The District Road Disparity and Its Impact on Logistics Distribution in Indonesia: A Regional Cluster Analysis

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Article Info

ISSN (online): 2582-7138
Volume: 06
Issue: 04
July - August 2025
Received: 09-05-2025
Accepted: 10-06-2025
Published: 21-06-2025
Page No: 192-197

Abstract
This study examines road infrastructure disparities and logistics distribution across Indonesia’s 34 provinces using BPS (2025) data. Multivariate regression and cluster analyses reveal district/city roads (81.25% of total roads) as the dominant predictor of logistics vehicle density ($\beta = 0.82$; $p < 0.01$), with every 1,000 km increase associated with 8,200 additional vehicles. Cluster analysis reveals three regional patterns: Efficient Cluster (Java-Bali, >300 vehicles/km), Vulnerable Cluster (Sumatra/Kalimantan, 100-300 vehicles/km), and Critical Cluster (Papua/Maluku/East Nusa Tenggara, <100 vehicles/km). A critical finding exposes the paradox of national road development in Eastern Indonesia: Papua underscores a national road paradox: despite having Indonesia’s second-longest national roads (2,778 km), it exhibits the lowest logistics-vehicle density (93.4/km). Policy recommendations include reallocating budgets to district roads in Critical Clusters and implementing a tiered logistics system (matching vehicle classes to road hierarchies). These measures address infrastructure inefficiency and promote equitable logistics development.

Keywords: Road Infrastructure, Logistics Vehicles, Regional Disparity, Regression Analysis, Transportation Policy

1. Introduction

Road infrastructure critically enables economic growth and logistics distribution across Indonesia's vast, geographically diverse archipelago (Iskandar and Arifin, 2023) [1]. As the world's largest archipelagic nation, Indonesia faces unique logistical challenges that demand robust connectivity (Sahara & Saputra, 2023) [2]. According to BPS (2025), the national road network comprises 47,817 kilometers (8.68% of total road length), provincial roads total 55,430 kilometers (10.07%), while district and city roads account for the vast majority 447,488 kilometers or 81.25% of total road infrastructure. This distribution underscores a structural dependence on subnational road networks for last-mile connectivity in logistics operations (Roudo *et al*., 2024) [3].

Logistics vehicles, particularly trucks and motorcycles, are not only facilitators of goods movement but also serve as indirect indicators of regional economic activity (Li *et al*., 2020). Provinces with extensive district road networks, such as East Java and North Sumatra, report high volumes of logistics traffic. East Java, for example, supports over 21 million motorcycles and more than 780,000 trucks. In contrast, outer-island provinces such as Papua and North Maluku, despite significant investment in national roads, exhibit disproportionately low logistics vehicle counts. This discrepancy suggests that road authority classification, rather than absolute road length, may play a more decisive role in determining logistics performance.

While statistical data from the Central Bureau of Statistics (BPS) has effectively mapped Indonesia’s road infrastructure and logistics vehicle distribution, few studies have explicitly analyzed the correlation between road network authority levels and logistics vehicle density. Infrastructure planning has historically emphasized the expansion of national roads, especially in underdeveloped eastern regions. However, the low logistics vehicle ratio in provinces like Papua, despite having one of the country's longest national road networks, raises questions about the efficiency and allocation of such investments.

This disconnect suggests that a reevaluation of infrastructure priorities may be necessary, particularly with regard to district-level connectivity (Sulistiono *et al*., 2018) [5].

