible financial flows from foreign investment while complying with anti-corruption legal regimes, such as the OECD Anti-Bribery Convention and the Extractive Industries Transparency Initiative (EITI).

The *second* is Economic Transformation, which concerns the shift from traditional economic patterns to modern systems driven by technology, global markets, and high-skilled manufacturing. This transformation requires FDI to move toward industries that strengthen export performance and human capital development.

The *third* is Local Business Climate Upgrades, which include regulatory and fiscal reforms that help cultivate domestic enterprises, ensure a level playing field with foreign investors, and promote public-private ventures that increase the competitiveness of local industries.

Lastly, Investment Promotion emphasizes the active role of host countries in promoting themselves to foreign investors as attractive destinations for FDI. The promotion is supported by high-quality infrastructure, investor-friendly licensing, and tax incentives (Moran, 1998).

Application to Indonesia

This framework is highly relevant in the context of Indonesia, where national priorities in FDI management have become an integral part of current development efforts and where the government acts as a planner, regulator, and facilitator of FDI. Given the current global need for sustainable infrastructure, Indonesia needs to ensure that foreign investment, especially investment aligned with strategic partnerships such as China's Belt and Road Initiative, is directed toward projects that fall within the scope of national sustainability priorities (Saraswati, 2020).

Indonesia has the opportunity to reap both the direct and structural benefits of FDI by enacting policies that enhance transparency, modernize the economy, improve the local business climate, and actively promote targeted sectors. In this way, the government

can ensure that foreign capital not only supports short-term growth but is also embedded within long-term sustainable development and economic resilience.

METHODOLOGY

This study uses a qualitative descriptive method to analyze the Indonesian government's policy management of Chinese FDI in the sustainable transportation sector. It is qualitative in nature because it examines complex interactions among institutions, bureaucratic procedures, and policy dynamics, which are more appropriately explored through qualitative rather than quantitative approaches (Abdussamad, 2021).

Research Design

This study employs a case study design with an observational timeframe of 2019–2024, which coincides with the implementation period of some major sustainable transportation projects, including the Jakarta–Bandung High-Speed Railway (KCIC). It integrates document review and semi-structured interviews to represent both policy perspectives and implementation experiences.

The data analysis is descriptive and analytical, drawing on Robert Keohane's Institutional Liberalism, which argues that interstate cooperation is possible through international institutional rules, norms, and supervisory mechanisms. In addition, Moran's framework is used to demonstrate how host countries can utilize the structural advantages of FDI through four main instruments: payment transparency, local economic development, business climate improvement, and investment promotion. Through this approach, the study aims at mapping the process by which Indonesia's domestic policies are integrated with international norms. The integration is a necessary phase to realize transparent, fair, and sustainable investment governance as vital part of a transnational regime (Weltbankgruppe, 2021).

Data and Data Source

The primary data were collected through interviews with officials from the Ministry of Investment/Investment Coordinating Board (BKPM), the principal institution responsible for foreign investment governance. The interviews were conducted online on Friday, 9 May 2025, at 13:30 WIB. The participants consisted of Mr. Jilteng Pamungkas, Senior Investment Governance Officer, Directorate of Infrastructure Planning; Marton AD and Janna P. Angus Jackson, Senior Investment Governance Officers, Directorate of East Asia, South Asia, Middle East, and Africa Promotion, Investment Governance and Policy Section; and Martha, Junior Investment Governance Officer, Investment Governance and Policy Section.

The interviews addressed issues related to transparency in FDI, investment promotion agencies, bureaucratic coordination, and sustainability challenges. The questions were designed to elicit institutional practices and policy rationales directly from officials overseeing Chinese direct investment portfolios.

The secondary data were collected from several sources, including official policy documents and government regulations, annual BKPM investment reports, peer-reviewed academic literature supporting the theoretical framework, OECD and UNCTAD reports, and other credible news media sources. The diversification of these sources aimed at providing a more comprehensive view of policy narratives and external evaluations of the policies.

The collected data were analyzed using the Miles and Huberman (1994) interactive

model, which includes three simultaneous processes. The *first* is data reduction, conducted by sorting interview transcripts and documents into key themes. The *second* is data display, carried out by presenting patterns of policy interaction and outcomes. The *third* is conclusion drawing and verification, conducted by interpreting the findings in relation to Moran's indicators, namely transparency of payment, economic transformation, local business climate improvement, and investment promotion. Information related to these indicators was organized into a coding scheme that integrated interview data and documentary materials. To ensure validity, data triangulation was applied by comparing official reports, interview responses, and secondary analyses.

FINDINGS

The Indonesian Investment Coordinating Board (BKPM) noted that inflows of FDI from China to Indonesia from 2019 to 2023 showed fluctuating patterns. The investments are viewed as a strategic opportunity for the Indonesian government to manage the flow of foreign investment and direct foreign capital toward sustainable infrastructure development. This is consistent with the national development agenda, which seeks to balance economic growth with social and environmental considerations while also advancing technological innovation. The following table presents the realization of Chinese FDI in Indonesia.

Table 1. Chinese FDI Realization in Indonesia

No.	Year	FDI
1	2019	$4.744.508,6
2	2020	$4.842.405,8
3	2021	$3.160.380,1
4	2022	$8.226.035,1
5	2023	$7.438.379,1

The governance framework for managing foreign investment can be illustrated in the following diagram.

Figure 1. Governance framework of FDI in Indonesia

The diagram above depicts the roles of the actors in effectuating FDI in Indonesia. The Ministry of Investment/BKPM is the main regulator in the government side for licensing, policy-making, investment applications, and supervision. Sustainable infrastructure will then be overseen by sectoral ministries, such as the Ministry of Public Works and Housing

(PUPR), the Ministry of Energy and Mineral Resources (ESDM), and the BUMN, which function as sectoral supervisors. The regulatory framework for FDI consists of licensing, incentives, monitoring, and evaluation mechanisms designed to attract both domestic and international investors and to direct capital toward priority sectors. Implementation is typically carried out by state-owned enterprises in partnership with private companies as operators, supported by funding from financial institutions. Civil society organizations and Non-Governmental Organizations (NGOs) also play an important role in monitoring and evaluating the social consequences of FDI-based projects.

In addition to examining how institutions and regulations are designed to govern FDI, it is equally important to explore how these processes affect specific projects. Sustainable transportation is one of the most significant sectors in which Chinese investors have made direct investments.

Table 2. List of sustainable transportation infrastructure projects with Chinese FDI

Types of Transportation Infrastructure	FDI
Kuala Tanjung Harbor	JV Pelindo I and Zhejiang Seaport Group (China)
Jakarta–Bandung High-Speed Railway	Joint Venture (PT KCIC) + FDI
Development of the Electric Vehicle (EV) Ecosystem	FDI, technology transfer, R&D facilities, and job opportunities

Chinese FDI in Indonesia's transportation sector has been manifested in various strategic projects that promote sustainability. The flagship project is the Jakarta–Bandung High-Speed Railway, which was developed under a 60:40 joint venture agreement between Indonesian state-owned enterprises and China Railway International. The Jakarta–Bandung High-Speed Railway project represents China's model of development cooperation. It combines the showcasing of China's economic and technological capacity with Indonesia's "New Developmentalism" under the Jokowi administration (Prasetyo, 2024).

In addition to providing new infrastructure, the project also facilitates technology transfer and workforce training. Chinese investment in Indonesia's transportation sector has therefore contributed not only to infrastructure development but also to the transfer of technology and the training of local workers (Quer et al., 2019).

Similarly, Chinese firms, international partners, and local contractors have been involved in construction projects under the Belt and Road Initiative framework, thereby increasing regional economic involvement in developments such as Kuala Tanjung Port in North Sumatra (Biro Komunikasi dan Informasi Publik, 2024). Progress has also been made in the development of an electric vehicle ecosystem, including the establishment of common industrial standards through partnerships with major Chinese companies such as BYD, CNGR, and CATL. This reflects the government's intention to accelerate the growth of sustainable investment.

This research also conducted direct interviews with BKPM officials to further understand FDI governance, particularly the role of the Ministry of Investment/BKPM as the lead institution. The interviews with FDI experts were conducted to obtain practical insights into policy mechanisms, regulatory challenges, and approaches to managing foreign investment, particularly from China. The key findings from these interviews are presented in the next part of this article.

The interview focuses on Chinese FDI in Indonesia in relation to the Belt and Road Initiative (BRI), and more specifically on the Jakarta–Bandung High-Speed Railway project. The respondents emphasized that the selection of the sustainable transportation sector is situated within Indonesia's national development agenda, in which Chinese FDI serves as a strategic instrument to support long-term economic growth, ecological sustainability, and technology transfer.

Bilateral relations between Indonesia and China have become crucial determinants of investment flows. Economic cooperation has deepened since the administration of Susilo Bambang Yudhoyono and continued into the presidency of Joko Widodo. During this period, Indonesia introduced a moratorium on nickel exports, which was clearly aimed at attracting Chinese investment to develop local downstream industries. The broader China–Indonesia Comprehensive Strategic Partnership (CSP), including the Investment Guarantee framework, reflects China's view of Indonesia as important not only in the regional context but also in the global supply chain (Siwi, 2013).

In terms of transparency, the government has regulated and limited the use of profit repatriation by requiring foreign exchange realized from exports to be placed with Bank Indonesia for a certain period. These measures are intended to enhance financial market stability, accountability, and investor protection.

In terms of investment promotion, the Indonesian Investment Coordinating Board (BKPM) serves as the main facilitator across sectors by following up on investor engagement from the planning stage through to realization. However, the findings also indicate that Chinese investors frequently approach Indonesia independently and do not necessarily require extensive promotion, which suggests a high level of interest in the domestic market. Thus, the government's main role is to facilitate investment and establish sufficient institutional arrangements to ensure that projects can be implemented smoothly.

The Online Single Submission (OSS) system, which involves several ministries, has also contributed to improvements in the local business climate. In the Indonesian context, the simplification and streamlining of procedures have led to more efficient government processes, lower transaction costs, and greater investor confidence in the business environment.

In addition, the socio-economic influence of Chinese FDI has been reflected in localized multiplier effects. Respondents noted important changes in communities around the investment locations, including job creation, increased local economic activity, and access to technology transfer. Tax holidays and restrictions related to cooperation with domestic companies are also policy measures used to maintain sustained investment.

The respondents also pointed out that the regulatory framework is well aligned with key sustainable development objectives. Spencer (2019) stated that the Investment Law, the Job Creation Law, and Government Regulation No. 5/2021 on risk-based licensing are key instruments that integrate SDG principles with ease of doing business, environmental protection, and legal certainty.

The KCIC project is seen as an example of sustainable transportation infrastructure in practice. In addition to reducing carbon emissions, the high-speed railway also improves interregional land transportation efficiency and mobility, as the travel time between Jakarta and Bandung has been

reduced to approximately 45 minutes. In relation to the SDGs, KCIC directly supports Goal 9 on Industry, Innovation, and Infrastructure by strengthening regional connectivity within the framework of green mobility (Rohim, 2024).

Overall, the interviews highlight that Chinese FDI plays an important role in Indonesia's economic transition by providing strategic direction for infrastructure development, improving the investment climate, and supporting the integration of Chinese FDI into Indonesia's sustainable development agenda.

DISCUSSION

Sustainable transport infrastructure has become a strategic priority in global development (Nasruddin et al., 2024). UNEP defines sustainable infrastructure as resource-efficient infrastructure with low carbon output that maximizes economic, social, and environmental benefits, resting on economic, social, and environmental pillars. This trajectory was further consolidated by the transition from the Millennium Development Goals (2000–2015) to the Sustainable Development Goals (2015–2030), which broadened the focus from social issues to a universal agenda consisting of 17 goals and 169 targets, with an emphasis on multi-stakeholder collaboration (Woodbridge, 2015). In the transportation sector, sustainability is not limited to public service provision but is also discussed in the context of Life Cycle Sustainability Assessment (LCSA), as reflected in the UN's Mobilizing Sustainable Transport for Development (2016) (Onat et al., 2017).

Indonesia aligns itself with this agenda through several legal and policy instruments, including Environmental Law No. 32/2009 (Undang-Undang Republik Indonesia Nomor 32 Tahun 2009, 2009), Presidential Regulation No. 59/2017 concerning SDGs implementation, and the 2020–2024 National Mid-Term Development Plan (*Rencanan Pembangunan Jangka Menengah Nasional,* or RPJMN), which focuses on building inclusive, energy-efficient, and low-emission infrastructure. This policy direction is further reflected in the Strategic National Projects (*Proyek Strategis Nasional,* or PSN), coordinated under KPPIP and the Coordinating Ministry for Economic Affairs. These projects include airports, ports, and railways, including flagship transportation projects such as the Jakarta–Bandung High-Speed Railway, which showcases sustainable transportation through energy efficiency, low emissions, and Transit-Oriented Development (TOD) (Peraturan Menteri Koordinator Bidang Perekonomian Nomor 4 Tahun 2024, 2024). Although challenges persist, such as the continued reliance on coal in the Kalimantan Green Industrial Zone, these projects indicate a gradual shift toward greener infrastructure.

Implementation depends on a network of state actors. Construction falls under the authority of the Ministry of Public Works and Housing (PUPR), planning is managed by Bappenas, fiscal support is provided by the Ministry of Finance, investment governance is handled by BKPM, and oversight is carried out by institutions such as BPK and KPK.

