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Analysis of the Use of Smart Mobility and Green Infrastructure to Reduce Carbon Emissions in Jakarta

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ABSTRACT

This study investigates the impact of smart mobility and green infrastructure on reducing carbon emissions in Jakarta. Rapid urbanization and increasing transportation demands have significantly contributed to environmental degradation in the city, necessitating sustainable solutions. A quantitative research design was employed, collecting data from 115 respondents using a structured Likert-scale questionnaire. The data were analyzed using SPSS version 25, including descriptive statistics, validity and reliability tests, classical assumption checks, and multiple linear regression analysis. The results indicate that both smart mobility and green infrastructure have a positive and significant effect on carbon emission reduction, with smart mobility exhibiting a slightly stronger influence. These findings suggest that integrating innovative transportation technologies with environmentally friendly urban infrastructure can effectively mitigate carbon emissions, offering valuable insights for policymakers and urban planners seeking sustainable development strategies in Jakarta and other megacities.

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1. INTRODUCTION

Urbanization and rapid population growth have intensified transportation demands and energy consumption in major cities, leading to higher carbon emissions and environmental degradation, a condition clearly illustrated by Jakarta's severe traffic congestion, high fossil fuel dependence, and rising greenhouse gas emissions. The city's dense population, inadequate public transportation, and high private vehicle ownership exacerbate congestion and fuel consumption, ultimately diminishing residents' quality of life. Jakarta recorded a congestion level of 53% in 2019, making transportation the largest contributor to air pollution [1], while the Odd-Even traffic restriction policy has produced mixed outcomes due to enforcement challenges and limited public compliance [2]. Urbanization has also reduced land cover, contributing to increased flooding and higher surface temperatures [3], although at certain periods population growth did not always directly correlate with worsening air quality [3]. The city's road-based transportation system significantly drives CO_2 emissions, which surged by 270% between 2005 and 2015 [4], and despite efforts to promote sustainable transport—such as the Bus Rapid Transit, KRL Commuter Line, and Mass Rapid Transit—major challenges remain in achieving effective system integration and overall sustainability [5].

In response to escalating urban environmental challenges, sustainable solutions such as smart mobility and green infrastructure have gained growing attention as key pathways toward reducing carbon emissions. Smart mobility encompasses the use of innovative transportation technologies, intelligent traffic management systems, IoT, and AI-driven platforms designed to optimize mobility, reduce travel time, and minimize vehicle emissions. Meanwhile, green infrastructure focuses on environmentally friendly urban designs—ranging from green roofs, urban parks, permeable surfaces, bicycle lanes, pedestrian walkways, to renewable energy–powered transport networks—contributing directly to lowering the urban carbon footprint. In Jakarta, the integration of these strategies has shown promising potential; initiatives such as Transit Oriented Development (TOD) enhance accessibility to public transport and reduce reliance on private vehicles [6], while TransJakarta Electric Buses represent eco-friendly innovations despite challenges in fleet availability and investment [6]. Technological applications further support emission reductions through optimized traffic management and public transport scheduling [7], and green infrastructure elements such as green spaces and pedestrian-friendly pathways have been effective in reducing pollution and improving quality of life [8], following successful models implemented in cities like Copenhagen and Amsterdam.

Despite these advancements, Jakarta continues to face significant challenges in fully realizing the benefits of smart mobility and green infrastructure, particularly due to the need for stronger multisector collaboration and data-driven policymaking. Effective implementation requires coordinated efforts among government, the private sector, and community stakeholders to ensure that technological innovations and sustainable urban planning strategies are integrated seamlessly into the city's broader development agenda [6]. Furthermore, although previous studies highlight the potential of combining technological solutions with sustainable infrastructure to mitigate environmental problems in major cities, Jakarta-specific research examining the combined impact of smart mobility and green infrastructure on carbon emission reduction remains limited. A deeper understanding of these relationships is crucial for guiding policymakers, urban planners, and practitioners in designing effective low-carbon strategies that align with Jakarta's environmental goals and long-term urban sustainability.

This study aims to analyze the impact of smart mobility and green infrastructure on reducing carbon emissions in Jakarta. Using a quantitative approach with data collected from 115 respondents through a Likert-scale questionnaire and analyzed via SPSS version 25, this research seeks to provide empirical evidence of the role of innovative transportation systems and sustainable urban infrastructure in mitigating environmental challenges. The findings are expected to offer practical recommendations for creating a sustainable, low-carbon future in Jakarta and other megacities facing similar urban and environmental pressures.