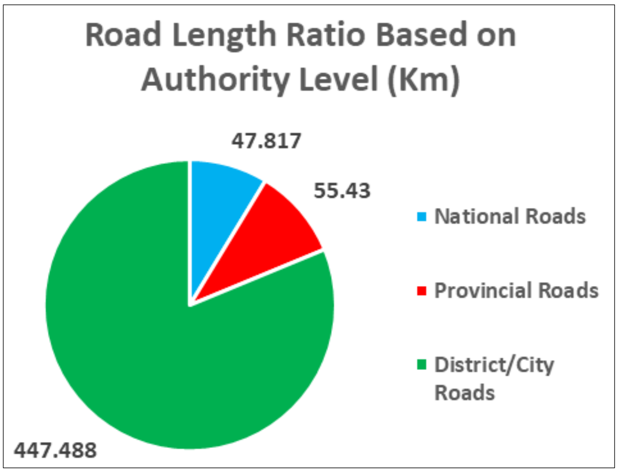

Fig 1: Road Length Distribution by Authority Level

This study aims to investigate the relationship between road length and logistics vehicle distribution across Indonesia's 34 provinces. By employing multivariate regression analysis and cluster classification, the research seeks to determine the degree to which each road category influences logistics performance. The study also categorizes provinces into performance clusters, offering a framework for identifying disparities and prioritizing infrastructure development. In doing so, this research contributes not only to the academic discourse on transportation planning but also to practical policy formulation targeting regional equity and efficiency.
The findings of this study are expected to inform multiple stakeholders. For policymakers, the results offer empirical guidance for rebalancing infrastructure investments, particularly toward district and city roads in underserved regions. For logistics operators, the study highlights areas with optimal and suboptimal infrastructure-vehicle alignment, potentially aiding in route planning and investment decisions. Finally, for academic researchers, this work provides a comparative benchmark and methodological approach for analyzing infrastructure impact on logistics systems within developing economies.

2. Methods

This study adopts a quantitative research design using secondary data obtained from the Central Bureau of Statistics (BPS) for the year 2025. The unit of analysis comprises all 34 provinces in Indonesia, each representing a unique logistical and infrastructural profile. The primary objective is to examine the statistical relationship between road infrastructure characteristics classified by administrative authority and the number of logistics vehicles operating in each province.
The independent variables include the total length of roads under three categories: national roads, provincial roads, and district/city roads (measured in kilometers). The dependent variable is the total number of logistics vehicles, comprising both trucks and motorcycles. To ensure analytical robustness, the model also includes control variables such as land area, population density, and the gross regional domestic product (GRDP) of the transportation sector.
The main analytical tools used are Pearson correlation and multiple linear regression. Pearson correlation assesses the strength and direction of bivariate relationships between road categories and logistics vehicle counts. The regression analysis follows the equation:

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon$$

Where
Y: logistics vehicles;
X_1: national roads;
X_2: provincial roads;
X_3: district/city roads

The significance of each coefficient (β) is evaluated at a 95% confidence interval.
Additionally, cluster analysis is applied to categorize provinces into performance groups based on their vehicle-to-road length ratios. These clusters are interpreted in terms of infrastructure effectiveness and regional logistics capacity. All statistical procedures are conducted using validated data from BPS, although the study acknowledges a limitation in not accounting for qualitative aspects of road infrastructure such as pavement conditions or congestion levels.

3. Results and Discussion

3.1. Geographic Disparities in Infrastructure and Logistics

The analysis reveals pronounced geographic disparities in the alignment between infrastructure provision and logistics activity (Yingfei *et al*., 2022). The Java-Bali region, characterized by dense economic activity and extensive road networks, exhibits the most efficient integration of road infrastructure and vehicle distribution (Prus & Sikora, 2021) [7]. For instance, East Java possesses a total road length of 42,466 km of which 38,532 km are district/city roads and supports more than 21 million logistics vehicles, yielding a vehicle-to-road ratio of 515.8 vehicles per kilometer. This high ratio reflects an optimal match between infrastructure availability and economic utilization (Lestari *et al*., 2025) [8]. In contrast, the province of Papua demonstrates a striking mismatch. Despite hosting Indonesia's second-longest national road network (2,778 km), it supports only 838,622 logistics vehicles, resulting in a vehicle-to-road ratio of just 93.4 vehicles/km (Rahayu, 2020) [9]. This underperformance is emblematic of infrastructural inefficiency and raises questions about the rationale behind prioritizing national road expansion in regions where logistics activity remains low (Theresa *et al*., 2025) [10].