The global expansion of China began with the reforms of 1978, followed by the 1992 Going Global policy and the Belt and Road Initiative in 2013. This expansion has been supported by industrial overcapacity, rising production costs, stricter environmental regulations, and abundant foreign reserves, which reached USD 4 trillion at their peak in 2014 and stabilized at USD 3.2 trillion by 2024 (Gallagher & Qi, 2021). Beijing uses its seven sovereign funds, including the China Investment Corporation, and its State-Owned Enterprises (SOEs) to direct FDI into

strategic sectors. In Indonesia, this ambition is reflected in projects such as Kuala Tanjung Port, the Jakarta–Bandung High-Speed Railwas, its planned extension to East Java, and industrial parks, e.g., IMIP in Sulawesi and IWIP in North Maluku (Sarmiento, 2023).

Chinese investment has been supported primarily by FDI in the transportation sector, arranged through Public-Private Partnerships (PPPs) and loans from Chinese financial institutions, including the China Development Bank. The KCIC project illustrates this model, as it is 60% owned by Indonesian SOEs and 40% by China Railway International, with 75% of its financing, amounting to USD 4.1 billion, provided by the China Development Bank. Beyond financing, these ventures facilitate technology transfer and management expertise while helping China integrate more deeply into global supply chains. Indonesia continues to offer other infrastructure projects, including toll roads, ports, airports, and renewable energy projects, which remain open to Chinese engagement (Assagaf et al., 2023).

During the period 2013–2024, Chinese FDI in Indonesia increased significantly. In 2013, China ranked only ninth among foreign investors, with a comparatively low inflow of USD 0.3 billion. This figure rose to USD 0.8 billion in 2014 and reached USD 31.8 billion cumulatively between 2020 and 2024. In 2020, China became Indonesia's second-largest investor, with USD 4.8 billion, before declining to USD 3.2 billion in 2021. It then increased again to USD 8.2 billion in 2022, USD 7.4 billion in 2023, and USD 8.1 billion in 2024, behind only Singapore and Hong Kong. These investments are concentrated in several major sectors, particularly metal processing industries (44%), transportation, warehousing, and telecommunications (20%), as well as manufacturing and mining. Flagship projects include toll roads, seaports, power plants, and the expansion of basic metal and chemical industries (Investasi, 2025).

The Bilateral Investment Treaty (BIT) between Indonesia and China was not renewed after its expiration in 2014. However, investment protection continues under the ASEAN–China Investment Agreement (ACIA), which entered into force in 2009 (Xiao, 2010). This agreement provides non-discrimination, investment protection, transfer of funds, investment promotion, and investor–state dispute settlement mechanisms. The guarantees provided by PT Penjaminan Infrastruktur Indonesia (PII) for the Jakarta–Bandung High-Speed Railway project, the fiscal and non-fiscal incentives offered at the Batang Integrated Industrial Estate, and the investment insurance provided by the China Export & Credit Insurance Corporation exemplify the practical implementation of these protections.

Stronger diplomatic relations have also become a foundation for the growing inflow of Chinese FDI. China has been Indonesia's main trading partner since 2013. In 2023, total trade between the two countries reached USD 127 billion (Kementerian Keuangan Republik Indonesia [Kemenkeu], 2025). The figure was supported by high-level visits and exchanges between the two governments. This finding is supported by previous research showing that China's outward FDI to Indonesia has become more decentralized over time. The geographical concentration index declined from 54.79 in 2006 to 48.70 in 2016, which indicates lower geographical concentration and wider investment dispersion across more provinces (Fu et al., 2018).

Domestically, Indonesia remains attractive because of its large population, growing middle class, and macroeconomic stability, which align with the competitive pricing and characteristics of Chinese consumer

products. These factors create a mutually reinforcing cycle in which FDI and trade are interconnected through market integration.

Besides, Indonesia has many natural and strategic minerals, which makes its investment in Indonesia even more interesting for China. Some of the projects that will be carried out include the processing of nickel and cobalt by Tsingshan Group to be used as a supporting battery for the Electric Vehicle (EV) sector, alongside clean energy projects such as solar power plants (*Pembangkit Listrik Tenaga Surya,* or PLTS) and geothermal power plants (*Pembanghkit Listrik Tenaga Panas Bumi,* or PLTP) that are consistent with Indonesia's national energy transition agenda (Reuters, 2025). This process is made more robust through domestic regulatory frameworks, i.e., the Omnibus Law on Job Creation (Law No. 11/2020) and BKPM Regulation No. 4/2021, which require technology transfer and partnerships with Small and Medium Enterprises (SMEs) and various capacity-building programs for domestic workers.

Transportation accounts for almost 20% of total Chinese FDI in Indonesia and is one of the key pillars within the broader context of sustainable infrastructure development (UNOPS, 2019). This includes strategic projects such as the development of Kuala Tanjung Port through cooperation with Zhejiang Provincial Seaport Investment Operation Group and the Port of Rotterdam Authority, as well as the establishment of an integrated electric vehicle ecosystem to support the transition toward clean transportation (Rahayu, 2019). Thus, Indonesia is now not only a regional production center but also an important part of China's "Dual Circulation" strategy, which seeks to balance the strengthening of its domestic market with the expansion of its global economic engagement (Dang & Nguyen, 2022).

Although investment sources can be diversified beyond China, Chinese FDI in Indonesia remains significant in strategic sectors. It enables Indonesia to continue utilizing Chinese expertise through strategic investment in transportation, energy, and mineral downstreaming, while allowing stakeholders to secure a greater share of development benefits. Beyond infrastructure expansion, financial transparency is also a key pillar of efficiency in public utility services because it creates space for equity and long-term sustainability (Ofosu & Sarpong, 2022). In this context, the principle of payment transparency in the provision of foreign capital becomes an important instrument for strengthening accountability in the management of external capital flows.

Moran (1998) identifies payment transparency as an important channel through which FDI may provide structural benefits, particularly because it limits opportunities for corruption and increases public access to information on financial flows. This principle is further operationalized through data disclosure, timely report, and anti-corruption measures aligning with global norms. Internationally, the OECD Anti-Bribery Convention serves as a key standard for business ethics (Leipziger, 2016). Although Indonesia has not ratified the convention, its longstanding status as a key OECD partner since 2007 and its decision to begin the full membership process in February 2024 provide strong encouragement for aligning domestic governance with international standards.

At the national level, transparency is structured through the OSS Risk-Based System, initiated by the Ministry of Investment/BKPM. This system consolidates licensing processes, defines business requirements, and enables real-time monitoring. The public can access quarterly and annual investment reports, submit

requests in accordance with the Public Information Disclosure Law, and browse raw datasets and investment data trends through the 'Satu Data BKPM' platform. These instruments provide greater investor security while also enhancing civic oversight.

However, transparency practices are still uneven. Public access to precise financial flows, concession agreements, and environmental impact analyses remains limited. Sources within BKPM indicate that certain portions of the data, particularly those related to Chinese State-Owned Enterprises (SOEs), are legally protected. This limits public scrutiny and increases dependence on government narratives. Compared with international best practices, Indonesia's mechanisms are less participatory than initiatives such as the OECD Anti-Bribery Convention and the Extractive Industries Transparency Initiative (EITI). This aspect is important, and Indonesia need to institutionalize open data standards, strengthen research accessibility, and implement integrated sustainability reporting for each strategic FDI project.

Payment transparency can be observed in large infrastructure projects such as the Jakarta–Bandung High-Speed Railway and in joint ventures between Indonesian companies and China Railway International (Octorifadli et al., 2021). In this project, the financing mechanisms are well documented in relevant reports involving BKPM and state-owned enterprises, while the involvement of PT PII reduces investment risks and strengthens fiscal accountability. The public availability of these reports, together with scrutiny from the Audit Board of Indonesia (BPK) and civil society, demonstrates that transparency instruments do not merely function as formal procedures but also serve as active mechanisms of accountability.

To enhance the opportunities created by Chinese FDI, the Indonesian government has sought to balance foreign investment with pro-local policies aimed at improving the domestic business climate. This supports the second element emphasized by Moran (1998), which argues that international firms should be encouraged to develop local suppliers in host countries. These efforts include equalizing import taxes, improving the quality of domestic production, and encouraging joint ventures.

Various regulatory frameworks support this agenda. Through the Local Content Requirement (*Tingkat Komponen Dalam Negeri,* or TKDN), Government Regulation No. 29/2018 promotes the use of domestically produced goods, while Government Regulation No. 45/2019 and Ministry of Finance Regulation No. 128/2019 offer "super tax deductions" of up to 200–300% for firms conducting vocational training and research and development (Pemerintah RI, 2019). Omnibus Law No. 11/2020 promotes technology transfer and partnerships with Micro, Small, and Medium Enterprises (MSMEs), while Presidential Regulation No. 10/2021 establishes the Positive Investment List. This regulation provides financial incentives such as tax holidays, tax allowances, and accelerated depreciation, as well as non-fiscal facilities such as access to industrial estates through the risk-based OSS system (BKPM, 2021).

This agenda also includes improvements to fiscal facilities for import duty exemptions under Ministry of Finance Regulation No. 188/2022 and BKPM Regulation No. 4/2021 for capital goods, raw materials, and imported technology that cannot be sourced domestically. These initiatives reduce production costs, make national businesses more competitive, and encourage foreign investment in national strategic projects.

The second pillar of this policy is technology transfer. In the development of Kuala Tanjung Port, Zhejiang Seaport Group and the Port of Rotterdam collaborate with smaller local contractors. The collaboration allows them to become part of global supply chains. In the electric vehicle sector, partnerships with CRRC, Hyundai–LG, CATL, and BYD help strengthen Indonesia's EV ecosystem. Local production of electric vehicles, such as the Wuling Air EV and Neta V-II, exceeded 40% domestic content in 2024, with a total of more than 13,000 units, and is expected to reach more than 60% domestic content in 2025 (Alamsyah, 2024).

Chinese FDI played a role in transforming Indonesia's business environment through a combination of pro-local regulations, financial incentives, and technology transfer. This synergy shows that FDI is not only a source of capital but also a driver of competitiveness and sustainable economic growth (Biro Komunikasi dan Informasi Publik, 2024). Chinese FDI has also contributed to Indonesia's structural transformation, particularly through high-impact projects in transportation, commodity logistics, and downstream industries. Technology transfer and industrial upgrading have been promoted through projects such as the Jakarta–Bandung High-Speed Railway (KCIC) and the electric vehicle ecosystem involving companies such as BYD, CATL, and CNGR. These projects create employment opportunities and local supplier networks, thereby supporting Moran's notion of "structural benefits," as also reflected in the interview data.

However, these advantages are concentrated regionally, particularly in Java and Sumatra. This regional limitation results in limited spillover effects in peripheral regions. As seen in Kenya and Brazil, uneven BRI infrastructure investment may reinforce existing industrial centers while leaving other regions behind, particularly in relation to spatial inequality. A similar pattern of uneven benefit and regional disparity is also found in BRI projects in Africa, where projects are geographically concentrated in areas that are already relatively well developed (Caria & Ghinoi, 2025).

Consequently, although economic restructuring is clearly visible, it remains uneven and still partly reliant on foreign expertise and technology. Future policies should therefore require more inclusive regional planning and skill localization programs to sustain these gains. Investment promotion is also a vital dimension of FDI governance in maintaining Indonesia's investment ecosystem. As emphasized by Moran (1998), the Indonesian Investment Coordinating Board (BKPM) serves as the main agency responsible for regulation, licensing, and investor facilitation, including for Chinese investors. Promotion efforts also include encouraging local vendors and domestic suppliers, thereby enabling more active participation from national firms and local communities.

BKPM Regulation No. 4/2021 provides the basis for simplifying risk-based licensing while granting various fiscal and non-fiscal incentives, including tax holidays, investment allowances, super deductions, and exemptions from import duties and value-added tax. These incentives focus on priority sectors such as sustainable transportation, renewable energy, and high-tech manufacturing. They also aim to create linkages with MSMEs, facilitate technology transfer, and support local labor absorption. BKPM accompanies investors from the initial stage through project realization, including by facilitating access to cost-effective land, either free of charge or at reduced cost, in integrated industrial zones.

Cross-ministerial coordination among BKPM, the Ministry of Transportation, and the Ministry of Public Works and Housing is required to strengthen the local business climate through an Integrated Sustainability and Investment Coordination Mechanism. Such coordination is intended to create a business environment that supports both investment incentives and environmental protection. More than simply measuring capital flows, this approach prioritizes the quality of investment over its size.

Cross-ministerial coordination also supports this agenda in several ways. The Ministry of Transportation promotes sustainable mobility through TOD regulations, LRT/MRT development, the EV Roadmap, and green port standards. The Ministry of Public Works and Housing (PUPR) strengthens connectivity through toll roads, bridges, and non-motorized transport facilities. The Ministry of Energy and Mineral Resources (ESDM) shapes renewable energy policy and EV charging networks. The Ministry of Environment and Forestry (KLHK) enforces green infrastructure principles. The Ministry of Industry supports EV and eco-friendly component industries under the Making Indonesia 4.0 agenda. Meanwhile, the Ministry of Finance administers fiscal incentives and PPPs schemes in the transportation sector (Rohim, 2024).

