



Bridging the Urban Transport Paradox: Transit-Oriented Development and the Integrated Low-Carbon Mobility Framework (ILCMF) for Metropolitan Jabodetabek

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The transportation sector is one of the largest contributors to global carbon emissions and represents a major challenge in the urban decarbonization agenda. In Indonesia, transportation accounts for approximately 27% of total national emissions, with the Greater Jakarta (Jabodetabek) metropolitan area being the highest contributor due to high daily mobility, urban sprawl, and governance fragmentation. This study aims to analyze the role of Transit-Oriented Development (TOD) as a systemic strategy in supporting the transition toward low-carbon mobility and to develop a conceptual model called the Integrated Low-Carbon Mobility Framework (ILCMF). The study identifies four key dimensions in the decarbonization of transportation — environmental, institutional, technological, and social — that interact to shape a sustainable urban mobility system. The findings reveal that the success of low-carbon mobility transformation depends on cross-sectoral policy integration, the electrification of public transport, and community participation in mobility behavior change. The ILCMF provides an integrative framework for metropolitan transportation policymaking that is efficient, inclusive, and aligned with Indonesia's Net Zero Emission 2060 target.

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INTRODUCTION

Transport has become the most crucial sector in the global debate over modern climate change. According to the Intergovernmental Panel on Climate Change (Forster et al., 2025), this sector contributes about 23% of the world's total energy-based CO₂ emissions, with over 70% originating from land-based motor vehicles. The International

Energy Agency (IEA) warns that without systemic transformation, global transportation emissions could increase by up to 60% by 2050 due to accelerating urbanization and dependence on fossil fuels (Fajar, 2025). However, transportation also remains a vital driver of connectivity, trade, and social mobility that underpins global economic growth. This duality produces what scholars refer to as the *paradox of transportation sustainability*—where transport acts simultaneously as a catalyst for economic progress and a major contributor to the climate crisis.

In the context of developing countries, this dilemma becomes more complex because improvements in accessibility are often not followed by a transformation toward low-carbon systems (Hackl, 2018). Indonesia faces a similar situation. Based on data from the Ministry of Environment and Forestry (Kementrian Perhubungan Republik Indonesia, 2024). Indonesia, 2024), the transport sector produces around 157 million tonnes of CO₂e per year, or 27% of national emissions, ranking second after the industrial energy sector. Private vehicle growth, averaging 6% annually, far exceeds public transport infrastructure growth, which is only 0.5%, indicating a sustainability trade-off between mobility progress and energy efficiency. These trends confirm that Indonesia's transportation system remains heavily fossil-dependent and lacks equity in access and environmental balance.

To address this issue, Indonesia has set a Net Zero Emission (NZE) target for 2060, as articulated in the *Long-Term Strategy for Low Carbon and Climate Resilience 2050 (LTS-LCCR)* and reinforced by Presidential Regulation No. 98 of 2021 on *Carbon Economic Value (NEK)* (Mulyani & Octalica, 2023). Within this national decarbonization roadmap, transportation is a top priority alongside energy and industry. Strategies include vehicle electrification, strengthening mass public transportation, and implementing Transit-Oriented Development (TOD) as a spatial framework for low-carbon transition (Irianto & Wibowo, 2025). Yet, achieving these targets depends not only on technological progress but also on cross-sectoral governance reform and behavioral transformation as essential enablers of sustainable mobility.

In the metropolitan context, Greater Jakarta (Jabodetabek) illustrates the paradox of urban mobility in developing nations. As the largest metropolitan area in Southeast Asia—with a population exceeding 34.5 million and more than 58 million daily trips daily (Kementrian Perhubungan Republik Indonesia, 2024) the region faces chronic congestion, air pollution, and spatial disparity between residential and economic centers. Despite the operation of TOD-related projects such as MRT Jakarta, LRT Jabodebek, and TransJakarta–KRL integration, most remain sectoral and infrastructure-focused. The region continues to rely heavily on private vehicles, while the share of public transport users has declined sharply over the last decade. As a result, Jakarta ranks consistently among the top three cities with the worst air quality globally, with PM_{2.5} concentrations reaching 65–70 µg/m³, four times above the WHO safe threshold IQAir (2025). Beyond environmental concerns, institutional fragmentation among the 14 local governments in Jabodetabek has created overlapping mandates, inconsistent priorities, and weak coordination, further limiting the effectiveness of decarbonization policies.

The transportation system in Greater Jakarta reflects a deep paradox between mobility expansion and sustainability goals. Despite large-scale investments in public transit and infrastructure, the dominance of private vehicles and institutional fragmentation persist, causing rising congestion and emissions. This reveals not only a technical gap but also a systemic governance failure that hampers the effectiveness of low-carbon transition policies.

Previous studies on Transit-Oriented Development (TOD) in Indonesia have largely focused on spatial and economic aspects—such as land-use efficiency and property value (Hackl, 2018) while neglecting institutional coordination, behavioral change, and cross-sectoral integration. Consequently, TOD implementation has often been sectoral and fragmented, producing limited decarbonization outcomes.

In response, this research formulates a new conceptual model — the Integrated Low-Carbon Mobility Framework (ILCMF) — which integrates environmental, institutional, technological, and social dimensions into a single adaptive system. This model constitutes a strong conceptual innovation and a potential policy reference, bridging theoretical gaps and offering strategic guidance for metropolitan governance reform, behavioral transformation, and Indonesia’s transition toward a Net Zero Transport System by 2060.