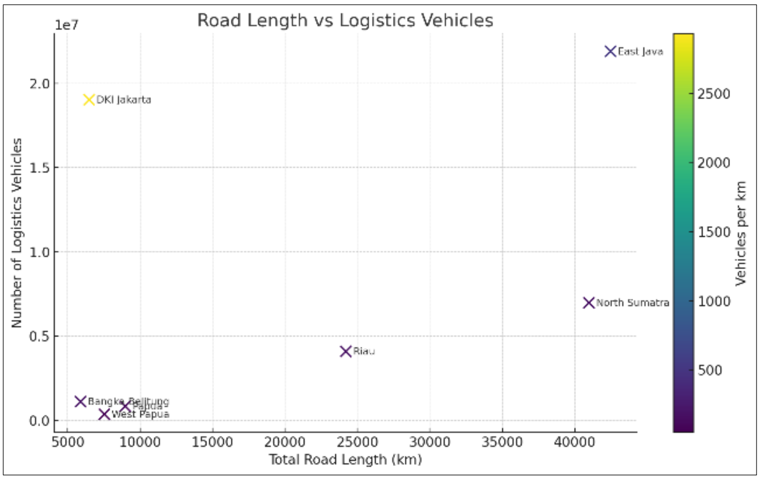

Fig 2: Scatter Plot of Road Length vs Logistics Vehicles

Several other provinces in eastern Indonesia follow similar patterns. Maluku and East Nusa Tenggara, for example, exhibit low vehicle counts despite moderate road development. This suggests that the mere presence of road infrastructure does not guarantee increased logistics mobility (Syzdykbayeva *et al*., 2025) [11]. Rather, effective distribution systems rely on integrated and accessible local networks that connect markets, warehouses, ports, and rural producers (Ding *et al*., 2023) [12].

Moreover, the study finds that archipelagic provinces with fragmented geographies are particularly disadvantaged. Limited intermodal connectivity, high transportation costs, and inadequate road maintenance further compound the problem (Kuteyi & Winkler, 2022) [13]. These findings underscore the need for targeted, context-sensitive infrastructure policies that consider geographic constraints and regional economic potential.

Therefore, addressing geographic inequality in logistics infrastructure necessitates not only fiscal investment but also institutional coordination, long-term maintenance strategies, and a reorientation of priorities toward district and city-level connectivity (Zakir, 2023) [14].

3.2. Dominant Influence of District/City Roads

The regression analysis strongly supports the hypothesis that district and city roads are the most significant predictors of logistics vehicle density. The estimated coefficient for district roads is $\beta = 0.82$ ($p < 0.01$), indicating a robust and statistically significant relationship. Specifically, every additional 1,000 km of district/city roads correlates with an estimated increase of 8,200 logistics vehicles. This finding affirms local infrastructure's critical role in supporting last-mile delivery and intra-regional supply chains.

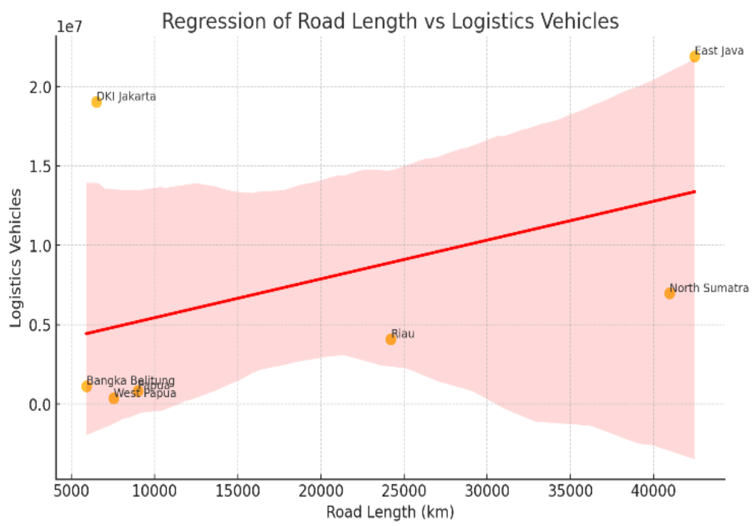

Fig 3: Regression Plot of Road Length vs Logistics Vehicles

To illustrate this, consider Central Java, which possesses 27,657 km of district roads. Based on the regression model, this corresponds to an expected 22,679-unit increase in logistics vehicles figures that align closely with empirical data. The model's explanatory power is also high ($R^2 = 0.89$), suggesting that nearly 90% of the variation in logistics vehicle volume across provinces can be explained by road infrastructure length.