BKPM emphasizes investment quality over quantity by prioritizing projects aligned with sustainability and SDG-related sectors, such as renewable energy, logistics, and green transportation, while supporting investors throughout the project lifecycle. This prioritization reflects a broader challenge that have been faced by Chinese development finance institutions, which continue to struggle with institutional fragmentation and the absence of a clear green strategy (Chiyemura et al., 2023). However, the investment is mostly state-centered, as large Chinese SOEs often operate independently. To meet international standards, BKPM should integrate sustainability indicators, e.g., labor rights, carbon intensity, and community benefits, into its investment promotion and monitoring framework.

Further challenges include reliance on external financing and technology, which may limit policy autonomy, and the concentration of benefits from large infrastructure projects, such as KCIC, in urban and industrial areas. Such a challenge leaves rural regions underserved. At the local level, projects may disrupt traditional livelihoods or trigger social tensions if community and environmental needs are overlooked. This reflects common FDI patterns in which investment tends to favor more developed regions over less developed ones (Fu et al., 2018).

Moreover, previous research highlights that around 40% of BRI-linked projects that are financed by the China Development Bank in Indonesia pose some risks to biodiversity and indigenous communities because the projects implement weak domestic governance and safeguards (Simmons, 2022). Concerns about social and environmental impacts, including risks to biodiversity and indigenous communities, are also a consistent theme in analyses of Chinese projects in various developing countries, as documented in case studies from the energy sector in Africa (Shen, 2020). These findings highlight the importance of more inclusive and careful planning, stronger regulatory oversight, and balanced regional development policies to ensure that Chinese FDI supports not only Indonesia's economic growth but also the citizen's social equity and the environment's long-term sustainability.

More importantly, Indonesia's investment promotion framework, which is based on

open-access laws, investor facilitation, fiscal and non-fiscal incentives, and inter-ministerial cooperation, supports the long-term sustainability of infrastructure and energy development. Several factors strengthen this role, including improvements in the local business environment, stronger competition, and greater opportunities for MSMEs and the national workforce. In this regard, FDI can function as a supporting force for economic transformation and inclusive growth.

Investment promotion is therefore central to Indonesia's FDI governance, with BKPM serving as the main institutional actor in risk-based licensing, fiscal and non-fiscal incentive provision, and investor assistance, particularly for investors from China. Through tax holidays, super tax deductions, and import duty exemption policies under BKPM Regulation No. 4/2021, combined with sectoral priorities in sustainable transportation, renewable energy, and high-tech manufacturing, BKPM seeks to direct foreign capital toward technology transfer, MSME partnerships, and local job creation.

This framework is reinforced by cross-ministerial coordination, including the EV Roadmap and green port policies of the Ministry of Transportation, the connectivity projects of the Ministry of Public Works and Housing, and the Making Indonesia 4.0 agenda of the Ministry of Industry. The involvement of Chinese companies in The Indonesian infrastructure projects shows how investment promotion can produce impacts by improving business climate, expanding local supply chains, and supporting inclusive and sustainable economic transformation.

CONCLUSION

This study presents exploratory descriptive research using qualitative content analysis as its primary methodological approach. It answers the question about 'How has the Indonesian government articulated a policy framework to guide the attraction of Chinese outward FDI for supporting sustainable transportation development?' Based on the four indicators proposed by Moran (1998), i.e., payment transparency, economic transformation, improvement of the local business climate, and investment promotion, Indonesia has achieved partial success, although several governance gaps remain. The OSS system and quarterly investment reports have improved access to investment data, but project-level disclosure remains limited. Continuous reforms are therefore required to strengthen transparency and accountability, particularly in relation to alignment with the principles of the OECD Anti-Bribery Convention.

Chinese FDI in Indonesia has contributed to technology transfer and supported industrial upgrading. When investments are linked to Special Economic Zones, job creation, and workforce training, they generate broader multiplier effects. However, these benefits are largely concentrated in Java, which highlights the need for more balanced regional development. Despite bureaucratic overlaps and competing policies, recent institutional reforms have generally improved the participation of local enterprises, particularly through the 2020 Job Creation Law and the Positive Investment List.

In the area of investment promotion, BKPM has shifted its focus from capital volume to investment quality by emphasizing sustainability and innovation in collaboration with sectoral ministries. Chinese FDI has strengthened Indonesia's development through technology transfer, job creation, and infrastructure expansion. The policy implications of this study include the need for stronger inter-institutional coordination, the inclusion of sustainability assessments in FDI monitoring, greater transparency in Belt and

Road projects, and the integration of local participation through SME partnerships and workforce training.

At the theoretical level, this research connects Institutional Liberalism with development-oriented FDI theory. It emphasizes that effective state capacity and institutional coordination in foreign investment governance are vital preconditions for sustainability. For Indonesia, Chinese FDI is more than a source of infrastructure financing; it also helps reshape the country's economic structure, local business environment, and socio-economic outcomes. By supporting firm-level technology transfer, encouraging the integration of SMEs, and strengthening institutional capacity, Chinese FDI contributes to Indonesia's development aspirations under the SDGs and can function as a force for systemic economic and governance reform.

LIMITATION AND IMPLICATION

Although this study offers important insights, it has several methodological and empirical limitations. *First,* the data collection process was primarily based on publicly available government sources and interviews with BKPM officials, which may reflect institutional perspectives more strongly than the views of private investors, civil society, or affected communities. *Second,* the study focuses only on the transportation sector within the 2019–2024 period, making it difficult to generalize the findings to other sectors, such as energy or manufacturing. *Third,* although the qualitative approach provides in-depth analysis, it does not include quantitative measurements of the sustainability outcomes of FDI.

Future research could conduct comparative analyses among ASEAN countries to examine how different governance structures produce varying FDI outcomes. Further studies could also incorporate quantitative indicators, such as green investment ratios, the number of new local jobs created, and carbon-reduction metrics, to assess sustainable development outcomes more precisely. Local-level case studies are also needed to examine community impacts and environmental governance more closely. In addition, future research should include multi-stakeholder perspectives, especially from local governments, NGOs, private-sector actors, and affected communities, in order to provide a more balanced understanding of FDI governance.

ABOUT THE AUTHORS

Haniyah Nurafifah, who holds a bachelor's degree in International Relations from Universitas Andalas, has strong academic interests in global political economy and sustainability studies. Virtuous Setyaka and Diah Anggraini Austin are lecturers in the Department of International Relations at Universitas Andalas. Both specialize in global political economy, with teaching and research interests focused on development, investment, and international cooperation.

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Integrating Disaster Risk Management into Infrastructure Governance: A Framework for Resilient Development in Indonesia

Muhammad Hakiem Sedo Putra[1], M. Ridho Ulya[2], Zainal Alim[3]

[1] Integrated Water Governance Engineering, Institut Teknologi Sumatera (ITERA), Indonesia
[2] Environmental Engineering, Universitas Lampung, Bandar Lampung, Indonesia
[3] Perum Jasa Tirta 1, Malang, Indonesia

Corresponding author:
Muhammad Hakiem Sedo Putra | muhammad.sedo@tka.itera.ac.id

ABSTRACT

Indonesia is highly vulnerable to disasters, e.g., floods, landslides, earthquakes, and volcanic eruptions; all of which pose serious risks to public infrastructure resilience. Although infrastructure investment continues to increase, disaster risk considerations are not fully integrated into infrastructure planning and governance. This study develops a conceptual framework for integrating Disaster Risk Management (DRM) into public infrastructure governance in Indonesia. Using secondary data from the National Disaster Management Agency, the Ministry of Public Works and Housing, and international development reports, the study applies a qualitative approach to examine policy frameworks, institutional arrangements, and the use of risk information in infrastructure planning. The findings show that infrastructure governance in Indonesia remains largely reactive, with limited use of hazard mapping in spatial planning and weak coordination among relevant institutions. The proposed framework emphasizes cross-sectoral coordination, systematic use of geospatial risk data, and community participation in planning and decision-making. Strengthening these mechanisms can enhance infrastructure resilience, reduce disaster-related losses, and support sustainable public infrastructure investment.

Keywords: Disaster Risk Management; Infrastructure Governance; Resilience

ABSTRAK

Indonesia merupakan negara yang sangat rentan terhadap bencana, seperti banjir, tanah longsor, gempa bumi, dan letusan gunung api, yang semuanya menimbulkan risiko serius terhadap ketahanan infrastruktur publik. Meskipun investasi infrastruktur terus meningkat, pertimbangan risiko bencana belum sepenuhnya terintegrasi ke dalam perencanaan dan tata kelola infrastruktur. Studi ini mengembangkan kerangka konseptual untuk mengintegrasikan Manajemen Risiko Bencana *(Disaster Risk Management)* ke dalam tata kelola infrastruktur publik di Indonesia. Dengan data sekunder dari Badan Nasional Penanggulangan Bencana, Kementerian Pekerjaan Umum dan Perumahan Rakyat, serta laporan pembangunan internasional, studi ini menerapkan pendekatan kualitatif untuk mengkaji kerangka kebijakan, pengaturan kelembagaan, dan pemanfaatan informasi risiko dalam perencanaan infrastruktur. Temuan penelitian menunjukkan bahwa tata kelola infrastruktur di Indonesia masih cenderung bersifat reaktif, ditandai dengan terbatasnya penggunaan peta bahaya dalam perencanaan tata ruang serta lemahnya koordinasi antar lembaga terkait. Kerangka yang diusulkan menekankan pentingnya koordinasi lintas sektor, pemanfaatan data risiko geospasial secara sistematis, serta partisipasi masyarakat dalam proses perencanaan dan pengambilan keputusan. Penguatan mekanisme tersebut dapat meningkatkan ketahanan infrastruktur, mengurangi kerugian akibat bencana, dan mendukung keberlanjutan investasi infrastruktur publik.

Kata Kunci: Ketahanan; Manajemen Risiko Bencana; Tata Kelola Infrastruktur

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INTRODUCTION

Located in the Pacific "Ring of Fire," Indonesia is vulnerable to a wide range of hazards, including earthquakes, tsunamis, volcanic eruptions, floods, and landslides. In 2023 alone, the National Disaster Management Authority (*Badan Nasional Penanggulang Bencana*, or BNPB) recorded more than 3,000 disasters, which displaced millions of people from their homes and damaged large areas of public infrastructure. Infrastructure systems, including transportation networks and nodes such as roads, water supply infrastructure, energy generation facilities, public housing, and communication infrastructure, are particularly vulnerable to such threats. This vulnerability is partly due to their intensive material requirements and the fact that a number of infrastructure assets have been constructed in hazard-prone areas, often with limited integration of disaster risk considerations into planning and governance mechanisms (Putra et al., 2021).

National development policy in Indonesia continues to prioritize infrastructure investment. Through the 2025–2029 National Medium-Term Development Plan (*Rencana Pembangunan Jangka Menengah Nasional,* or RPJMN), infrastructure development has been one of the strategic priorities for strengthening connectivity, economic competitiveness, and resilient infrastructure systems (Bappenas, 2024). However, natural disasters have delayed many projects and demonstrated the need for stronger alignment between Disaster Risk Management (DRM), governance, and planning. Infrastructure is vital for economic growth and connectivity, but its long-term performance depends largely on risk-informed governance and planning that can adequately address disaster risks (Napitupulu & Putra, 2024).

Despite the enactment of laws related to disaster management, such as Law No. 24 of 2007 on Disaster Management, the integration of disaster risk into infrastructure governance remains weak in Indonesia. Various studies have shown fragmented institutional arrangements in the planning and implementation of infrastructure projects (Sagala et al., 2019; Siagian et al., 2021), particularly where coordination among ministries or agencies concerned with disaster risk reduction is still limited. Furthermore, hazard and risk data produced by national institutions are not consistently integrated into infrastructure planning or spatial development processes (Asian Development Bank, 2020). As a result, infrastructure projects often prioritize short-term economic efficiency and construction speed rather than long-term resilience to natural hazards.

The most recent Indonesian government regulation concerning the national disaster management agenda for the 2025–2029 period is the BNPB Regulation No. 1 of 2025 concerning National Disaster Management Planning. This policy emphasizes stronger prevention, mitigation, preparedness, and early warning efforts, as well as improved emergency response and recovery services. It also highlights cross-sectoral collaboration and community involvement, including the participation of people with disabilities, in the disaster management process to ensure inclusive protection (Abdillah et al., 2025). Nevertheless, many infrastructure projects continue to focus on cost efficiency and construction speed, often overlooking long-term resilience. Consequently, disasters not only disrupt public services but also lead to financial losses and humanitarian crises.

With regard to the above situation, this study seeks to: (1) analyze the current state of disaster risk integration within Indonesia's infrastructure governance framework; (20 identify key institutional, technical, and policy gaps that hinder risk-informed infrastructure development; and (3) propose a governance framework to embed DRM into infrastructure planning, implementation, and monitoring.

This research is expected to contributes to the growing body of literature on sustainable infrastructure governance by providing an Indonesia-specific framework that integrates disaster risk considerations (Edjossan-Sossou et al., 2020). This study might be utilized to assist policymakers, development partners, and infrastructure practitioners by offering practical recommendations for strengthening risk-informed infrastructure governance. Beyond Indonesia, the findings may also provide lessons for other low- and middle-income countries facing similar challenges in integrating DRM into infrastructure planning and governance.