Accordingly, the main research problem addressed in this study is: *How can an integrated, cross-dimensional model such as ILCMF strengthen the effectiveness of Transit-Oriented Development (TOD) as both a spatial and policy mechanism to achieve sustainable, low-carbon mobility in Greater Jakarta?*

From an academic perspective, there remains a clear research gap in Indonesian TOD studies. Most prior research emphasizes spatial and economic efficiency but rarely incorporates social, institutional, and behavioral dimensions within the broader context of urban decarbonization (Hackl, 2018; Suryawan et al., 2024). Non-technical factors—such as inter-agency coordination, public perception, and mobility culture—are critical yet understudied determinants of TOD success. Additionally, studies in developing countries often separate transportation analysis from energy policy and digital innovation, failing to explain the systemic links among spatial planning, behavioral dynamics, and climate governance.

Therefore, this study aims to analyze the role of Transit-Oriented Development (TOD) as a cross-dimensional strategy for achieving sustainable transportation integration in the Greater Jakarta metropolitan area. Furthermore, it develops the Integrated Low-Carbon Mobility Framework (ILCMF) that connects four key dimensions—environmental, institutional, technological, and social—within an interactive system.

Theoretically, this study expands the discourse on sustainable mobility from a sectoral to an integrative approach, positioning TOD not merely as a spatial planning concept but as a systemic transition mechanism. Practically, the results are expected to serve as a policy reference for designing decarbonization strategies through cross-sector collaboration and public participation.

This study addresses three core research questions:

1. How can the Transit-Oriented Development (TOD) framework align with Indonesia’s sustainable mobility and carbon reduction goals?
2. What governance and social factors most influence the effectiveness of TOD implementation in Greater Jakarta?
3. How can technological and policy innovations accelerate the transition toward a Net Zero Emission (NZE) 2060-oriented urban transport system?

By answering these questions, the research aims to enhance both theoretical understanding and practical policymaking for addressing the paradox of transportation sustainability and advancing an inclusive, efficient, and low-carbon future for Indonesia’s urban mobility.

LITERATURE REVIEW

Theoretical Foundation of Transit-Oriented Development (TOD)

Conceptually, Transit-Oriented Development (TOD) is an urban development paradigm that places public transportation as the center of interaction between humans and space (Stojanovski, 2020). Yap et al. (2021) explained that TOD is based on three main principles: density, diversity, and design. This principle emphasizes the importance of the development of mixed-use development around public transportation nodes so that people can live, work, and do activities without relying on private vehicles.

Global empirical studies show that the application of TOD is consistently able to reduce the paradox of urban emissions, where increased mobility actually reduces carbon intensity. The World Bank report (2023) notes that cities such as Tokyo, Hong Kong, and Seoul have managed to reduce CO₂ emissions by 35–45% through high density, short distances, and increased use of public transportation. In addition to ecological impacts, TOD also supports the right to mobility by expanding access for lower-middle-income groups (Suryawan et al., 2024).

However, the implementation of TOD in developing countries is often mired in systemic contradictions in governance (Yap et al., 2021). Fragmentation between institutions, overlapping authority, and social resistance to changes in mobility behavior cause the TOD approach to fail to function as a cross-sectoral strategy (Forster et al., 2025). Therefore, TOD should not be understood solely as a spatial project, but needs to be repositioned as an integrative policy instrument that unites transportation, spatial planning, energy, and social behavior policies in one adaptive urban system.

The Paradox of Sustainability in Urban Mobility

The sustainability paradox of urban mobility arises when increasing economic connectivity actually accelerates environmental degradation. Suryawan et al. (2024) highlights the demand-induced effect, where the construction of road infrastructure aimed at reducing congestion instead increases travel volume and carbon emissions. Jabodetabek is a real representation of this irony. Although the construction of toll roads and public transportation is massive, the use of private vehicles still dominates (Ortúzar, 2019).

Data from the DKI Jakarta Environment Agency (2024) shows that the transportation sector accounts for 44% of total urban greenhouse gas emissions, with 80% of them coming from private vehicles (Sasmita Nugroho, 2025). Ironically, the addition of 147 km of new toll roads since 2018 has actually increased the congestion rate by 13% (Google Mobility Report, 2024). This fact reinforces the thesis of Canton (2025) that expanding road capacity is just an illusion of efficiency which means that the more roads are built, the greater the demand for travel and the carbon emissions generated. This condition confirms the need for policy transformation from a supply-oriented approach to an integrated system based on TOD. Transportation development is not enough to be understood as physical expansion, but as a systemic strategy to address the trade-offs between mobility growth and ecological sustainability.

Social and Behavioral Dimensions in Transportation Sustainability

Transformation towards a low-carbon transportation system cannot be achieved without changing people's behavior (Forster et al., 2025). In the context of Jabodetabek, there is an intention-action gap that reflects a behavioral paradox where high awareness of environmental impacts is not followed by real action. The ITDP survey (2023) found

that 74% of citizens support public transportation to reduce pollution, but only 33% use it regularly. Comfort, travel time, and perception of social status are dominant factors in choosing a mode of transportation (Sultana et al., 2019).

Suryawan et al. (2024) call this phenomenon an environmental behavioral paradox, where mobility decisions are influenced more by social norms and self-identity than ecological awareness. To bridge the gap, many developed cities are adopting nudging policy and social incentive approaches. The "Green Commute" program in Singapore and the "Smart Mobility" program in Seoul are successful examples of how policy innovation can change people's mobility habits through a combination of technology and behavioral rewards (Ortúzar, 2019).