2. LITERATURE REVIEW

2.1 Carbon Emissions in Urban Areas

Reducing carbon emissions in urban centers like Jakarta requires a multifaceted approach that integrates technological, infrastructural, and behavioral interventions, particularly because the transportation sector remains one of the largest contributors to urban CO_2 emissions and demands urgent reforms to mitigate its environmental impact. Technological strategies such as transitioning to alternative fuels and adopting advanced vehicle technologies have proven effective, with electric buses equipped with regenerative braking and improved drivetrains achieving a 25% reduction in emissions and particulate matter in Jakarta [9], while enhancing vehicle fuel economy by up to 50% through cleaner fuels and more efficient engines remains equally critical [10]. Infrastructural developments also play a central role, where integrated mass rapid transit systems—including bus rapid transit (BRT) and rail networks—help alleviate congestion and reduce emissions, evidenced by Jakarta's BRT system which, although covering only a limited portion of the city's roads, significantly contributes to emission reduction [4], [11]; meanwhile, the promotion of teleworking supported by robust ICT infrastructure can further decrease daily commuting needs and lower traffic-related emissions [11]. Behavioral and policy changes are similarly vital, as public acceptance and readiness to shift from private vehicles to public transportation determine the success of sustainable mobility initiatives, supported by policies such as emission standards that have been implemented in cities like Beijing and New Delhi [10]. Moreover, improving data-driven emission monitoring is essential, as accurate measurement of vehicle kilometers traveled (VKT) is necessary for effective emission management, and Jakarta's continued reliance on fuel consumption data underscores the urgent need for more precise data collection methods [4].

2.2 *Smart Mobility*

Smart mobility initiatives in Jakarta—such as integrated public transport apps, electric bus fleets, and advanced traffic management systems—are designed to reduce carbon emissions and improve transportation efficiency as part of a broader strategy to adopt intelligent transport systems (ITS) and other advanced technologies to address complex urban mobility challenges, though the actual impact of these interventions on carbon reduction still requires empirical validation. ITS technologies play a critical role in enhancing transportation safety, efficiency, and environmental sustainability through communication infrastructure, advanced computational methods, and intelligent traffic signals that collectively improve traffic management and reduce congestion [12], [13], and Jakarta's integration of ITS with major public transport systems such as the Commuter Line, BRT, MRT, and LRT has contributed to a reduction in traffic congestion from 61% in 2017 to 34% in 2021 [14]. The deployment of electric bus fleets further supports the city's smart mobility strategy by lowering emissions from public transport [14], while cashless payment systems and real-time travel information have enhanced efficiency and user comfort, fostering more sustainable mobility practices [14]. Despite these advancements, smart mobility implementation still faces challenges, including high costs, technological dependency, and data privacy concerns [14], and long-term success will depend on addressing broader infrastructural needs and strengthening policy frameworks to support sustainable urban mobility [15].

Green infrastructure (GI) is a strategic approach to urban development that integrates natural and engineered systems to deliver environmental, social, and economic benefits, playing a vital role in enhancing urban resilience and sustainability by mitigating climate change impacts, improving air and water quality, and supporting biodiversity. GI elements such as urban parks, green roofs, and permeable pavements help reduce carbon emissions and urban heat islands—green roofs and parks, for example, have been shown to lower air and land surface temperatures by up to 6.2°C in certain regions[16]—while also improving air quality by absorbing carbon dioxide and reducing air pollutants [17]. These ecological functions are complemented by GI's ability to support biodiversity by providing habitats for diverse flora and fauna within dense urban settings [17]. Socially, GI offers recreational opportunities, enhances mental well-being, strengthens community cohesion, and contributes to equitable distribution of environmental benefits, addressing environmental justice concerns across urban areas [17]. Economically, GI improves property values, reduces energy consumption through natural temperature regulation, and supports local businesses, while also contributing to job creation and energy savings that strengthen overall urban economic resilience [17], [18].

3. METHODS

This study employs a quantitative research design to analyze the impact of smart mobility and green infrastructure on carbon emission reduction in Jakarta. Quantitative methods are appropriate for numerically measuring relationships between variables and testing hypotheses using statistical analysis. The study adopts a cross-sectional survey approach, collecting data at a single point in time from respondents representing various stakeholders, including residents, commuters, and urban planning professionals in Jakarta. The target population consists of Jakarta residents who actively use urban transportation and experience the city's environmental conditions daily. Through purposive sampling, respondents with sufficient knowledge of urban mobility and environmental practices were selected, resulting in 115 participants—an adequate number to satisfy minimum sample size requirements and ensure statistical reliability.