In the context of this research, the concept of infrastructure governance is used to refer to the institutional arrangements, policy frameworks, and decision-making processes that guide the process of planning, financing, implementation, and management of infrastructure systems. It is characterized by the participation of multiple actors, including government, the private sector, and local communities; all of whom play a role in shaping the design, operation, and maintenance of infrastructure (Monstadt & Coutard, 2019).

THEORETICAL FRAMEWORK

Effective infrastructure governance ensures that development aligns with broader policy objectives, such as economic growth, social equity, and environmental sustainability. In the DRM context, infrastructure governance also includes the integration of hazard information, risk assessments, and resilience standards into infrastructure planning and implementation processes.

This research examines the incorporation of DRM into infrastructure development through the lens of disaster risk governance. Disaster risk governance focuses on the roles of institutions, the dissemination and utilization of risk information, and the participation of relevant actors in development processes vulnerable to disasters (Tierney, 2012; UNDRR, 2015). In this case, the governance of resilient infrastructure depends on three key elements: (1) institutional coordination among relevant agencies, (2) the systematic use of risk and hazard information in infrastructure planning, and (3) the active participation of stakeholders, including local communities and private sector actors. These dimensions serve as the analytical framework for examining how disaster risk considerations are integrated into infrastructure governance in Indonesia.

Disaster Risk and Infrastructure Vulnerability

Disaster risk is commonly understood as a function of hazard, exposure, and vulnerability (UNDRR, 2015). Because of their fixed location and long-life cycle, infrastructure systems are inherently vulnerable to various types of hazards. Floods can damage bridges and roadways, earthquakes can disrupt power grids and water pipelines, and landslides can cut off communities from access to critical facilities (Moraitis et al., 2020). Infrastructure resilience is therefore central to achieving the Sustainable Development Goals (SDGs), particularly Goal 9 on resilient infrastructure and Goal 11 on sustainable cities and communities (Davies, 2023).

In Southeast Asia, poor integration of risk assessment into infrastructure planning has been found to generate significant socio-economic costs (Asian Development Bank, 2020). The 2018 Sulawesi earthquake and tsunami, for example, caused devastating casualties and damaged key infrastructure, thereby delaying recovery efforts (Wakhungu et al., 2021). These examples emphasize the need to integrate disaster risk into infrastructure planning.

Governance Frameworks in DRM

Governance plays a critical role in determining how disaster risks are managed within infrastructure systems. According to Tierney (2012), disaster governance extends beyond government institutions to include networks of stakeholders, such as the private sector, civil society, and international organizations. Effective governance frameworks rely on coordination, transparency, and accountability (Fadillah et al., 2025).

Indonesia has made progress through regulatory instruments such as the Disaster Management Law, Law No. 24/2007, and the National Disaster Management Plan 2020–2024. However, scholars argue that these frameworks are often not systematically integrated into sectoral infrastructure planning (Siagian et al., 2021). Fragmentation across ministries and agencies results in overlapping responsibilities and limited enforcement of risk-informed standards (Putra et al., 2023).

Risk-Informed Infrastructure Planning and Its International Best Practices

Risk-informed planning requires the use of hazard maps, vulnerability assessments, and predictive modeling in the design and siting of infrastructure. The Sendai Framework for Disaster Risk Reduction 2015–2030 advocates mainstreaming Disaster Risk Reduction (DRR) into development planning, including infrastructure investment. Risk-informed infrastructure not only reduces disaster losses but also enhances long-term sustainability (Putra et al., 2023).

Although previous studies have examined disaster risk and infrastructure resilience in various sectors and regions, limited attention has been given to how disaster risk information is integrated into infrastructure governance and policy frameworks at the national level. In particular, the roles of institutional coordination, cross-sectoral planning mechanisms, and the systematic use of risk data in infrastructure decision-making remain insufficiently explored (Sagala et al., 2019). This disconnect between data and practice hampers resilience.

Comparative studies from Japan, Chile, and New Zealand demonstrate that effective integration of DRM into infrastructure planning and governance requires institutional mechanisms, available financing instruments, and active participation from local communities. Japan, for example, has codified disaster risk considerations into public works through strict building codes

and continuous monitoring (Putra, 2025). Chile has also become an international model for earthquake-resistant design standards, which have evolved over time based on advances in scientific knowledge.

These global cases illustrate the need to mainstream resilience into both technical standards and governance mechanisms. Indonesia could strengthen its infrastructure resilience measures by drawing on these best practices while adapting them to national and local contexts (Putra et al., 2025).

Research Gaps

Although there is an emerging body of literature on DRM in Indonesia, studies that specifically address governance dimension of infrastructure resilience remain limited. Most existing studies focus on technical mitigation measures, such as structural engineering, rather than institutional integration. Besides, little research has examined how national and local risk data can be effectively integrated into infrastructure projects during the design and implementation stages. This gap provides a basis for the present research to propose a governance framework that connects policy, technical planning, and community involvement (Napitupulu & Putra, 2024).

METHODOLOGY

Research Design

This study employs a qualitative descriptive research design using secondary data-based analysis. The research investigates the incorporation of DRM into infrastructure governance in Indonesia (Pattharaprachayakul et al., 2021), focusing on policy frameworks, institutional arrangements, and spatial risk data. The method is exploratory as it seeks to identify gaps and propose a particular governance framework (Rossi et al., 2023).

Data Source

The study relies on multiple sources of secondary data:

1. Government reports: publications from the National Disaster Management Authority (BNPB), the Ministry of Public Works and Housing (PUPR), and the Ministry of National Development Planning/National Development Planning Agency (Bappenas) (Scano et al., 2021).

2. International institutions: reports from the United Nations Office for Disaster Risk Reduction (UNDRR), the Asian Development Bank (ADB), and the World Bank (Putra et al., 2025).

3. Academic literature: peer-reviewed journal articles, policy studies, and case studies on disaster risk reduction and infrastructure governance (Prameswara et al., 2024).

4. Geospatial data: hazard maps, risk assessments, and disaster statistics available from BNPB and the Indonesian Geospatial Information Agency (*Badan Informasi Geospasial,* or BIG).

Analytical Framework

The analysis is guided by the disaster risk governance framework (Tierney, 2012; UNDRR, 2015), which emphasizes three dimensions:

1. Institutional frameworks, which examines the roles and responsibilities of government agencies in integrating DRM into infrastructure planning (Stantis et al., 2024).

2. Risk information, which assesses the availability and use of hazard data and risk mapping in infrastructure decision-making.

3. Stakeholder participation, which evaluates the extent to which communities, private sector actors, and civil society are engaged in governance processes.

A comparative review of international best practices from Japan, Chile, and New Zealand is also conducted to contextualize Indonesia's position and identify relevant, transferable lessons.

Selection of Case Studies

This paper analyzes three representative hazard types and their related infrastructure vulnerabilities:

1. Floods, particularly in Jakarta metropolitan area, where flooding frequently disrupts infrastructure and housing.

2. Landslides, particularly in West Java and Central Java, where hillside infrastructure projects are vulnerable to slope movement.

3. Earthquakes, particularly in Sulawesi, including the 2018 Palu earthquake and tsunami, which severely damaged critical infrastructure.

These cases were selected because they represent high-frequency and high-impact hazards in Indonesia and provide insights into broader governance challenges.

Data Analysis Procedure

Data analysis was conducted in the following three steps:

1. Content analysis, used to assess the integration of DRM into policy, legal, and institutional frameworks.

2. *Spatial overlay*, used to assess hazard maps in relation to infrastructure development plans in order to identify areas exposed to risk.

3. Comparative benchmarking, used to compare governance practices in Indonesia with international best practices and identify possible areas for improvement.

Limitations

The availability and quality of secondary data constitute a limitation of this research. Although hazard maps and disaster statistics are publicly available (publics & 2019, 2019), they vary significantly in terms of granularity and consistency across regions. In addition, this study does not involve fieldwork or primary data collection, which may have provided a deeper understanding of institutional and community-level conditions. However, reliance on multiple secondary sources and triangulation helps minimize these limitations (Chai et al., 2023).

FINDINGS

Current State of Disaster Risk Integration in Infrastructure Governance

Indonesia has made progress in disaster management policy through such legal instruments as Law No. 24/2007 on Disaster Management and the establishment of the National Disaster Management Authority (BNPB). However, the evidence shows that DRM remains a fragmented and reactive component of infrastructure planning. Infrastructure projects often lack sufficient funding for resilience, and in some cases, construction speed is prioritized over structural robustness.

For example, BNPB has produced hazard maps, but these maps are not yet used as mandatory references in feasibility studies or environmental impact assessments. Consequently, several large infrastructure projects have been developed in hazard-prone areas. The Jakarta flood in 2020 damaged recently rehabilitated road networks and

public transportation facilities, partly due to inadequate risk-based spatial planning.

At the institutional level, coordination among ministries, including the Ministry of Public Works and Housing (PUPR), Bappenas, and the Ministry of Environment and Forestry, remains weak. This results in overlaps and inefficiencies, as each agency tends to develop its own policies and programs. This finding is consistent with the broader literature, which shows that fragmented policy and limited coordination can hinder effective governance (Darmawan et al., 2021).

Case Study Findings

To illustrate the analysis, this study focuses on three representative hazard types and their associated infrastructure vulnerabilities.

1. Flooding in Jakarta

Jakarta is highly vulnerable to flooding. Data from BNPB show that approximately 150 flood incidents are recorded each year. Toll roads, drainage systems, and residential complexes are among the most affected types of infrastructure. Although flood hazard maps are available, the data are rarely processed and incorporated into building permits or urban development plans.

For instance, a 2022 case study showed that flood risks in the Jakarta Mass Rapid Transit (MRT) project were not assessed until after construction had commenced. This resulted in significant additional costs for mitigation measures, such as pumping stations and flood barriers. As a result, the project became more vulnerable to risk and financial loss, as these corrective measures could have increased project costs by up to 30% due to the need to retrofit or reinforce weak points after construction had already begun.

2. *Landslides in West and Central Java*

West and Central Java, where hilly terrain is common, frequently experience landslides. Infrastructure projects such as rural roads, bridges, and housing developments are often located on unstable slopes, making them vulnerable to slope movement. Spatial comparison between BNPB landslide-prone areas and road and port infrastructure maps indicates that more than 20% of rural infrastructure in Central Java intersects with landslide-prone areas.

Weak enforcement of slope stabilization guidelines reflects limited institutional control. In many cases, local governments lacl the technical expertise and financial resources needed to implement detailed mitigation plans. This indicates that the problem is not only an engineering issue but also a governance issue.

3. Earthquake in Sulawesi

Critical infrastructure, including bridges, ports, and power facilities, was destroyed by the 2018 Palu earthquake and tsunami. According to post-disaster assessments, many buildings failed to comply with earthquake-resistant design codes. In addition, land-use planning did not adequately consider liquefaction-prone areas, which resulted in widespread damage to properties and public facilities.

The above cases illustrate a gap in regulatory enforcement. Although building codes exist, compliance monitoring remains weak. Interviews and reports by BNPB (2019) show that oversight agencies do not have sufficient capacity to inspect all construction activities in a timely manner. At the same time, contractors often prioritize cost minimization over resilience.

Based on the aforementioned findings, three important governance gaps can be identified:

1. Institutional fragmentation: ministries and agencies often operate in silos, leading to weak coordination and duplication of efforts.
2. Limited application of risk information: although hazard maps and risk assessment are available, they are not systematically used in infrastructure planning and design.
3. Weak enforcement of regulatory frameworks: limited oversight capacity causes building codes and disaster risk reduction standards to be widely ignored in practice.

International Best Practices

The benefits of mainstreaming disaster risk at every stage of infrastructure development can be seen in countries such as Japan, Chile, and New Zealand.

1. Japan integrates disaster risk management into comprehensive urban planning through strict enforcement of building codes and continuous risk education for engineers and contractors.
2. Chile applies comprehensive building codes supported by seismic risk assessments, which are regularly updated based on new scientific knowledge and post-disaster learning.
3. New Zealand has adopted risk-sharing governance, involving local governments, communities, and private developers in resilience planning.

In contrast, Indonesia's system remains largely project-based and reactive rather than systemic and preventive. This comparison highlights the need for institutional reform and stronger engagement with key stakeholders.

Table 1. Comparative practices of DRM in infrastructure governance

Country	Policy Integration	Institutional Coordination	Regulatory Enforcement
Indonesia	Partially integrated; DRM is mentioned in spatial and infrastructure policy	Fragmented; overlapping ministries and local agencies	Often weak; compliance gaps remain in building and infrastructure codes
Japan	Fully integrated into national development planning	Strong national-local coordination; central disaster agency	Strict enforcement of building and safety standards
Chile	Embedded in land-use planning and building codes	Decentralized but with clear municipal roles	Seismic codes are rigorously enforced after major earthquakes
New Zealand	Mandated through civil defence and risk reduction acts	Well-defined roles across government levels, with strong community links	Mandatory compliance with resilience standards

Towards a Governance Framework for Risk-Informed Infrastructure

Based on the case findings and the international best practices (in Japan, Chile, and New Zealand), this study proposes a governance framework for incorporating Disaster Risk Management (DRM) into infrastructure development, as illustrated in Figure 1. The framework consists of five main components:

1. Policy integration: making hazard maps and risk assessments as mandatory references in all infrastructure-related planning documents.
2. Institutional coordination: establishing an inter-ministerial task force on risk-informed infrastructure to reduce fragmentation.
3. Capacity building: strengthening the capacity of local government officials and project implementers in risk-based planning and monitoring.
4. Community engagement: involving communities in identifying local risks and co-creating mitigation strategies.
5. Financial mechanisms: establishing dedicated resilience funds and incentives for developers whose projects comply with designated resilience standards.