In addition, the social dimension is also related to spatial justice. Densely populated areas on the outskirts of Greater Jakarta, such as North Bekasi and South Tangerang, have not been fully served by the mass transportation system. As a result, low-income groups rely on low-cost, high-emission vehicles. This inequality of access reinforces the mobility justice dilemma, where the most vulnerable groups bear the greatest environmental impact.

Synthesis and Conceptual Gaps

This literature review confirms that transportation sustainability is a multidimensional issue that involves complex interactions between the environment, institutions, technology, and social behaviors. In this context, Transit-Oriented Development (TOD) has the potential to be an integrative framework to bridge the paradox of transportation development, as it combines space efficiency, modal shifts, technological innovation, and social inclusivity (Yap et al., 2021). However, the research gap is still significant, especially in developing countries such as Indonesia. Most studies on TOD have focused on spatial and economic aspects consisting of land efficiency, property value, and connectivity, but have not fully explored the institutional, behavioral, and policy dimensions across sectors that affect the decarbonization of transportation. As a result, TOD policies are often mired in systemic contradictions between agencies, where space, transportation, and energy planning runs without adequate coordination.

In response to this gap, the study proposes a new conceptual model, the Integrated Low-Carbon Mobility Framework (ILCMF) (Forster et al., 2025). This framework views TOD not just as a spatial approach, but as a systemic governance mechanism that synergizes four main dimensions, namely environmental, institutional, technological, and social in one sustainable transition system. With this approach, TOD is positioned as a strategic instrument to overcome the irony of urban mobility development, while supporting Net Zero Urban Mobility 2060 in metropolitan areas such as Greater Jakarta.

RESEARCH DESIGN AND METHODOLOGY

This study adopts a conceptual and qualitative-descriptive approach that integrates theoretical synthesis, secondary data analysis, and interactive visualization. The objective of this methodological design is to construct a comprehensive understanding of the relationship between urban mobility, governance, and low-carbon transition within the Jabodetabek metropolitan context. The research was conducted through several stages:

1. Literature-Based Conceptual Synthesis

The first stage involved an extensive review of academic literature, policy documents, and empirical reports related to sustainable mobility, Transit-Oriented Development (TOD), carbon governance, and low-carbon transition frameworks

(2018–2025). This synthesis helped identify theoretical gaps and policy contradictions in current TOD implementation.

2. Secondary Data Analysis

The second stage utilized secondary data from official institutions such as the Ministry of Transportation, BPTJ, IQAir, and the World Bank. Data on transportation volume, emissions, and mobility behavior were analyzed to describe systemic patterns of carbon lock-in and governance fragmentation in the metropolitan area.

3. Interactive Visualization and Spatial Interpretation

The third stage developed spatial heatmaps and trend visualizations to illustrate the correlation between mobility density, carbon emissions, and air pollution distribution in Jabodetabek. This visualization was produced using geospatial interpretation and serves as a diagnostic tool to support conceptual validation.

4. Model Formulation and Analytical Integration

The final stage integrated all findings into the Integrated Low-Carbon Mobility Framework (ILCMF). The model was constructed to connect four core dimensions—environmental, institutional, technological, and social—within a unified systemic transition approach.

This methodological combination enables the research to bridge theoretical concepts with empirical realities, ensuring that the proposed model is both conceptually robust and policy-relevant for sustainable metropolitan mobility transformation.

CONCEPTUAL FRAMEWORK AND ANALYTICAL APPROACH

Conceptual Foundations

Various sustainable transportation development models such as *Avoid–Shift–Improve (ASI)* and the *Compact City* paradigm have long been a reference in efforts to reduce carbon emissions (Suryawan et al., 2024). However, such models tend to place policy, technological, and social aspects separately tending to create conceptual fragmentation that weakens implementation on the ground. In the context of rapid urbanization such as Greater Jakarta, all of these aspects form a contradictory and interdependent system, so that an integrated approach is an urgent need.

Relying on the TOD theory from Stojanovski (2020) this study synthesizes three main principles consisting of *density*, *diversity*, and *design* with the theory of adaptive governance and social behavior. The result is a reinterpretation of TOD as a policy ecosystem, not just a spatial strategy. By placing the goal of decarbonization into institutional structures, technological innovation, and community participation, this approach affirms that the transformation of low-carbon mobility demands a balance between spatial efficiency, social legitimacy, and institutional coherence.

Thus, this study seeks to bridge the epistemological trade-off between physical planning theory and public policy, while expanding the space for sustainability analysis from a technocratic approach to a collaborative systemic paradigm.

Conceptual Model: Integrated Low-Carbon Mobility Framework (ILCMF)

As a conceptual contribution, this study proposes the Integrated Low-Carbon Mobility Framework (ILCMF) as a model that brings together diverse theoretical and empirical perspectives in a single cross-dimensional transition system (Wimbadi et al., 2021). In this model, *Transit-Oriented Development (TOD)* acts as a catalyst that

connects four main subsystems: environmental, institutional, technological, and social, which interact dynamically and reinforce each other (Yap et al., 2021).

The environmental dimension focuses on mitigating carbon emissions through dense urban planning, reducing daily travel distances, shifting modes to public transportation, and using clean energy. This approach is in line with the *low-carbon transition literature* (Schwanen, 2020) (which emphasizes the importance of *spatial density* to reduce emissions per capita. In the context of Jabodetabek, this dimension also serves to unravel the ecological irony, where uncontrolled urbanization actually increases the carbon footprint.

The institutional dimension highlights the *governance dilemma* due to the fragmentation of authority in metropolitan areas. Greater Jakarta, with 14 government entities, reflects systemic contradictions in governance that often hinder the synchronization of transportation policies and energy management. The ILCMF proposes the establishment of a metropolitan transportation authority such as *the Greater Jakarta Transport Authority (GJTA)* which has a cross-regional mandate for planning coordination, pembiayaan, dan pengawasan kebijakan transportasi rendah karbon secara terpadu.