The primacy of district roads may be attributed to their spatial penetration. Unlike national highways that often serve intercity corridors, district roads enable access to local markets, distribution centers, and production sites. In Indonesia, where much of the economy remains rural and fragmented, this layer of infrastructure constitutes the backbone of logistical activity (Gleissner & Femerling, 2013) [15]. Importantly, this does not diminish the value of national roads but rather highlights the complementarities required for system-wide efficiency.

Given these findings, a strategic pivot toward district/city road development is both empirically justified and economically necessary, particularly for regions with chronic infrastructure deficits.

3.3. Cluster-Based Logistics Performance

Through cluster analysis, provinces are grouped into three categories based on their logistics vehicle-to-road ratios: the Efficient Cluster (>300 vehicles/km), Vulnerable Cluster (100–300 vehicles/km), and Critical Cluster (<100 vehicles/km). This classification provides a nuanced view of infrastructure performance across regions.

The Efficient Cluster includes Java-Bali provinces such as DKI Jakarta and East Java. For example, Jakarta reports over 19 million logistics vehicles and only 6,485 km of roads, resulting in a density of 3,254.5 vehicles/km. These regions benefit from historical infrastructure investment, urban agglomeration, and a mature logistics ecosystem.

In contrast, provinces like Riau and South Kalimantan fall within the Vulnerable Cluster. While possessing moderate road infrastructure and vehicle counts, these areas show underutilization and congestion risks. Riau's vehicle-to-road ratio, for instance, stands at 169.2 vehicles/km suggesting latent capacity but also potential for overload under economic expansion.

The Critical Cluster includes Papua, Maluku, and West Papua. These provinces not only exhibit the lowest vehicle densities (<100/km) but also struggle with fragmented infrastructure, high operating costs, and logistical isolation. In West Papua, the ratio is merely 47.9 vehicles/km, a figure that reflects both infrastructural inadequacy and weak logistics demand.

Table 1: Cluster-Based Logistics Performance

Cluster	Region Example	Vehicles/km	Policy Focus
Efficient	DKI Jakarta, East Java	>300	Congestion management, maintenance
Vulnerable	Riau, South Kalimantan	100–300	Capacity building, rebalancing investment
Critical	Papua, West Papua	<100	District road development, logistics incentives

This cluster-based classification underscores the need for differentiated policy approaches. Efficient clusters require maintenance and congestion management, vulnerable clusters need capacity upgrades, while critical clusters demand foundational investment in district road infrastructure (Gertler *et al*., 2024) [16].

Thus, infrastructure policy must be spatially targeted and performance-sensitive, moving beyond aggregate road length to focus on actual usage and economic relevance.

3.4. National Road Anomalies and Overload Risks

The regression results also indicate that national roads exert limited influence on logistics vehicle distribution. With a coefficient of $\beta = 0.11$ and a non-significant p-value ($p > 0.05$), national road length appears weakly correlated with logistics density across provinces. This finding is further illustrated by anomalies such as Bangka Belitung, where provincial roads span only 851 km but support more than 51,000 trucks, equating to 60.5 trucks/km. This exceeds the Ministry of Transportation's recommended safety threshold of 40 trucks/km, indicating a potential overload issue.

Overloading poses severe risks to infrastructure sustainability, vehicle safety, and long-term fiscal efficiency (Pinkaew *et al*., 2025) [17]. Provinces with limited road networks but high vehicle density are particularly vulnerable. Without proper load regulation and vehicle classification policies, road degradation accelerates, increasing maintenance costs and reducing the lifespan of public assets (Allen *et al*., 2025) [18].