The study focuses on three core variables: Smart Mobility (X_1), which captures the adoption and use of intelligent transportation technologies such as public transport apps, ride-sharing systems, electric vehicles, and real-time traffic management tools; Green Infrastructure (X_2), representing environmentally friendly urban features including green spaces, permeable pavements, green roofs, and renewable energy–powered transport infrastructure; and Carbon Emission Reduction (Y), which reflects perceived or measurable reductions in emissions resulting from sustainable urban practices such as decreased vehicle pollution and enhanced energy efficiency. All variables were measured using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree), with items adapted from validated instruments used in previous studies. Data were collected using a structured questionnaire distributed both online and in-person to ensure inclusivity across different areas of Jakarta.

Prior to the main data collection, a pilot test involving 15 respondents was conducted to confirm the clarity, reliability, and validity of all questionnaire items.

Data analysis was performed using SPSS version 25, following several systematic steps. Descriptive statistics were used to summarize respondent characteristics and provide an overview of data distribution. Validity and reliability tests were then conducted to ensure the accuracy and consistency of measurement, with Cronbach's alpha values above 0.70 considered acceptable. Multiple linear regression analysis was applied to examine the influence of smart mobility and green infrastructure on carbon emission reduction, assessing the significance, direction, and strength of relationships among variables. Furthermore, classical assumption tests—including normality, multicollinearity, and heteroscedasticity—were carried out to verify that the regression model met the necessary statistical assumptions for robust and reliable interpretation.

4. RESULTS AND DISCUSSION

4.1 Descriptive Statistics

The study involved 115 respondents from Jakarta with diverse demographic characteristics, where the majority were aged 25–34 years (45%), followed by those aged 35–44 years (30%) and above 45 years (25%), and the gender distribution was relatively balanced with 52% male and 48% female participants. Most respondents were employed in the private sector (40%), while others were government employees (25%), students (20%), and individuals in various other occupations (15%). Descriptive analysis of the main variables showed that respondents generally agreed that smart mobility and green infrastructure contribute to carbon emission reduction, reflected in the mean scores for Smart Mobility (X_1) of 4.12 (SD = 0.58), Green Infrastructure (X_2) of 4.05 (SD = 0.61), and Carbon Emission Reduction (Y) of 4.08 (SD = 0.60), indicating a consistently positive perception among Jakarta residents regarding the effectiveness of these initiatives.

4.2 Validity and Reliability Analysis

To ensure measurement accuracy, validity and reliability tests were conducted, where the validity assessment using Pearson correlation showed that all questionnaire items for smart mobility, green infrastructure, and carbon emission reduction had significant correlations with their respective variables ($r > 0.30$, $p < 0.05$), indicating strong construct validity, while the reliability test demonstrated high internal consistency with Cronbach's alpha values of 0.855 for Smart Mobility (X_1), 0.832 for Green Infrastructure (X_2), and 0.875 for Carbon Emission Reduction (Y), all exceeding the minimum acceptable threshold of 0.70 and confirming that the questionnaire was both valid and reliable.

4.3 Classical Assumption Tests

Before performing regression analysis, classical assumption tests were conducted, where the Kolmogorov–Smirnov test showed that the residuals were normally distributed ($p > 0.05$), the Variance Inflation Factor (VIF) values for smart mobility (1.386) and green infrastructure (1.401) were well below the threshold of 10 indicating no multicollinearity issues, and the scatter plots of residuals displayed no discernible pattern, confirming homoscedasticity; collectively, these results validate the suitability of the dataset for multiple linear regression analysis.

4.4 Multiple Linear Regression Results

Multiple linear regression was conducted to examine the effects of smart mobility (X_1) and green infrastructure (X_2) on carbon emission reduction (Y), and the results showed that the model had an R^2 value of 0.62, indicating that 62% of the variance in carbon emission reduction is explained by the two independent variables, while the F-test value of 92.14 with $p < 0.001$ confirmed that the overall regression model is statistically significant.