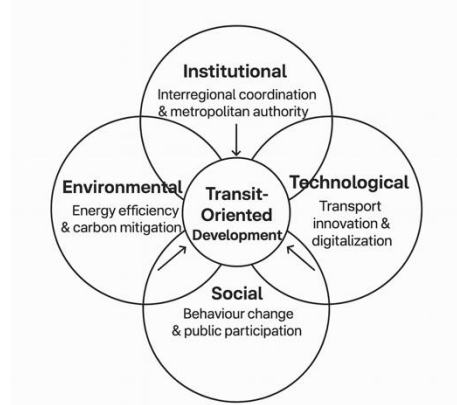
The technology dimension is the motor of efficiency, transparency, and innovation. Initiatives such as vehicle electrification, transportation digitalization, and the implementation of Intelligent Transport Systems (ITS) function to reduce energy consumption while optimizing mobility. The integration of multimodal data in a single smart mobility platform allows for real-time synchronization of schedules, fares, and information, resulting in the dual benefits of operational efficiency and reduced emissions (Ortúzar, 2019).

Meanwhile, the social dimension determines long-term sustainability. Transforming people's behavior is needed to close *the intention-action gap*, where environmental awareness has not always been followed by real action. ILCMF utilizes the perspective of *behavioral economics* and *social practice theory* (Schwanen, 2020) to explain how perceptions of comfort, social status, and community norms affect transportation choices. Through public education, behavior-based incentives, and community participation, a culture of mobility change can grow gradually but sustainably (Sultana et al., 2019).

These four dimensions form an integrative system with a mutual reinforcement mechanism. Technological innovation supports environmental efficiency; inclusive governance increases social legitimacy; and behavior change strengthens the effectiveness of public policies. Thus, within the framework of the ILCMF, TOD evolved from a physical planning strategy to a systemic transition mechanism towards adaptive, collaborative, and equitable low-carbon urban transportation.

As a synthesis of the conceptual description above, Figure 1 shows the structure and dynamics of interdimensional interactions in the Integrated Low-Carbon Mobility Framework (ILCMF). This model places Transit-Oriented Development (TOD) as the center of the integration of low-carbon mobility systems, which serve as a catalyst for cross-dimensional coordination—environmental, institutional, technological, and social (Stojanovski, 2020).

Figure 1. Integrated Low-Carbon Mobility Framework



Source: developed by the author based on the synthesis of theory and analysis

Each dimension has a complementary role, where technological innovation drives energy efficiency and emission reduction; institutional reform ensures policy consistency; the social dimension strengthens public legitimacy and behavior change; Meanwhile, the environmental dimension is the final goal in carbon mitigation efforts (Hackl, 2018). The two-way arrow indicates the interactive and adaptive nature of this system, where changes in one dimension will provide feedback (feedback loop) to the other dimension. Thus, ILCMF represents a systemic transition mechanism that bridges spatial policies, technological innovation, and social transformation in realizing sustainable transportation in Greater Jakarta.

Model Analysis and Visualization Process

The analysis process in this study is carried out in stages to maintain the integration between theory, secondary data, and conceptual model design. The first stage, conceptual synthesis, involves mapping the literature related to sustainability, TOD, and transportation governance to identify points of convergence and *policy contradictions* (Stojanovski, 2020). The second stage, the formulation of an integrative framework, compiles an ILCMF model that functionally connects policy theory and implications.

Visually, ILCMF is described as an interactive concentric system. At the core of the model, TOD becomes the center of spatial and operational integration (Wimbadi et al., 2021). The next layer includes four subsystems, namely environmental, institutional, technological, and social that interact through reciprocal flows. Each interaction demonstrates a causal relationship consisting of institutional reforms driving the adoption of green technologies, technologies lowering emissions, and social change strengthening policy legitimacy.

The outermost layer illustrates national policy cohesion towards Net Zero Emission 2060, emphasizing the importance of cross-sector coordination between energy, transportation, and spatial planning. With this design, ILCMF shows that transportation sustainability cannot be achieved through sectoral solutions, but through an evolutionary and inclusive multi-level governance system (Sultana et al., 2019).

Conceptual Contributions

The Integrated Low-Carbon Mobility Framework (ILCMF) model offers theoretical and practical contributions to the study of sustainable transport in developing countries (Wimbadi et al., 2021). Conceptually, this model expands the meaning of

Transit-Oriented Development (TOD) from just a spatial strategy to a cross-sector governance mechanism to support the decarbonization of metropolitan transportation.

In theory, the ILCMF expands the *Avoid–Shift–Improve (ASI) paradigm* by adding institutional and social dimensions, overcoming the classic policy dilemma between technical efficiency and public legitimacy (Schwanen, 2020). Thus, transportation sustainability is understood as the result of multi-level interactions between effective governance, technological innovation, and social transformation.

From a policy perspective, ILCMF offers a solution to the trade-offs of transportation governance in Greater Jakarta by encouraging the formation of an integrated metropolitan authority as well as the synergy of digitalization, electrification, and community participation. This model shows how institutional reform and social innovation can work together to reduce carbon emissions without sacrificing economic growth (Schwanen, 2020). In addition, the ILCMF closes the conceptual literature gap that has dominated TOD studies in Southeast Asia — which tends to focus on spatial and economic dimensions. This model introduces a *multi-level governance* approach that integrates national policies, metropolitan coordination, and local initiatives in a single low-carbon transition system.