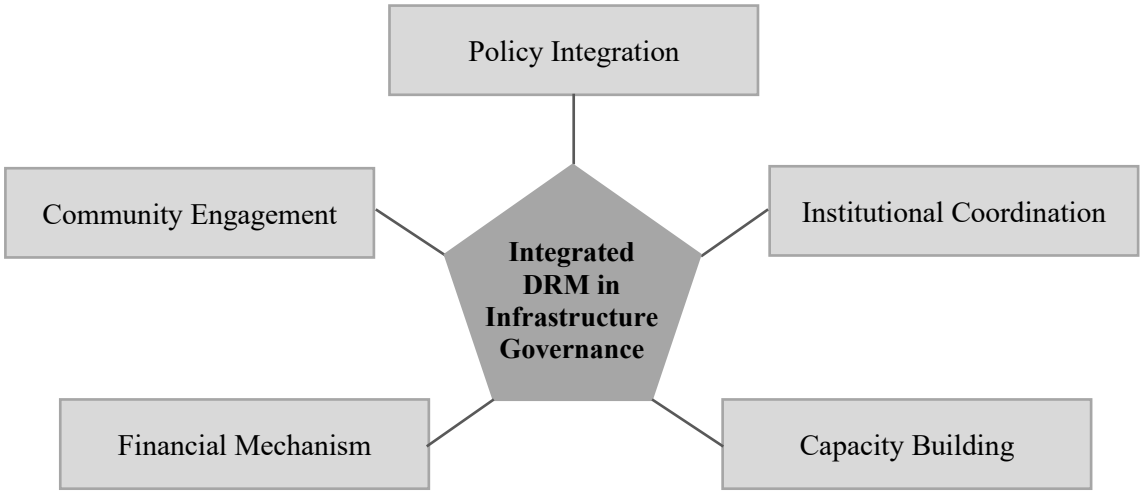

Figure 1. Proposed framework of integrated DRM in infrastructure governance

Implications for Sustainable Development

Integrating disaster risk into infrastructure governance is not only a technical aspect but also a strategic necessity for sustainable development. Infrastructure resilience directly influences economic stability, social welfare, and environmental sustainability. Through a risk-informed approach, Indonesia can reduce the long-term costs of disaster recovery, safeguard public investment, and strengthen trust in governance institutions.

Dimension	Key Challenges	Opportunities
Policy Integration	DRM remains sectoral; weak mainstreaming across infrastructure sectors	Ongoing revision of infrastructure masterplans to include resilience
Institutional Coordination	Overlapping mandates; limited central-local coordination	Potential role of BNPB as the central coordinating agency
Data Utilization	Hazard maps are underutilized; real-time data sharing is limited	Advances in GIS and digital platforms for multi-hazard data
Regulatory Enforcement	Weak compliance monitoring; limited sanctioning capacity	Growing post-disaster awareness and stronger civil society oversight
Financing Mechanism	Dependence on donor funding; limited use of risk transfer instruments	Emerging PPP frameworks for resilience bonds and insurance schemes

Table 2. Key challenges and opportunities in Indonesia's DRM integration

DISCUSSION

Fragmentation of Institutional Roles

The findings reveal that disaster risk integration in Indonesia's infrastructure governance is hindered by fragmented institutional responsibilities. Ministries and agencies such as PUPR, Bappenas, and BNPB operate with overlapping mandates, resulting in policy silos and weak cross-sectoral collaboration. This finding aligns with Tierney's (2012) disaster governance theory, which argues that risk management requires multi-actor coordination rather than single-agency intervention.

The absence of a central coordinating body for infrastructure resilience exacerbates duplication and inefficiency. For instance, BNPB provides hazard maps, yet their systematic use in infrastructure design is rarely mandated by PUPR. Such institutional misalignment weakens the effectiveness of existing regulations, making infrastructure projects vulnerable to hazards despite the presence of legal frameworks.

Although hazard and risk data are available, their application in decision-making remains limited. This reflects a broader knowledge-to-action gap as scientific and technical data are not effectively translated into planning processes. According to Sagala et al. (2019), Indonesia's risk maps are often treated as supplementary information rather than as core planning tools.

This gap illustrates a disconnect between technical capacity and governance enforcement. Unlike Japan, where seismic data are embedded into national building codes, Indonesia's hazard information remains underutilized. This prevents the mainstreaming of DRM into feasibility studies, environmental impact assessments, and public procurement standards.

Regulatory Enforcement Challenges

The Sulawesi earthquake case highlights weak enforcement of building codes. Although Indonesia has technical standards for earthquake-resistant structures, compliance is still inconsistent due to limited monitoring capacity. Contractors and local governments often prioritize cost-saving over resilience, which reflects focus on short-term economic incentives rather than on long-term sustainability.

The gap is not only a technical problem but also governance-related issue. Weak oversight, corruption risks, and resource limitations undermine institutional capacity to enforce standards. The issue demonstrates that disaster resilience is not solely an engineering matter but also a governance challenge that requires transparency, accountability, and appropriate incentives.

Lessons from International Best Practices

International comparisons reinforce the importance of institutionalized DRM. Japan shows how strict enforcement of building codes and the integration of hazard data into every planning stage can create a culture of resilience. Meanwhile, Chile shows that regularly updating technical standards based on new seismic data reduces vulnerability to earthquakes. Furthermore, New Zealand provides an inclusive governance model, in which local governments and communities share responsibility for resilience, thereby creating accountability and ownership.

For Indonesia, the key lesson is that resilience requires a systemic and preventive approach rather than ad-hoc interventions. This implies the need to rethink infrastructure governance as a continuous process of adaptation, informed by science and supported by robust institutions.

Risk-Informed Governance Framework

The proposed framework, as illustrated in Figure 1, shows how DRM can be embedded into infrastructure governance through five interrelated pillars:

1. Policy integration ensures that hazard data are used as compulsory references in planning.
2. Institutional coordination reduces fragmentation by establishing inter-ministerial collaboration.
3. Capacity building equips local governments with technical expertise.
4. Community engagement ensures that local risks are recognized and addressed.
5. Financial mechanisms provide resources and incentives for compliance with resilience standards.

By combining these five elements, the framework transforms DRM from a reactive measure into a proactive governance system. The implementation of this framework has several implications:

1. Economic efficiency: Investing in resilience at the planning stage is more cost-efficient than recovering from disasters after they occur.
2. Social equity: Community engagement prevents at-risk groups from being neglected in resilience planning.
3. Environmental sustainability: Integrating risk-informed approaches into infrastructure planning helps protect natural assets and conserve biodiversity.
4. Governance legitimacy: Transparent enforcement of resilience standards improves public confidence in institutions.

CONCLUSION

This study aims to explore and support DRM governance in Indonesia's infrastructure sector through stronger institutional coordination, better data utilization, more effective regulatory enforcement, and the adoption of relevant international best practices. The findings show that Indonesia has made significant progress in producing hazard maps, technical standards, and legal frameworks as part of its national disaster risk reduction strategy. Yet, institutional fragmentation, inadequate use of risk data, and weak regulatory enforcement continue to undermine the resilience of public infrastructure.

The comparison with Japan, Chile, and New Zealand shows that embedding DRM into governance processes is not only a technical matter but also a question of governance structure. Resilience depends on strong institutions, transparent enforcement, and adequate mechanisms for participation. These countries demonstrate that resilience is achieved not through reactive measures but through proactive, risk-informed governance frameworks.

The proposed conceptual framework in Figure 1 identifies five interrelated pillars: policy integration, institutional coordination, capacity building, community engagement, and financial mechanisms. These pillars serve as key pathways for mainstreaming DRM into infrastructure governance. This integrated approach enables Indonesia to move from fragmented measures toward a comprehensive resilience strategy focused on systemic prevention.

In short, strengthening DRM in infrastructure governance generates multiple benefits. It contributes to economic efficiency by reducing recovery costs, promotes social equity through participation, supports

environmental sustainability, and strengthens institutional legitimacy. This study reminds policymakers, practitioners, and researchers that disaster resilience must be treated as a governance priority in infrastructure planning, financing, and implementation.

If successfully implemented, this approach will not only mitigate disaster risks but also support Indonesia's long-term aspiration for sustainable and resilient infrastructure development.

ABOUT THE AUTHORS

Muhammad Hakiem Sedo Putra is a researcher and practitioner in the fields of water resources management, infrastructure governance, and environmental policy. His academic interests include disaster risk reduction, Public-Private Partnership (PPP) models for resilience, and sustainable infrastructure development. He has published several papers on water infrastructure, environmental engineering, and policy studies in national and international journals. Together with M. Ridho Ulya and Zainal Alim, he is currently conducting research on the integration of disaster risk management into infrastructure planning and governance in Indonesia. He can be contacted via email at Muhammad.sedo@tka.itera.ac.id.

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Energy-Related Infrastructure Efficiency and Environmental Performance in ASEAN-5

Laili Fitria[1], Putra Maha Muda[2]

[1] Universitas Tanjungpura, Pontianak, Indonesia
[2] Center for Educational Assessment Management, Ministry of Primary and Secondary Education, Jakarta, Indonesia.

Corresponding author:
Laili Fitria | fitria.laili@gmail.com

ABSTRACT

This paper examines how infrastructure efficiency, proxied by GDP per unit of energy use, relates to environmental and economic factors in ASEAN-5 countries. The study covers Indonesia, Malaysia, the Philippines, Thailand, and Vietnam from 2010 to 2023, using annual data from the World Bank's World Development Indicators. The empirical analysis applies pooled ordinary least squares, fixed-effects, and random-effects panel models, with the Hausman specification test to determine the preferred estimator. The regression sample is based on available country-year observations after accounting for missing data. The fixed-effects results show that carbon dioxide emissions per capita are negatively and significantly associated with infrastructure efficiency, while electricity consumption per capita is positively and significantly associated with it. GDP per capita and the renewable energy share have positive coefficients in the fixed-effects model, but these estimates are not statistically significant at conventional levels. Overall, the findings suggest that lower CO_2 emissions per capita and higher electricity consumption per capita are more consistently associated with infrastructure efficiency, while GDP per capita and renewable energy share show less robust statistical relationships in the present sample. These results highlight the importance of combining cleaner energy use with more productive energy systems.

Keywords: ASEAN; Environmental Performance; Infrastructure Efficiency; Panel Regression

ABSTRAK

Artikel ini mengkaji efisiensi infrastruktur, yang diproksikan melalui PDB per unit penggunaan energi, berkaitan dengan faktor lingkungan dan ekonomi di negara-negara ASEAN-5. Kajian ini mencakup Indonesia, Malaysia, Filipina, Thailand, dan Vietnam sejak 2010 hingga 2023, dengan menggunakan data tahunan dari World Development Indicators. Analisis empiris dilakukan dengan menerapkan model *pooled ordinary least squares*, *fixed-effects*, dan *random-effects panel*, serta menggunakan uji spesifikasi Hausman untuk menentukan estimator paling sesuai. Sampel regresi didasarkan pada observasi negara-tahun yang ada setelah memperhitungkan data yang hilang. Hasil *fixed-effects* menunjukkan bahwa emisi karbon dioksida per kapita berhubungan negatif dan signifikan dengan efisiensi infrastruktur, sedangkan konsumsi listrik per kapita berhubungan positif dan signifikan dengannya. PDB per kapita dan pangsa energi terbarukan memiliki koefisien positif dalam model *fixed-effects*, tetapi estimasi tersebut tidak signifikan secara statistik pada tingkat konvensional. Secara keseluruhan, temuan ini menunjukkan bahwa emisi CO_2 per kapita yang lebih rendah dan konsumsi listrik per kapita yang lebih tinggi lebih konsisten berkaitan dengan efisiensi infrastruktur, sementara PDB per kapita dan pangsa energi terbarukan menunjukkan hubungan statistik yang kurang kuat dalam sampel penelitian ini. Hasil ini menegaskan pentingnya memadukan penggunaan energi yang lebih bersih dengan sistem energi yang lebih produktif.

Kata Kunci: ASEAN; Efisiensi Infrastruktur; Kinerja Lingkungan; Regresi Panel

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INTRODUCTION

Infrastructure has become one of the most important drivers of economic development and structural change in ASEAN countries. Rapid urbanization, industrial growth, and rising income levels have increased pressure on transportation networks, electricity systems, and other core services, requiring governments to make substantial infrastructure investments.

At the same time, this expansion has been accompanied by rising energy use and increasing greenhouse gas emissions, especially in rapidly developing middle-income countries. These trends raise questions about whether current development pathways can be sustained in the future and whether infrastructure systems can support growth while limiting pressure on environmental systems (Wang & Su, 2020; Sarkodie & Strezov, 2019; Acheampong, 2018). In this context, the efficiency of infrastructure and energy use, understood as the economic output generated from each unit of energy consumed, has become a key issue in sustainable development in ASEAN.