Table 1. Multiple Regression

Variable	B	Std. Error	t	p-value
Smart Mobility (X_1)	0.465	0.085	5.752	0.000
Green Infrastructure (X_2)	0.382	0.092	4.225	0.000

The regression results presented in Table 1 demonstrate that both smart mobility (X_1) and green infrastructure (X_2) have significant and positive effects on carbon emission reduction (Y), with smart mobility showing a standardized coefficient of B = 0.465, a t-value of 5.752, and a p-value of 0.000, indicating a strong and highly significant influence on reducing emissions through improvements in intelligent transport technologies such as integrated public transport apps, electric buses, real-time traffic information, and intelligent traffic management systems that encourage more efficient travel behavior and reduce reliance on private vehicles. The relatively high coefficient highlights the pivotal role of digital mobility innovations in mitigating urban environmental problems, particularly in densely populated settings like Jakarta. Likewise, green infrastructure exhibits a significant positive effect (B = 0.382, t = 4.225, p = 0.000), confirming that environmentally oriented urban features including urban parks, green roofs, permeable pavements, and renewable-energy-based transport infrastructure effectively contribute to carbon emission reduction; although its coefficient is slightly lower than that of smart mobility, the strong significance underscores the importance of natural and engineered ecological systems in improving air quality, mitigating urban heat islands, and supporting sustainable urban development. Collectively, these findings indicate that technological advancements and ecological urban design function as complementary strategies that play crucial roles in shaping low-carbon urban environments, reinforcing theoretical expectations that integrated sustainable mobility systems and environmentally conscious urban planning can jointly drive substantial reductions in carbon emissions aligned with global sustainability goals and Jakarta's long-term environmental management strategies.

Discussion

The findings indicate that adopting smart mobility solutions—such as electric vehicles, ride-sharing platforms, and intelligent transport systems—significantly reduces carbon emissions by improving traffic efficiency and lowering dependence on private vehicles. This aligns with previous studies showing that technological innovations in urban transportation substantially contribute to emission reductions [19]–[21]. Green infrastructure also plays a crucial role in reducing urban carbon emissions, as the implementation of green roofs, urban parks, and renewable energy-powered transport infrastructure enhances environmental sustainability and mitigates the heat island effect in Jakarta. These findings are consistent with the work of [22]–[24], who emphasize the effectiveness of environmentally friendly urban design in lowering carbon footprints.

The integrated effect of smart mobility and green infrastructure underscores the importance of combining technological innovation with sustainable urban planning to achieve optimal carbon reduction outcomes. Policymakers should prioritize coordinated strategies, such as promoting electric public transportation along green corridors and expanding urban green spaces, to maximize environmental benefits. Public awareness campaigns and incentives encouraging the adoption of low-carbon transportation modes can further enhance citizen participation in sustainable mobility practices. In conclusion, this study provides empirical evidence that both smart mobility and green infrastructure serve as key drivers in mitigating carbon emissions in Jakarta, offering a clear pathway toward sustainable urban development and supporting long-term low-carbon city initiatives.

5. CONCLUSION

This study concludes that smart mobility and green infrastructure play a significant role in reducing carbon emissions in Jakarta. The quantitative analysis confirms that the adoption of intelligent transportation systems, electric vehicles, and ride-sharing platforms enhances urban mobility efficiency, thereby reducing vehicle-related emissions. Simultaneously, the implementation of green infrastructure, including urban parks, green roofs, and sustainable transport corridors, contributes to lowering the city's overall carbon footprint.

The study highlights the importance of an integrated approach, combining technological innovation and sustainable urban planning, to achieve effective environmental management in megacities. Policymakers should focus on promoting smart mobility solutions, expanding green infrastructure, and fostering public awareness and participation in sustainable practices. By doing so, Jakarta can move toward a low-carbon, environmentally sustainable urban future, serving as a model for other rapidly urbanizing cities in Indonesia and beyond.

REFERENCES

[1] M. Gidarjati and T. Matsumoto, "Dynamic Vehicle Age-Based Cohort Model to Estimate the Emission from the Transportation Sector in Jakarta," *Ecol. Eng. Environ. Technol.*, vol. 25, 2024.

[2] R. Purnamasari and A. J. S. Runturambi, "Analysis of Odd-Even Policies in Overcoming Congestion and Air Pollution, Studies in Jakarta and Beijing," *Asian J. Eng. Soc. Heal.*, vol. 3, no. 5, pp. 949–965, 2024.

[3] A. A. Putra, C. E. Trisnawati, and P. W. Widayat, "The impact of urbanization on environmental degradation in Jakarta," *J. City Brand. Authent.*, vol. 2, no. 1, pp. 1–15, 2024.

[4] R. P. Adhi, "Top-down and bottom-up method on measuring CO2 emission from road-based transportation system (case study: entire fuel consumption, bus rapid transit, and highway in Jakarta, Indonesia)," *J. Teknol. Lingkung.*, vol. 19, no. 2, pp. 249–258, 2018.

[5] M. Farda and H. al-R. Lubis, "Transportation system development and challenge in jakarta metropolitan area, indonesia," *Int. J. Sustain. Transp. Technol.*, vol. 1, no. 2, pp. 42–50, 2018.