Thus, the ILCMF is not only a theoretical innovation, but also a practical policy framework that is relevant for Indonesia in realizing efficient, inclusive, and *Net Zero Emission 2060-oriented* mobility. This model confirms that true transportation sustainability can only be achieved through synergy between structure, behavior, and innovation, not simply through infrastructure expansion.

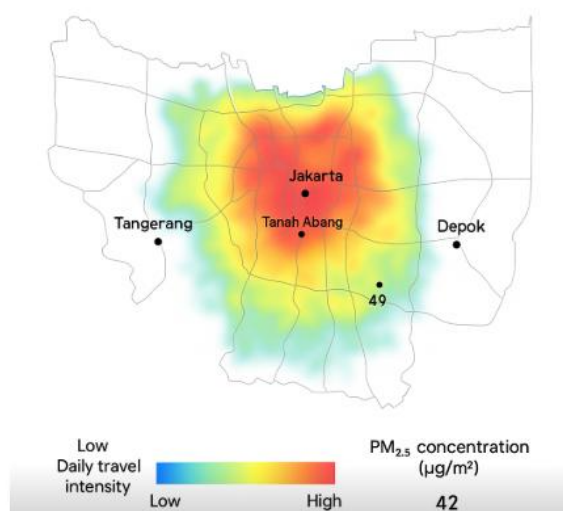
ANALYSIS AND DISCUSSION

Transport Paradox in Jabodetabek

The mobility phenomenon in Greater Jakarta reflects the classic development paradox, where economic progress and environmental degradation go hand in hand. With a population of more than 34.5 million people, this metropolitan area serves as a center of national economic growth as well as the epicenter of congestion and air pollution in Southeast Asia. Data from the Greater Jakarta Transportation Management Agency Jakarta (2025) shows that daily trips have increased from 47 million in 2015 to 58 million in 2023. Ironically, the proportion of trips by private vehicle rose from 54% to 68%, while the use of public transport dropped from 42% to 28%.

To provide a visual overview of the relationship between mobility intensity and air pollution in the Greater Jakarta metropolitan area, Figure 2 shows a heatmap-based spatial map that represents the distribution of traffic density levels and air pollutant concentrations (PM_{2.5}) in this region.

Figure 2. Spatial Map of Mobility and Pollution of Jabodetabek (Heatmap)



Source: developed by the author based on secondary data and spatial interpretation

The pattern shown on the map shows that the highest mobility density and concentration of air pollution accumulate in centers of economic activity and transportation, such as Central Jakarta, South Jakarta, and parts of Tangerang and Bekasi. These areas are marked with red zones, illustrating the high intensity of daily travel as well as significant carbon emissions from fossil fuel motor vehicles. Meanwhile, green to yellow zones in Bogor, southern Depok, and East Bekasi showed relatively better air quality and lower levels of mobility.

This spatial distribution confirms the paradox of urban mobility in Greater Jakarta, where the center of economic growth is also the center of environmental degradation. Pollution concentrations in areas with high mobility reinforce the empirical findings of BPTJ (2024) and IQAir (2024) that the transportation sector is a major contributor to carbon emissions and fine particulates (Sasmita Nugroho, 2025). In addition, the map illustrates the effect of carbon lock-in geographically, where areas with dense road infrastructure and private vehicles tend to maintain high emission levels despite the availability of public transportation modes.

The spatial patterns visualized in this heatmap reinforce the urgency of implementing the Transit-Oriented Development (TOD) approach systemically (Stojanovski, 2020). By concentrating activities on public transport nodes and improving intermodal connectivity, traffic congestion and emissions in red zones can be significantly reduced. Therefore, this visualization not only illustrates existing conditions, but also serves as a *diagnostic tool* to identify policy priorities and areas of intervention in the decarbonization strategy of metropolitan transport.

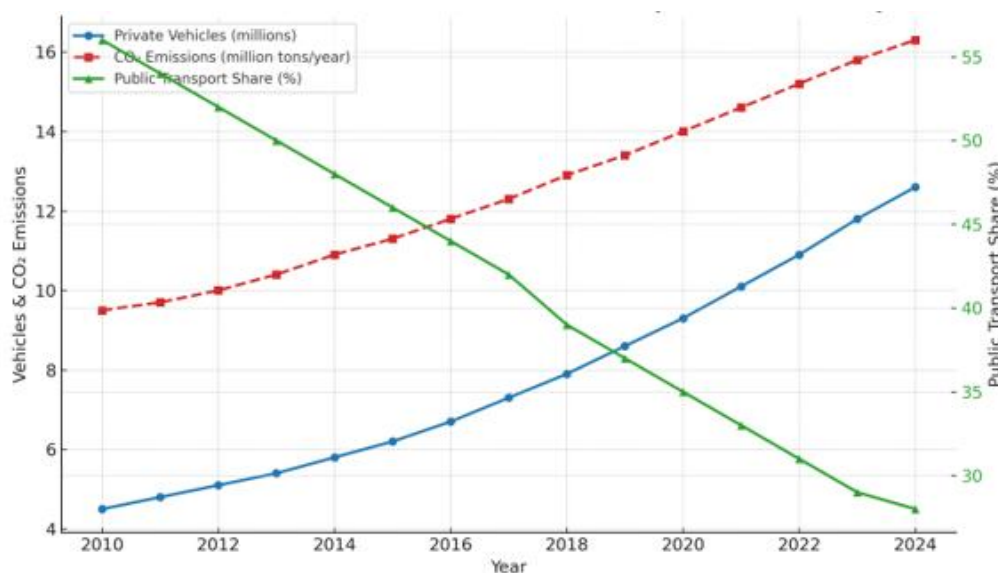
This trend has direct implications for the surge in carbon emissions. The total CO₂ emissions of the transportation sector in Greater Jakarta now reach 16.3 million tons per year, an increase of almost 30% in a decade. About 80% is produced by fossil-fueled private vehicles, exposing a condition of carbon lock-in, where systemic dependence on high-emission modes of transport is difficult to change without structural reform (Kementrian Perhubungan Republik Indonesia, 2024).