In this paper, "energy-related infrastructure efficiency" refers to the macro-level ratio of economic output to energy input, or GDP per unit of energy use. This measure reflects how productively the energy supplied through infrastructure systems is converted into economic value. This indicator is qualitatively different from engineering-level energy efficiency, which is usually measured at the technology or equipment level. The relationship between these concepts differs across contexts. While the aggregate indicator used in this study incorporates aspects of infrastructure design, technology adoption, and the structure of economic activity, it should not be equated with engineering-level measures of efficiency. Unless otherwise specified, this study uses this macro-level definition of efficiency throughout the analysis.

Many scholars have examined the relationships among economic growth, energy use, and CO_2 emissions in ASEAN. However, fewer studies have used GDP per unit of energy use as the main outcome variable for evaluating the efficiency of energy-related infrastructure (Dogan & Inglesi-Lotz, 2020; Zhang et al., 2016). Most existing studies focus on aggregate linkages and do not directly measure infrastructure or energy efficiency as the dependent variable. Nor do they systematically investigate the determinants of such efficiency across countries.

More specifically, the combined effects of economic development, emissions intensity, and energy mix on infrastructure efficiency in ASEAN-5 remain relatively underexplored. This paper addresses this gap by examining

infrastructure efficiency, proxied by GDP per unit of energy use, in Indonesia, Malaysia, the Philippines, Thailand, and Vietnam from 2010 to 2023. To achieve this objective, the study models the relationships between GDP per capita, CO_2 emissions per capita, electricity consumption per capita, renewable energy share, and infrastructure efficiency using a panel-data framework.

This study addresses two research questions:

1. How has infrastructure efficiency, measured as GDP per unit of energy use, developed in ASEAN-5 countries from 2010 to 2023?

2. What is the relationship between GDP per capita, CO_2 emissions per capita, electricity consumption per capita, renewable energy share, and infrastructure efficiency in these countries over time?

This paper makes three main contributions to the existing literature. *First,* unlike most ASEAN energy studies that treat energy consumption or CO_2 emissions as the main outcome, this study uses GDP per unit of energy use as the dependent variable. This allows the analysis to assess infrastructure efficiency more directly in relation to relevant economic and environmental variables, rather than examining development only through the lens of energy use or emissions.

Second, the paper applies a country fixed-effects panel framework, with the Hausman test used to determine whether the fixed-effects or random-effects model is more appropriate. This provides robust evidence of within-country associations among ASEAN-5 countries over the most recent available period, 2010–2023.

Third, the study combines CO_2 emissions per capita, renewable energy share, electricity consumption per capita, and GDP per capita in a single analysis, thereby capturing the interconnected influence of carbon intensity, energy mix, electrification, and economic development on infrastructure efficiency in the region.

THEORETICAL FRAMEWORK

Infrastructure Investment and Energy Efficiency

Infrastructure and energy systems are cornerstones of economic development because they facilitate production, mobility, and access to basic services. At the same time, these systems also determine the level and structure of energy demand. Empirical studies show that economic growth can be decoupled from energy use, depending on infrastructure quality and technology. In this context, energy intensity, or energy use per unit of output, can improve through technological advancement and more efficient production of goods and services (Wang & Su, 2020; Balsalobre-Lorente et al., 2018; Sadorsky, 2013; Stern, 2012).

Against this background, GDP per unit of energy use, often expressed as GDP in national currency per kilogram of oil equivalent, serves as a high-level indicator of infrastructure and final-demand efficiency because it shows how an economy converts energy inputs into economic value added (Stern, 2012). Although this indicator is aggregate and sector-neutral, it has been widely used in cross-country analyses because it is available, comparable, and relatively easy to interpret (Apergis & Payne, 2010). In this sense, trends in GDP per unit of energy use can provide an initial proxy for the evolution of infrastructure and energy-system efficiency over time in transitioning economies such as those applied in the ASEAN countries.

Economic Growth, Emissions, and Energy Use in ASEAN

A growing body of literature exists on the relationships between economic growth, energy use, and carbon dioxide emissions in ASEAN and other developing regions. Many studies examine the Environmental Kuznets Curve (EKC) hypothesis, the causal relationship between GDP and energy use, or fossil fuel consumption as a driver of emissions (Nathaniel & Khan, 2020; Saboori et al., 2012; Lean & Smyth, 2010; Ang, 2008). For example, Saboori et al. (2014) report an EKC-type relationship between GDP and CO_2 emissions for selected ASEAN countries, while Lean and Smyth (2010) show evidence of long-run linkages between electricity consumption and economic growth in Malaysia. Other regional studies emphasize the need for cleaner energy mixes and stronger policy frameworks due to rising energy demand and emissions associated with rapid urbanization and industrialization (Kirikkaleli & Adebayo, 2021; Nasreen & Anwar, 2014; Sadorsky, 2013).

Nevertheless, most of this literature uses total or per capita emissions and energy use as the main outcome variables, rather than an explicit efficiency metric such as GDP per unit of energy use. Consequently, limited empirical evidence is available on how macro-level indicators of infrastructure or energy efficiency respond to changes in income, emissions intensity, and the energy mix in ASEAN-5.

Links between Infrastructure Efficiency and Environmental Performance

Conceptually, higher infrastructure and energy efficiency may facilitate the decoupling of economic growth from environmental pressure (Wang & Su, 2020; Sarkodie & Strezov, 2019). Provided that the carbon intensity of energy does not increase at the same time, more output can be generated per unit of energy consumed. Thus, a given level of GDP can, in principle, be produced with lower emissions (Stern, 2012). In contrast, high CO_2 emissions per capita may reflect a more carbon-intensive capital and energy base, indicating that part of the growth process is driven by inefficient or fossil fuel-dependent economic activity (Apergis & Payne, 2010).

The composition of the energy mix also matters, as a larger renewable share in final energy consumption may reduce emissions per unit of energy used and therefore lead to more favorable environmental performance at a given level of infrastructure efficiency (Balsalobre-Lorente et al., 2018; Sadorsky, 2009). Conversely, demand-side studies indicate that gains in electricity access and electricity use can facilitate economic development under a sustainability-oriented hypothesis, although environmental benefits remain conditional on the carbon intensity of power generation (Stern, 2012; Lean & Smyth, 2010; Ang, 2008). In the ASEAN context, examining how GDP per unit of energy use co-evolves with CO_2 emissions, renewable energy penetration, and electricity consumption can help explain whether infrastructure and energy systems are moving countries closer to, or further from, low-carbon development pathways.

More recent studies have examined energy efficiency, energy intensity, renewable energy, and environmental performance at the ASEAN and Southeast Asian levels. Khuong et al. (2019) showed that urbanization, energy mix, energy intensity, and activity effects jointly determine ASEAN energy demand, while Fitriyanto and Iskandar (2019) analyzed the determinants of energy intensity in nine ASEAN economies using an Arellano–Bond GMM panel approach. In the context of the ASEAN-5, Dağdeviren et al.

(2020) re-examined the relationship among CO_2 emissions, energy consumption, and economic growth, accounting for cross-sectional dependence and country heterogeneity.

Recent panel-data studies have also employed fixed-effects models, GMM estimators, and quantile-based estimators to address heterogeneous effects or endogeneity in the ASEAN energy-environment literature, including studies on emissions from electricity generation (Voumik et al., 2022) and the effects of renewable energy (Ilyas et al., 2024). Similarly, Tran et al. (2024) confirmed that renewable energy use has a negative relationship with CO_2 emissions in ASEAN and supports environmental quality. Although a growing body of literature has examined these factors, only a limited number of studies have used GDP per unit of energy use as the main outcome variable and examined its relationship with CO_2 intensity, renewable energy share, and electrification within a unified panel framework for ASEAN-5 (Nathaniel & Khan, 2020).

Overall, the literature indicates that most ASEAN energy studies focus on energy use, emissions, and growth, while GDP per unit of energy use has received less attention as a main outcome variable. This paper, therefore, employs a panel-data approach to analyze energy-related infrastructure efficiency in ASEAN-5.

METHODOLOGY

Study Area and Period

This empirical analysis focuses on five ASEAN economies: Indonesia, Malaysia, the Philippines, Thailand, and Vietnam, hereafter referred to as ASEAN-5. These countries are among the largest and most dynamic economies in the region. Over the past two decades, they have experienced rapid economic growth, structural transformation, and increasing energy demand, making them suitable cases for investigating the relationship between infrastructure efficiency and environmental performance (Nasreen & Anwar, 2014; Sadorsky, 2013; Lean & Smyth, 2010).

The focus on ASEAN-5 is based on three selection criteria. *First,* these five economies are among the largest in Southeast Asia in terms of both GDP and population, making the findings relevant to the region's main economic engines. *Second,* all five countries have comprehensive or nearly comprehensive WDI indicator coverage since 2010, allowing for consistent comparison. *Third,* this group displays significant diversity in economic structure, energy mix, and emissions intensity, which allows cross-country analysis through within-group variation. Singapore is omitted because its characteristics as a geographically small, high-income city-state, with limited agricultural activity and nearly universal electrification, would make it a structural outlier that could drive pooled and fixed-effects estimates. Smaller ASEAN economies, including Laos, Brunei, Myanmar, Cambodia, and Timor-Leste, are excluded based on the availability of WDI data for key indicators over the full study period.

The study covers the period from 2010 to 2023, subject to data availability for the selected indicators, and is structured as an annual country-year panel. The raw dataset contains up to 70 country-year observations, calculated as five countries multiplied by 14 years. However, the effective regression sample is smaller because some variables contain missing values, particularly the renewable energy share and several observations for 2023. Accordingly, the econometric analysis is based on the available observations rather than on a fully balanced panel.

Data Sources

All variables used in this study are obtained from the World Development Indicators (WDI) database published by the World Bank, which compiles harmonized economic, social, and environmental statistics from officially recognized international sources (World Bank, 2025a). The WDI dataset provides annual, internationally comparable indicators for GDP, energy use, emissions, and population for a large sample of countries, including the ASEAN-5 economies. In particular, the analysis draws on GDP per capita in current US dollars (NY.GDP.PCAP.CD), carbon dioxide emissions per capita based on AR5 global warming potentials (EN.GHG.CO2.PC.CE.AR5), renewable energy consumption as a share of total final energy use (EG.FEC.RNEW.ZS), electricity consumption per capita (EG.USE.ELEC.KH.PC), and GDP per unit of energy use, expressed in constant 2021 PPP dollars per kilogram of oil equivalent (EG.GDP.PUSE.KO.PP.KD). Because the World Bank metadata distinguishes between related series for this indicator, the study uses a single series definition consistently through the text, tables, and appendix. These indicators are accessed through the World Bank open data interface and merged into a country-year panel for ASEAN-5.

Table 1. Variables, definitions, and data sources

Variable name	Description	Unit	WDI code	Transformation in Model
Infrastructure efficiency (Eff)	GDP per unit of energy use	Constant 2021 PPP $ per kgoe	EG.GDP.PUSE.KO.PP.KD	Level (Eff)
GDP per capita (GDPpc)	Gross domestic product per capita (current prices)	Current USD per person	NY.GDP.PCAP.CD	ln(GDPpc)
CO_2 emissions per capita (CO2pc)	Carbon dioxide emissions per capita (AR5 greenhouse gases)	Tonnes CO_2-eq per person	EN.GHG.CO2.PC.CE.AR5	ln(CO2pc)
Renewable energy share (Renew)	Renewable energy consumption in total final energy use	Percent of final energy consumption	EG.FEC.RNEW.ZS	Level (%)
Electricity use per capita (Elecpc)	Electricity consumption per capita	kWh per person per year	EG.USE.ELEC.KH.PC	ln(Elecpc)

Table 1 presents the variables used in the analysis, including their definitions, units of measurement, WDI codes, and data sources. The table also indicates which variables are used in levels and which are transformed into natural logarithms for the econometric model (World Bank, 2025a, 2025b, 2025c).

The original panel includes 70 country-year observations, consisting of five countries observed over 14 years from 2010 to 2023. After removing observations with missing values, the effective regression sample consists of 60 complete-case observations. The missing values mainly relate to renewable energy share for Indonesia and Malaysia in 2022 and 2023, and GDP per unit of energy use for Malaysia in 2023. The analysis is performed using the available complete observations through listwise deletion, while

sensitivity analysis may be used to examine potential biases that could arise from case deletion. Since the missingness is concentrated in the most recent years and is likely caused by publication lags in the World Bank WDI database, it is unlikely to introduce systematic selection bias across the sample. This variation in data coverage means that the number of observations is reported separately for each variable in the descriptive statistics shown in Table 3.

Variable Construction

This study measures infrastructure efficiency using GDP per unit of energy use (Eff), measured in PPP dollars per kilogram of oil equivalent of total energy consumption. This variable serves as the dependent variable. The ratio is interpreted as a general measure of energy and infrastructure efficiency, indicating the amount of economic value generated per unit of energy input, with higher values denoting greater efficiency (World Bank, 2025b, 2025c; United Nations, 2001).