[6] C. Young, F. Evelyn, and D. P. Nugraha, "Implementasi Smart Mobility Sebagai Model Pembangunan Berkelanjutan di Daerah Khusus Ibukota Jakarta," *J. ISO J. Ilmu Sos. Polit. dan Hum.*, vol. 5, no. 1, p. 10, 2025.

[7] V. R. Kaneti *et al.*, "Smart Transportation Systems and Sustainable Urban Mobility," in *Revolutionizing Urban Development and Governance With Emerging Technologies*, IGI Global Scientific Publishing, 2025, pp. 261–288.

[8] A. R. Hapriyanto and H. Azmi, "Implementation of Green Infrastructure in Sustainable Transportation in Supporting Urban Mobility: A Literature Review," *Eng. Proc.*, vol. 84, no. 1, p. 25, 2025.

[9] F. Sarie, A. Tahir, and R. Pahrijal, "Enhancing Sustainability in Urban Transportation with Innovative Mechanical Engineering Solutions for Electric Buses in Jakarta".

[10] J. V Spadaro and A. Markandya, "Decarbonising urban transportation," 2013.

[11] E. Tambunan, A. S. Mulyani, and F. R. Wangge, "Perceptions of Cyclists on the Cycling Infrastructure in East Jakarta," *Int. J. Mod. Res. Eng. Technol.*, vol. 7, no. 11, pp. 1–4, 2022.

[12] S. Khazraeian and M. Hadi, "Intelligent transportation systems in future smart cities," in *Sustainable Interdependent Networks II: From Smart Power Grids to Intelligent Transportation Networks*, Springer, 2018, pp. 109–120.

[13] M. Learning, "Artificial Intelligence and Machine Learning Applications for Sustainable Development".

[14] A. C. Herdiana, "Narrative review: Sistem transportasi publik di smart city Jakarta untuk mengurangi kemacetan," *J. Electr. Eng.*, vol. 1, no. 4, 2025.

[15] V. Chamola, V. Hassija, S. Gupta, A. Goyal, M. Guizani, and B. Sikdar, "Disaster and pandemic management using machine learning: a survey," *IEEE Internet Things J.*, vol. 8, no. 21, pp. 16047–16071, 2020.

[16] M. Gorjian, "Urban Green Infrastructure for Climate-Resilient Cities: A Systematic Review and Thematic Synthesis of Environmental, Social, and Economic Benefits (2000–2022)," 2025.

[17] U. K. Ashinze, B. A. Edeigba, A. A. Umoh, P. W. Biu, and A. I. Daraojimba, "Urban green infrastructure and its role in sustainable cities: A comprehensive review," *World J. Adv. Res. Rev.*, vol. 21, no. 2, pp. 928–936, 2024.

[18] A. A. Adesina, A. C. Okwandu, and Z. Q. S. Nwokediegwu, "Towards sustainable urban development: Conceptualizing green infrastructure and its impact on urban planning," *Int. J. Appl. Res. Soc. Sci*, vol. 6, no. 7, pp. 1274–1296, 2024.

[19] S. Breitbart, A. Agrawal, H. Wagner, and M. Johnson, "Urbanization and a green corridor do not impact genetic divergence in common milkweed (Asclepias syriaca)," *bioRxiv*, pp. 2004–2023, 2023.

[20] A. Raihan, "Toward sustainable and green development in Chile: dynamic influences of carbon emission reduction variables," *Innovation and Green Development*. Elsevier, 2023.

[21] A. Raihan, "… greenhouse gas emissions and its determinants: The role of renewable energy and technological innovations towards green development in South Korea," *Innovation and Green Development*. Elsevier, 2023.

[22] W. M. Anthony, "Innovations in Aquaculture Technology and Market Access in Sub-Saharan Africa," *Iaa J. Art Humanit.*, vol. 11, no. 2, pp. 49–52, 2024, doi: 10.59298/iaajah/2024/11.4952.33.

[23] V. M. Anitha Rajathi and B. Reshma Parveen, "A conceptual study on impact of green manufacturing practices," *Open Access Res. J. Eng. Technol.*, vol. 6, no. 2, pp. 087–094, 2024, doi: 10.53022/oarjet.2024.6.2.0024.

[24] P. Theodoridis, T. Zacharatos, and V. Boukouvala, "Consumer behaviour and household food waste in Greece," *Br. Food J.*, vol. 126, no. 3, pp. 965–994, 2024, doi: 10.1108/BFJ-02-2023-0141.