The ecological impact is even more worrying. Based on the IQAir report the concentration of PM_{2.5} pollutants in Jakarta averages 65–70 µg/m³, or four times above

the WHO safe threshold ($15 \mu\text{g}/\text{m}^3$) (Sasmita Nugroho, 2025). Pollution from transportation accounts for the dominant proportion, especially from diesel vehicles and motorcycles. Socio-economically, the Health Effects Institute study (2024) estimates that transportation pollution results in economic losses of up to USD 2.8 billion per year and more than 10,000 premature deaths.

"The causal relationship between the increase in the number of private vehicles, the decrease in the use of public transportation, and the increase in carbon emissions in the Greater Jakarta area can be observed more clearly in the following Figure 3. This graph shows the dynamics of transportation over the period 2010–2024, showing that the growth of private vehicles is directly proportional to the increase in CO₂ emissions, while the proportion of public transport users continues to decline significantly. The pattern confirms that the main challenge in urban mobility systems lies not only in the availability of infrastructure, but also in the structural dependence on fossil fuel-based modes of transportation."

Figure 3. Trends in Vehicle Growth, CO₂ Emissions, and Public Transportation Use



Source: Processed by the author based on data from BPTJ (2024), World Bank (2023), and Ministry of Transportation (2024)

Figure 3 shows the dynamic trend between the growth in the number of private vehicles, the increase in carbon dioxide (CO₂) emissions, and the decrease in the use of public transportation in the Greater Jakarta area during the period 2010–2024. This graph confirms that the higher the ownership of private vehicles, the greater the contribution of the transportation sector to urban carbon emissions. During the period, the number of private vehicles increased from about 2.5 million units to more than 6.2 million units, while the proportion of public transport users decreased sharply from 56% to just 28%. This trend is directly proportional to the increase in CO₂ emissions from 9.8 million tons to 16.3 million tons per year (Sasmita Nugroho, 2025).

The linkage between the three variables reflects the carbon lock-in effect that occurred in Greater Jakarta — where the growth of private vehicles strengthens dependence on fossil fuels, even as public transportation policies continue to expand. This

phenomenon confirms the *hypothesis induced demand* Loo et al. (2023) that increasing the capacity of road infrastructure without a shift in mode actually worsens emissions.

This condition confirms the irony of mobility policy, where every effort to improve connectivity through road construction actually exacerbates congestion and emissions. This phenomenon is known as induced demand Hymel (2019) which means that the greater the road capacity, the higher the demand for travel. Without a paradigm shift towards systemic low-carbon mobility, Greater Jakarta risks being trapped in a vicious cycle between economic growth, dependence on private vehicles, and a decline in environmental quality.

TOD Implementation and Gaps

In response to this mobility crisis, the government initiated the Transit-Oriented Development (TOD) policy since 2016 through the Greater Jakarta Transportation Master Plan (RITJ) and DKI Jakarta Governor Regulation Number 67 of 2019. Currently, more than 20 TOD areas have been developed, including strategic nodes such as Dukuh Atas, Lebak Bulus, Fatmawati, Tanah Abang, West Bekasi, and Cawang (P. G. Jakarta, 2019). This initiative is accompanied by the presence of mass public transportation modes such as MRT Jakarta, LRT Jabodebek, TransJakarta, and KRL Commuter Line which function as the backbone of regional integration.

The initial impact was quite positive. MRT Jakarta serves around 213,000 passengers per day, LRT Jabodebek around 60,000, while TransJakarta serves more than one million daily users. Kementrian Perhubungan Republik Indonesia (2024) estimates that if spatial integration, tariffs, and schedules are fully implemented, transportation emissions can be reduced by up to 1.8 million tons of CO₂ per year. However, this achievement still leaves an implementable contradiction between the policy vision and the operational reality.

Institutional fragmentation between agencies consisting of BPTJ, the Jakarta Transportation Agency, and local governments will cause a significant governance gap. The Index of Transit Integration in Greater Jakarta only achieved a score of 55 out of 100 Fawwaz & Rakhmatulloh (2021), far below sustainable cities such as Seoul and Singapore. In addition, some TOD projects emphasize commercial functions rather than social roles, making them commoditized transit spaces rather than instruments of mobility inclusion. As a result, TOD in Greater Jakarta is still operating within a sectoral framework, not yet a cross-policy system as the original concept. This shows the transportation policy dilemma between short-term economic orientation and long-term systemic needs. Without cross-sector coordination and proper incentive mechanisms, the potential of TOD as a catalyst for low-carbon mobility is difficult to fully realize.

Behavioral and Governance Barriers

The next obstacles are social and institutional. a study Fawwaz & Rakhmatulloh (2021) shows that although 74% of Greater Jakarta residents are aware of the benefits of public transportation to the environment, only 33% use it regularly. This difference reflects the intention-action gap, which is the gap between awareness and behavior (Suryawan et al., 2024). The factors of comfort, travel time, and perception of social status make private vehicles remain a symbol of efficiency and prestige.