For measurement consistency, the dependent variable, GDP per unit of energy use, is expressed in constant 2021 PPP dollars. This adjustment addresses price-level differences across countries and over time, allowing for more meaningful efficiency comparisons. GDP per capita is used as an explanatory variable and is measured in current US dollars, reflecting variation in nominal income. This is one of the most commonly used measures in cross-country energy-growth studies (Sadorsky, 2013; Lean & Smyth, 2010).

A more PPP-consistent specification would be preferable, but the current approach follows standard practice in the literature and does not qualitatively alter the interpretation of the results. As a sensitivity check, the model was also assessed using GDP per capita in constant 2015 US dollars, and the direction and significance of the coefficients remained unchanged.

It should be noted that GDP per unit of energy use is an indicator of energy productivity rather than a direct or sector-specific measure of infrastructure efficiency (Destek & Sinha, 2020; Acheampong, 2018). Nevertheless, this study adopts it as a proxy for three reasons. *First,* major infrastructure-related systems, including transportation, electricity generation, and industrial production, are closely connected to aggregate energy demand. Therefore, changes in these systems are expected to be reflected in national-level energy productivity indicators. *Second,* this indicator is publicly available, internationally comparable, and widely used in cross-country analyses of infrastructure and energy performance, making it appropriate for this study (World Bank, 2025b; Apergis & Payne, 2010). *Third,* the available data do not allow for a more disaggregated analysis because a macro-level infrastructure efficiency index is not available for all five ASEAN countries throughout the entire study period. These constraints are discussed further in the limitations section.

The main independent variables are GDP per capita in current US dollars (GDPpc), which reflects the level of economic development; carbon dioxide emissions per capita in tonnes (CO2pc), which captures the average emissions intensity of economic activity; renewable energy consumption as a share of total final energy use (Renew), which reflects the role of low-carbon energy sources in the energy mix; and electricity consumption per capita in kilowatt-hours (Elecpc), which represents the extent of electrification and modern energy use (Munir et al., 2020; Saboori et al., 2012; Lean & Smyth, 2010; Ang, 2008).

To reduce skewness and improve interpretability in a log-linear specification, GDP per capita, CO_2 emissions per capita, and electricity consumption per capita are transformed into natural logarithms prior to estimation. This is consistent with common practice in energy-growth-emissions panel studies (Nasreen & Anwar, 2014; Sadorsky, 2013; Lean & Smyth, 2010; Ang, 2008). Renewable energy share is retained in percentage terms because it is a bounded variable and is commonly modeled in levels when representing the energy mix (Apergis & Payne, 2010; Sadorsky, 2009).

The dependent variable, infrastructure efficiency proxied by GDP per unit of energy use, is retained in level form in the estimated model. Under this specification, the coefficients on the logged explanatory variables are interpreted as semi-log effects on the level of infrastructure efficiency, while the coefficient on renewable energy share captures the marginal association of a one-percentage-point change in the renewable share. This treatment of variables is consistent with previous empirical studies on energy efficiency and the energy-growth-emissions nexus, which often rely on log-linear specifications to capture proportional effects and reduce the influence of outliers (Nasreen & Anwar, 2014; Stern, 2012; Sadorsky, 2009; Ang, 2008).

Empirical Model and Estimation Strategy

The empirical model is adapted from the standard log-linear panel framework commonly used in the energy-growth-emissions literature (e.g., Sadorsky, 2013; Stern, 2012; Lean & Smyth, 2010; Ang, 2008). The standard specification typically regresses an energy or emissions outcome on income, energy mix, and electrification variables while accounting for country fixed effects. In this study, the specification is modified by replacing the conventional emissions-side outcome with GDP per unit of energy use as the dependent variable, following Stern's (2012) approach to modeling energy efficiency trends. The selected regressors are theoretically relevant and have been widely used in empirical studies in the ASEAN context. This adaptation enables the model to examine the drivers of energy-related infrastructure efficiency rather than emissions or energy demand.

The empirical specification is therefore adapted from log-linear panel models commonly used in the energy-growth-emissions literature, in which energy use, emissions, or energy intensity is regressed as a function of income, energy structure, and other macroeconomic determinants (Sadorsky, 2013; Lean & Smyth, 2010; Ang, 2008). Building on Stern's (2012) modeling logic, this study reformulates the specification by using GDP per unit of energy use as the dependent variable. This adjustment allows the analysis to focus on energy-related infrastructure efficiency rather than emissions or total energy demand.

The study estimates the following country fixed-effects panel model:

$$Effit = \alpha i + \beta 1 \ln(GDPpcit) + \beta 2 \ln(CO2pcit) + \beta 3 Renewit + \beta 4 \ln(Elecpcit) + \varepsilon it$$

where *i* indexes countries and *t* indexes years. The dependent variable, Effit, denotes GDP per unit of energy use. The term αi captures country-specific fixed effects that absorb time-invariant heterogeneity across countries, such as geography, long-run institutional characteristics, and structural economic differences. This follows standard fixed-effects panel modelling, where unobserved country-specific factors are controlled through country-level intercepts (Baltagi, 2021). The term εit is the idiosyncratic error term.

Following standard panel-data practice, the empirical analysis estimates pooled ordinary least squares, fixed-effects, and random-effects models to compare alternative assumptions about unobserved country heterogeneity (Baltagi, 2021; Wooldridge, 2010). Pooled OLS provides a benchmark specification but does not explicitly control for unobserved country-specific effects. The fixed-effects model controls for time-invariant country characteristics that may be correlated with the regressors, whereas the random-effects model is more efficient if the unobserved country effects are uncorrelated with the explanatory variables (Baltagi, 2021). The Hausman specification test is then used to determine whether the fixed-effects or random-effects estimator is more appropriate for inference (Hausman, 1978).

Endogeneity is a possible concern in this specification. Reverse causality may occur because greater infrastructure efficiency may itself influence electricity consumption, energy demand, and CO_2 emissions in subsequent periods. In addition, potential multicollinearity among the selected regional proxies needs to be considered, while further improvements in model implementation could account for possible endogenous relationships between infrastructure efficiency and macroeconomic variables such as fuel prices, industrial structure, institutional quality, technology adoption, or sector-specific infrastructure investment. Although the fixed-effects estimator absorbs time-invariant country characteristics, it does not fully address dynamic endogeneity or omitted-variable problems.

Table 2. Empirical model specification

Item	Specification / Description
Dependent variable	Effit: infrastructure efficiency measured as GDP per unit of energy use, expressed in USD per kgoe, PPP
Main explanatory variables	ln(GDPpcit): log GDP per capita, current USD; ln(CO2pcit): log CO_2 emissions per capita, tonnes per person; Renewit: renewable energy share in final energy consumption, percent; ln(Elecpcit): log electricity consumption per capita, kWh per person
Expected signs	β_1, ln(GDPpc) > 0; β_2, ln(CO2pc) < 0; β_3, Renew ≥ 0; β_4, ln(Elecpc) > 0, based on prior studies on energy efficiency and emissions (Sadorsky, 2013; Stern, 2012)
Baseline model	Effit = αi + β1 ln(GDPpcit) + β2 ln(CO2pcit) + β3 Renewit + β4 ln(Elecpcit) + εit
Estimators employed	Pooled OLS, Fixed Effects (FE), and Random Effects (RE) estimators are employed. The FE estimator controls for unobserved time-invariant country-specific heterogeneity, whereas the RE estimator is efficient only under the assumption that the unobserved individual effects are uncorrelated with the explanatory variables (Baltagi, 2021).
Fixed effects	Country fixed effects are included in the FE specification to control for unobserved time-invariant heterogeneity across countries.
Hausman test	Null hypothesis: the RE estimator is consistent and efficient. Alternative hypothesis: the FE estimator is consistent and preferred for inference. Model selection is based on the Hausman (1978) specification test.
Preferred specification	Fixed-effects panel model with country fixed effects; model choice is based on the Hausman specification test.

Table 2 summarizes the empirical model specification, including the dependent variable, explanatory variables, expected coefficient signs, and the three estimators employed: pooled OLS, FE, and RE. The table also presents the planned model-

selection procedure using the Hausman specification test. The Hausman test was conducted after estimating both the FE and RE models, and the test statistic and p-value are reported in the Results section and in the note to Table 5.

To assess the robustness of the main results, two additional checks were conducted. *First,* the preferred fixed-effects model was re-estimates using one-period lagged explanatory variables: ln(GDPpc)t−1, ln(CO_2pc)t−1, Renewt−1, and ln(Elecpc)t−1. This specification reduces the risk that contemporaneous changes in infrastructure efficiency directly determine the explanatory variables in the same year. *Second,* GDP growth was added as an additional control variable to account for short-run macroeconomic variation. These checks are reported in Appendix Table A1 (after the Reference section). They are intended as diagnostic robustness tests rather than as a full causal identification strategy.

Because some indicators contain missing values, the regression analysis is estimated using the available complete observations. The fixed-effects specification is implemented with country fixed effects, which focuses the analysis on within-country variation over time.

Descriptive Statistics and Correlation

Before estimating the panel regression models, descriptive statistics are reported for all variables to characterize their distribution and variation across countries and over time. Because data availability differs across indicators, the number of observations varies by variable. Accordingly, the descriptive statistics summarize the available observations for each series rather than a fully balanced panel. In addition, Pearson correlation coefficients are computed among the main variables to provide an initial view of pairwise relationships and potential multicollinearity before regression estimation. The regression models are then estimated using the complete-case sample implied by the joint availability of the variables included in the specification.

Table 3. Descriptive statistics for ASEAN-5, 2010–2023

Variable	N	Mean	Median	Std. dev.	Min.	Max.
GDP per capita (USD)	70	5,318.40	3,857.33	2,940.83	1,683.16	11,754.57
CO_2 emissions per capita (tonne)	70	3.49	2.67	2.34	0.86	8.19
Renewable energy (% final)	60	22.72	24.25	10.50	2.00	37.90
Electricity use (kWh per capita)	67	2,118.53	1,788.72	1,405.87	622.21	4,986.12
GDP per unit of energy (USD/kgoe)	67	12.65	12.34	2.43	8.97	17.17

Table 3 presents the summary statistics for infrastructure efficiency, GDP per capita, CO_2 emissions per capita, renewable energy share, and electricity consumption per capita across all available country-year observations.

Table 4. Correlation matrix of key variables

Variable	ln(GDPpc)	ln(CO2pc)	Renew (%)	ln(Elecpc)	Infra efficiency	GDP growth (%)
ln(GDP per capita)	1.000	0.899***	−0.910***	0.861***	−0.658***	−0.235*
ln(CO_2 per capita)	0.899***	1.000	−0.883***	0.963***	−0.828***	−0.151
Renewable energy share (%)	−0.910***	−0.883***	1.000	−0.847***	0.579***	0.152
ln(Electricity use per capita)	0.861***	0.963***	−0.847***	1.000	−0.843***	−0.167
Infrastructure efficiency (Eff)	−0.658***	−0.828***	0.579***	−0.843***	1.000	0.136

Note: Pearson correlation coefficients are reported for the available observations of each variable pair. Significance levels are denoted by *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.10$.

Table 4 reports the Pearson correlation matrix among the main variables. It highlights the bivariate associations between infrastructure efficiency and each determinant, as well as correlations among the explanatory variables, which help inform the interpretation of the regression coefficients.

The correlation matrix reveals high pairwise correlations among several regressors, notably between ln(CO_2 per capita) and ln(Electricity per capita) ($r = 0.963$) and between ln(GDP per capita) and ln(CO_2 per capita) ($r = 0.899$). These correlations raise potential multicollinearity concerns in the pooled OLS specification.

However, the fixed-effects within transformation mitigates this concern by focusing on within-country variation over time, which is generally lower than the cross-sectional variation that drives most of the observed pairwise correlations. Variance inflation factors (VIFs) were computed for the pooled OLS model, and all values remain below 10, confirming that multicollinearity does not severely distort the estimates.

RESULTS

Descriptive Patterns of Infrastructure Efficiency and Environmental Indicators

Figure 1 plots the trend of infrastructure efficiency, measured as GDP per unit of energy use, for Indonesia, Malaysia, the Philippines, Thailand, and Vietnam over the period 2010–2023. The figure shows heterogeneous rather than uniformly upward trends across ASEAN-5. The Philippines shows the highest and clearest medium-term increase among these countries, while Thailand's increase appears gradual and relatively monotonic over the long run. Indonesia rises sharply during the first half of the sample period, reaches its peak in the mid-2010s, then declines somewhat before modestly recovering in the final observed year. Vietnam also performs well in the initial years of the sample, but then declines slightly before partially recovering later. Malaysia shows a more subdued and fluctuating pattern over time. Overall, efficiency improved in several ASEAN-5 economies, but the trends were not consistent across countries.

Because 2023 values are unavailable for Malaysia, the Philippines, and Vietnam in the underlying dataset, the final year should be interpreted with caution in cross-country comparisons. For a cleaner visual comparison, the figure may alternatively be truncated at 2022.