Other issues are spatial inequality and mobility equity. Densely populated areas in the suburbs such as North Bekasi and South Tangerang are not yet fully connected to the mass transportation system. As a result, low-income groups rely on high-emission low-

emission motorcycles and vehicles. This pattern deepens the mobility divide, where vulnerable groups bear the brunt of the highest pollution impacts.

From the institutional side, Greater Jakarta faces a contradiction in metropolitan governance. Fourteen local governments have different development priorities, so transportation policies often overlap. The absence of a single authority weakens coordination and accountability of cross-regional policies. As a result, the national vision of Net Zero Transport is not fully implemented at the local level. This creates a multi-level governance dilemma, where national ambitions are hampered by regional fragmentation.

Innovation and Policy Acceleration

Accelerating the transition to low-carbon mobility requires a combination of technological innovation and policy reform (Suryawan et al., 2024). Electrification of motor vehicles is the main strategy. Based on data from the Ministry of Energy and Mineral Resources (2024), the national target is to set 15 million units of electric vehicles operating by 2035. However, the adoption rate in Greater Jakarta only reached 1.2% of the total vehicle population. The main obstacle is the limitation of infrastructure: by 2025 there will be only 420 Public Electric Vehicle Charging Stations (SPKLU), while the ideal need reaches more than 3,000 units (Kementrian Perhubungan Republik Indonesia, 2024).

In addition to electrification, the implementation of Intelligent Transport Systems (ITS) has shown tangible results. ITS in the Sudirman–Thamrin corridor, for example, has managed to reduce travel time by 18% and save fuel by up to 12%, equivalent to a reduction of 45,000 tons of CO₂ per year (Suryawan et al., 2024). This kind of digital innovation proves that smart mobility not only improves efficiency, but also serves as a measurable climate mitigation tool.

In terms of policy, the implementation of Carbon Economic Value (NEK) as stipulated in Presidential Regulation No. 98/2021 opens up opportunities for the implementation of carbon pricing in the transportation sector. Emission-based parking and toll schemes can encourage private vehicle users to switch to public mode, while creating new funding for green infrastructure. Furthermore, green financing through carbon credits and public-private partnerships (PPPs) can accelerate the development of clean transportation networks and integrated digital systems (Kementrian Perhubungan Republik Indonesia, 2024).

As such, technological innovation and carbon economy policies should be seen as two sides of a cross-dimensional transformation—technology provides the tools for change, while policy provides direction, legitimacy, and sustainability incentives.

Toward an Integrated Low-Carbon Mobility Framework (ILCMF)

The results of empirical analysis and literature synthesis show that mobility challenges in Greater Jakarta are multidimensional and systemic, involving the interaction between environmental, social, technological, and institutional factors. Therefore, a single sector-based solution is no longer adequate. An integrative approach is needed that brings structural, technological, and behavioral aspects together into one collaborative framework (Wimbadi et al., 2021).

The Integrated Low-Carbon Mobility Framework (ILCMF) model offers such a transition structure. In this model, TOD serves as a axis of spatial and policy integration that connects four main pillars: carbon mitigation and energy efficiency (environment), cross-

regional coordination and institutional (institutional) reform, transportation digitalization and electrification (technology), and behavioral transformation and public (social) participation. This four-dimensional synergy results in an efficient, inclusive, and Net Zero Emission 2060-oriented mobility system (Suryawan et al., 2024).

More than that, the ILCMF represents a new paradigm of urban mobility governance in developing countries — where decarbonization is not only understood as an environmental issue, but as a social and institutional transformation project. With the application of this model, Greater Jakarta has the potential to become a green transition policy laboratory in Southeast Asia, demonstrating that economic growth and ecological sustainability should not be positioned as two opposing poles, but can be brought together in an integrated metropolitan governance framework.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study concludes that the fundamental challenge of the transportation system in Greater Jakarta lies in the paradox between mobility growth and environmental sustainability. The dominance of private vehicles, chronic congestion, and rising carbon emissions indicate the persistence of a *carbon lock-in* that deepens dependence on fossil energy. Infrastructure expansion without spatial and institutional integration has worsened air pollution and diminished the quality of urban life.

To overcome this paradox, the study develops the Integrated Low-Carbon Mobility Framework (ILCMF), which integrates four key dimensions — environmental, institutional, technological, and social — into a unified system for sustainable mobility transformation. Within this framework, Transit-Oriented Development (TOD) serves not only as a spatial policy tool but also as a governance mechanism that connects energy efficiency, institutional reform, technological innovation, and social adaptation.

Theoretically, the ILCMF contributes to the development of a holistic understanding of decarbonization in developing metropolitan regions, emphasizing that sustainability in urban transportation must be addressed through multi-dimensional integration rather than sectoral intervention. Future research is encouraged to empirically validate the ILCMF model using quantitative and system dynamics approaches to measure the relationship between TOD density, mobility behavior, and emission intensity.

Recommendations

The transition toward low-carbon transportation in Greater Jakarta requires a paradigm shift from a purely technical to a structural, institutional, and behavioral approach. Governance reform is essential, particularly through the establishment of the Greater Jakarta Transport Authority (GJTA) to coordinate transportation, spatial, and energy policies across administrative boundaries. This integrated authority would align local and national policies with Indonesia's Net Zero Transport 2060 vision, ensuring coherence and efficiency in metropolitan mobility planning.

Economic instruments must also be optimized through carbon pricing, green financing, and public-private partnerships (PPP) to support the decarbonization of public transportation, fleet electrification, and the development of inclusive housing in TOD areas. Fiscal policy should act not only as a funding mechanism but as a transformative tool that directs investments toward sustainable infrastructure and digital mobility innovation.

In the technological domain, the acceleration of electrification and digitalization through zero-emission corridors, Intelligent Transport Systems (ITS), and integrated mobility data platforms will enhance efficiency, reduce energy consumption, and strengthen transparency. However, electrification must be accompanied by a renewable energy transition to ensure that carbon reductions are genuine and measurable.

From the social perspective, behavior change remains the cornerstone of sustainability. Programs such as *Green Mobility Awareness* and incentives for multimodal and green commuting can foster a culture of sustainable mobility. Ensuring equitable access to affordable housing in TOD zones will also prevent carbon gentrification and social exclusion.

REFERENCES

- Dwitama, R. H., & Ningrum, N. K. (2025). IoT-Based Prediction of Ornamental Plant Water Needs Using Sugeno Fuzzy Algorithm. *Journal of Applied Informatics and Computing*, 9(4), 1751–1759.
- Fajar, A. N. (2025). Strategi Blue Bird dalam Menghadapi Disrupsi Ride-Hailing di Indonesia. *Ekonomi Dan Pembangunan Indonesia*, 3(3).
- Fawwaz, F., & Rakhmatulloh, A. R. (2021). Analisis Pelayanan Integrasi Antarmoda Berdasarkan Persepsi Pengguna Di Krl Stasiun Sudirman. *Jurnal Pengembangan Kota*, 9(1), 111–123.
- Forster, P. M., Smith, C., Walsh, T., Lamb, W. F., Lamboll, R., Cassou, C., Hauser, M., Hausfather, Z., Lee, J.-Y., & Palmer, M. D. (2025). Indicators of Global Climate Change 2024: annual update of key indicators of the state of the climate system and human influence. *Earth System Science Data Discussions*, 2025, 1–72.
- Hackl, A. (2018). Mobility equity in a globalized world: Reducing inequalities in the sustainable development agenda. *World Development*, 112, 150–162.
- Hymel, K. (2019). If you build it, they will drive: Measuring induced demand for vehicle travel in urban areas. *Transport Policy*, 76, 57–66.
- Irianto, A. D., & Wibowo, K. U. (2025). PENGEMBANGAN INOVASI TRANSIT ORIENTED DEVELOPMENT DENGAN ELECTRIC VEHICLE SEBAGAI SMART MOBILITY PENGURANGAN EMISI DAN PEMBANGUNAN BERKELANJUTAN DI IBU KOTA NUSANTARA. *Integrative Perspectives of Social and Science Journal*, 2(2 Maret), 1495–1508.
- Jakarta, M. (2025). *Sepanjang 2024, Lebih Dari 40,8 Juta Orang Gunakan MRT Jakarta*. <https://www.jakartamrt.co.id/id/info-terkini/sepanjang-2024-lebih-dari-408-juta-orang-gunakan-mrt-jakarta>
- Jakarta, P. G. (2019). Penyelenggaraan Kawasan Berorientasi Transit. *Peraturan Menteri Agraria*.
- Kementrian Perhubungan Republik Indonesia. (2024). Transportasi Umum Massal Indonesia Menuju Zero Emission. *Kementrian Perhubungan Republik Indonesia*, 1(1). <https://doi.org/10.26418/lantang.v1i1.18812>

- Loo, B. P. Y., Li, L., & Namdeo, A. (2023). Reducing road transport emissions for climate policy in China and India. *Transportation Research Part D: Transport and Environment*, 122, 103895.
- Mulyani, H. T. S., & Octalica, C. (2023). Keterkaitan Sustainability Report Dengan Kesiapan Implementasi Regulasi Pemerintah Melalui Peraturan Presiden No. 98 Tahun 2021 Tentang Penyelenggaraan Nilai Ekonomi Karbon. *Jurnal Media Akuntansi (Mediasi)*, 6(1), 79–86.
- Ortúzar, J. de D. (2019). Sustainable urban mobility: What can be done to achieve it? *Journal of the Indian Institute of Science*, 99(4), 683–693.
- Sasmita Nugroho, S. E. (2025). Menteri LH Pimpin Uji Emisi Nasional di Kawasan Berikat: Langkah Nyata Menuju Langit Biru di Kawasan Pelabuhan. *Kementerian Lingkungan Hidup/Badan Pengendalian Lingkungan Hidup (KLH/BPLH)*. kemenlh.go.id
- Schwanen, T. (2020). Low-carbon mobility in London: a just transition? *One Earth*, 2(2), 132–134.
- Stojanovski, T. (2020). Urban design and public transportation–public spaces, visual proximity and Transit-Oriented Development (TOD). *Journal of Urban Design*, 25(1), 134–154.
- Sultana, S., Salon, D., & Kuby, M. (2019). Transportation sustainability in the urban context: a comprehensive review. *Urban Geography*, 40(3), 279–308.
- Suryawan, I. W. K., Mulyana, R., Septiariva, I. Y., Prayogo, W., Suhardono, S., Sari, M. M., & Ulhasanah, N. (2024). Smart urbanism, citizen-centric approaches and integrated environmental services in transit-oriented development in Jakarta, Indonesia. *Research in Globalization*, 8, 100181.
- Wimbadi, R. W., Djalante, R., & Mori, A. (2021). Urban experiments with public transport for low carbon mobility transitions in cities: A systematic literature review (1990–2020). *Sustainable Cities and Society*, 72, 103023.
- Yap, J. B. H., Chua, C. Y., & Skitmore, M. (2021). Towards sustainable mobility with transit-oriented development (TOD): understanding greater Kuala Lumpur. *Planning Practice & Research*, 36(3), 314–336.