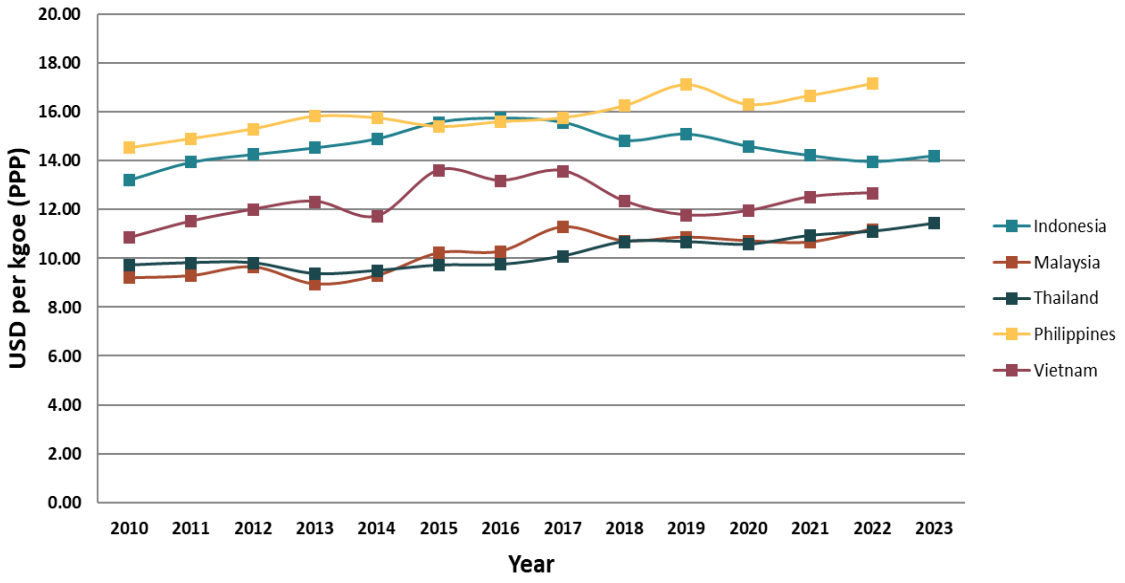

Figure 1. Trends in infrastructure efficiency, GDP per unit of energy use, in ASEAN-5, 2010–2023.

Note: 2023 values are unavailable for Malaysia, the Philippines, and Vietnam. For a clearer cross-country comparison, the figure may alternatively be read up to 2022 (Source: Authors' visualization based on World Bank World Development Indicators)

Panel Regression Estimates

Table 5 reports the panel regression results for infrastructure efficiency using pooled OLS, fixed-effects, and random-effects estimators. After estimating the FE and RE models, the Hausman (1978) specification test was conducted to select the preferred estimator. The test rejects the random-effects assumption; therefore, the FE model is used as the preferred specification for inference. In the FE model, GDP per capita has a positive but statistically insignificant coefficient. The coefficient on CO_2 emissions per capita is negative and statistically significant, indicating a negative within-country association between CO_2 emissions per capita and infrastructure efficiency. The coefficient on renewable energy share is positive but statistically insignificant, indicating that no statistically robust association is observed in the FE model. The coefficient on electricity consumption per capita is positive and statistically significant, indicating a positive within-country association with infrastructure efficiency after controlling for the other regressors and country-specific fixed effects.

Table 5. Panel regression results for infrastructure efficiency: Pooled OLS, FE, and RE

Variable	Pooled OLS Coef.	Pooled OLS p-value	FE Coef.	FE p-value	RE Coef.	RE p-value
ln(GDP per capita)	−0.1413	0.8404	1.4617	0.2319	3.1178	0.0089
ln(CO_2 per capita)	−3.0043***	0.0011	−3.3374**	0.0101	−6.0846***	0.0000
Renewable energy share (%)	−0.1691***	0.0000	0.0555	0.1928	−0.0680	0.1015
ln(Electricity use per capita)	−2.2808***	0.0023	4.5354***	0.0009	1.6375	0.1880
Constant	37.5466***	0.0000	—	—	−18.0727*	0.0737

Note: Table 5 reports estimated coefficients and p-values for the pooled OLS, fixed-effects, and random-effects models. The regression sample contains 60 observations due to missing data in some indicators. In the FE model, the within R^2 is 0.4263. The Hausman test statistic is $H = 7.55 \times 10^{10}$ ($df = 4$, $p < 0.001$), indicating that the FE model is preferred over RE. Significance levels are denoted by *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.10$.

Two robustness checks are presented here. In the lagged FE model, the signs of the main coefficients remain broadly consistent with the baseline specification: GDP per capita, renewable energy share, and electricity consumption per capita are positive, while CO_2 emissions per capita are negative. However, the statistical significance changes. The lagged coefficient of CO_2 emissions per capita loses statistical significance and becomes negligible, while lagged renewable energy share and lagged electricity consumption appear to have positive and statistically significant effects over a longer time horizon.

The second robustness check adds GDP growth as an additional control variable. In this specification, the baseline results remain broadly consistent: CO_2 emissions per capita remain negative and statistically significant, electricity consumption per capita remains positive and statistically significant, and GDP growth is not statistically significant. These findings indicate that most of the main effects are relatively robust to the inclusion of an additional macroeconomic control, although causal interpretation should still be treated with caution.

DISCUSSION

Interpretation of Key Relationships

1. On CO_2 per Capita: Negative, Significant

The negative coefficient on CO_2 emissions per capita indicates that if ASEAN-5 countries continue to follow carbon-intensive development patterns, infrastructure efficiency may be constrained. This result can also be interpreted in light of the carbon lock-in literature, which argues that the longevity of fossil fuel-based technologies, infrastructure, and institutions can hinder transitions toward low-carbon energy systems (Unruh, 2000; Seto et al., 2016). In the ASEAN-5 country panel, the coefficient on CO_2 emissions per capita is negative, indicating that higher emissions levels are associated with lower GDP per unit of energy use.

This finding is particularly relevant for ASEAN countries experiencing industrial expansion, where a larger energy base may not necessarily translate into higher productivity per unit of energy if the adoption of energy-efficient technologies remains slow (Sadorsky, 2013). The result also aligns with the Environmental Kuznets Curve (EKC) framework, which suggests that countries in earlier stages of industrialization may experience rising emissions intensity before efficiency gains become more visible.

2. On Electricity per Capita: Positive, Significant

The positive and statistically significant coefficient on electricity consumption per capita in the fixed-effects model is consistent with the electrification-productivity channel documented in the structural transformation literature. Broader and more reliable access to electricity enables the adoption of more productive technologies in manufacturing, services, and logistics, thereby increasing economic output per unit of total energy consumed (Lean & Smyth, 2010; Ang, 2008).

However, this result should be interpreted cautiously because the environmental implications of electrification depend on the electricity generation mix. If additional electricity demand is met primarily through carbon-intensive generation, higher electricity use may improve measured energy productivity without necessarily reducing emissions.

3. On Renewable Energy Share: Positive, Not Significant

The positive but statistically insignificant coefficient on renewable energy share may reflect limited within-country variation during the study period. In several ASEAN-5 economies, renewable energy shares changed slowly, while fossil fuels continued to dominate the energy mix. This makes it difficult to detect a statistically significant association within the available sample. Thus, the statistically insignificant coefficient should not be interpreted as evidence that renewable energy lacks environmental value. Rather, in this sample, the result may reflect limited short-run variation, slow infrastructure turnover, or the early-stage nature of the renewable energy transition in several ASEAN-5 economies.

Policy Implications for ASEAN-5 Infrastructure and Energy Planning

The findings provide several practical implications for infrastructure and energy policy in ASEAN-5.

First, governments should integrate energy-efficiency indicators into infrastructure appraisal frameworks. Since this study measures infrastructure efficiency using GDP per unit of energy use, infrastructure projects should be assessed not only by investment size or output growth but also by their expected contribution to reducing energy intensity and emissions per unit of output. Such indicators can be applied in the national infrastructure plans, public-private partnership evaluations, feasibility studies, and post-project monitoring.

Second, the negative and statistically significant association between CO_2 emissions per capita and infrastructure efficiency suggests that carbon-intensive development may reduce the economic productivity of energy use. ASEAN-5 countries should therefore prioritize investments that lower the carbon intensity of infrastructure systems, including low-carbon electricity generation, industrial energy-efficiency upgrades, public transport improvement, grid-loss reduction, and the gradual retirement or retrofitting of high-emission capital stock. These measures are particularly important in sectors with

long-lived infrastructure, such as power generation, transportation, logistics, and industrial estates.

Third, the positive association between electricity consumption per capita and infrastructure efficiency indicates that electrification can support more productive economic activity when paired with cleaner and more efficient electricity systems. Policy should therefore promote productive electrification in industrial processes, public transportation, digital infrastructure, cold-chain logistics, and energy-efficient buildings, while also accelerating grid decarbonization and renewable energy integration. This policy direction is aligned with ASEAN's regional energy cooperation agenda, particularly the ASEAN Plan of Action for Energy Cooperation and the ASEAN Power Grid, which emphasize energy connectivity, energy security, sustainability, and clean energy cooperation.

Fourth, ASEAN-5 countries should accelerate renewable energy deployment while addressing practical implementation barriers such as grid limitations, financing constraints, permitting delays, and intermittency management. In the authors' interpretation, the statistically insignificant renewable energy coefficient may reflect limited within-country variation, slow infrastructure turnover, and time lags between renewable energy deployment and measurable efficiency gains rather than the absence of policy relevance.

Finally, green finance and transition-finance mechanisms should be linked to measurable improvements in energy productivity and CO_2 reduction, following emerging regional examples such as the Indonesia and Vietnam Just Energy Transition Partnership frameworks.

Limitations and Future Research

This study has several limitations. *First,* GDP per unit of energy use is an aggregate proxy for infrastructure efficiency rather than a direct measure of infrastructure performance. It does not disaggregate the data by sector, project type, or service-quality dimensions such as reliability, resilience, and inclusiveness. *Second,* the effective regression sample is restricted because some indicators have missing values, thereby limiting the number of complete observations for the panel models. *Third,* because the analysis includes only five ASEAN economies over the 2010–2023 period, it is unable to estimate more complex dynamics, interactions, and non-linear relationships. *Fourth,* the model omits several potentially important determinants, including fuel costs, institutional quality, industrial structure, and sectoral infrastructure investment.

Although the lagged-variable model and GDP-growth control provide useful robustness checks, they do not fully eliminate potential endogeneity. Dynamic feedback between infrastructure efficiency, electricity consumption, and CO_2 emissions, as well as omitted variables such as fuel prices, institutional quality, industrial structure, and sector-level infrastructure investment, may still affect the analysis. Future studies could address these issues using longer panels, sector-level data, and dynamic panel estimators such as Arellano–Bond GMM (Arellano & Bond, 1991).

CONCLUSION

This study assessed energy-related infrastructure efficiency in ASEAN-5 countries using GDP per unit of energy use as the main outcome variable. By examining this indicator in relation to GDP per capita, CO_2 emissions per capita, renewable energy share, and electricity consumption per capita, the

study provides a macro-level analysis of the relationship between energy productivity, environmental conditions, and economic structure in the region.

The fixed-effects results show that CO_2 emissions per capita have a negative and statistically significant association with infrastructure efficiency, while electricity consumption per capita has a positive and statistically significant association. Meanwhile, GDP per capita and renewable energy share have positive coefficients but are statistically insignificant. These results imply that, in the current sample, lower carbon intensity and more productive electricity use are more strongly associated to infrastructure efficiency than income growth alone.

The findings underline the need to incorporate energy productivity and emissions indicators into infrastructure planning. In addition to expanding electricity use, improving infrastructure efficiency in ASEAN-5 requires cleaner energy systems, a stronger emphasis on reducing carbon intensity in investment planning, and more robust data on the value added by infrastructure projects. Future research should extend the analysis by using sector-level infrastructure indicators, longer time periods, and dynamic panel methods.

ABOUT THE AUTHORS

Laili Fitria is a lecturer in the Department of Environmental Engineering at Universitas Tanjungpura, Pontianak, Indonesia. Her expertise lies in climate change and risk-related studies, with research interests covering environmental assessment, climate vulnerability, and sustainable environmental management. She is actively engaged in academic teaching and research on environmental issues, particularly those related to climate impacts and adaptation. She can be contacted via email at fitria.laili@gmail.com.

Putra Maha Muda works at the Center for Educational Assessment Management, the Indonesian Ministry of Primary and Secondary Education (*Balai Pengelolaan Pengujian Pendidikan*, or BP3), Jakarta, Indonesia. His expertise is in the fields of computer science, big data analysis, and application/software development. His professional and research interests include data-driven analysis, information systems, digital tools, and application design to support decision-making and institutional needs. He can be contacted at r.putra83@gmail.com.

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Appendix Table A1. Robustness checks for the fixed-effects model

Variable	Baseline FE coef.	Baseline p-value	Lagged FE coef.	Lagged p-value	FE + GDP growth coef.	FE + GDP growth p-value
ln(GDP per capita)	1.4617	0.2319	0.8310	0.5250	1.4662	0.2354
ln(CO_2 per capita)	-3.3374**	0.0101	-0.9063	0.5030	-3.3474**	0.0109
Renewable energy share (%)	0.0555	0.1928	0.1048**	0.0245	0.0561	0.1969
ln(Electricity per capita)	4.5354***	0.0009	3.3918**	0.0171	4.5615***	0.0011
GDP growth (%)	—	—	—	—	0.0025	0.9242
Observations	60		60		60	
Countries	5		5		5	
Within R^2	0.4263		0.2542		0.4264	

Note: The dependent variable is GDP per unit of energy use. All models include country fixed effects. The lagged FE model uses one-period lagged explanatory variables. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

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