This dynamic is particularly pronounced in rapidly urbanizing areas and industrial zones, where demand outpaces capacity. Furthermore, national roads while crucial for inter-regional mobility often bypass local economic nodes, thereby limiting their direct impact on logistics flows within provinces (Li *et al*., 2025).

Therefore, infrastructure planning must account for usage intensity, not merely physical expansion (Neuman, 2012) [20]. Performance indicators such as load per kilometer and vehicle class distribution should inform budget allocations and policy prioritization.

A rebalancing of investments toward road types with higher logistics utility, especially district roads, would yield more equitable and efficient outcomes.

3.5. Data-Driven Balancing Strategies

In response to the findings, this study proposes several strategic recommendations aimed at improving logistics equity and infrastructure utilization. First, development priorities should focus on expanding district/city road networks in provinces classified under the Critical Cluster. For instance, West Sulawesi requires an estimated 2,000 km of additional district roads to achieve the minimum logistics density threshold of 100 vehicles/km.

Second, a tiered logistics system is advocated, whereby vehicle types are matched with road hierarchy levels. Heavy-duty trucks (≥10 tons) should be limited to national roads, medium-duty trucks (4–10 tons) to provincial roads, and light vehicles (<4 tons) to district roads. Such a system not only protects infrastructure integrity but also enhances distribution efficiency and safety.

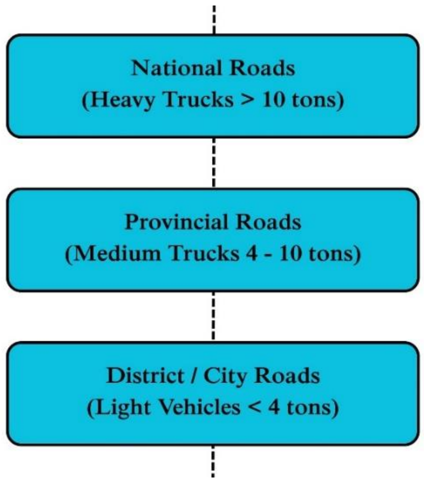

Fig 4: Proposed Tiered Logistics System

These proposals are grounded in data and aligned with international best practices on sustainable logistics and infrastructure governance. They reflect a shift toward evidence-based policymaking, where road investment decisions are guided by performance metrics rather than political considerations.
Importantly, these strategies require institutional commitment, inter-governmental coordination, and continuous monitoring to be effective over the long term.

4. Conclusion

This study has investigated the relationship between road infrastructure and the distribution of logistics vehicles across Indonesia's 34 provinces. Drawing on official BPS data and applying multivariate regression and cluster analysis, the research provides empirical evidence for the dominant role of district and city roads in enabling efficient logistics operations.
The analysis confirms that district/city roads, which constitute over 81% of Indonesia's total road network, serve as the primary determinant of logistics vehicle density. A statistically significant regression coefficient ($\beta = 0.82$, $p < 0.01$) indicates that an additional 1,000 km of such roads correlates with an increase of approximately 8,200 logistics vehicles. In contrast, national and provincial roads demonstrate relatively limited influence, with national roads being statistically insignificant in the regression model. These findings substantiate the "Local Infrastructure Primacy" theory, which posits that subnational connectivity is essential in archipelagic and rural-dominated economies.
The cluster analysis further reveals spatial disparities in logistics performance. The Efficient Cluster, dominated by Java-Bali, achieves over 300 vehicles/km, while the Critical Cluster, comprising Papua, West Papua, and Maluku, struggles to exceed 100 vehicles/km. These discrepancies highlight not only infrastructure imbalances but also the need for regionally targeted interventions. High vehicle-to-road ratios in certain provinces, such as Bangka Belitung, also suggest overload risks that may compromise infrastructure durability and safety.
To address these challenges, the study recommends a reorientation of infrastructure development toward district/city roads, particularly in the eastern and peripheral regions. A tiered logistics system aligned with road hierarchy and load capacity is also proposed to optimize vehicle deployment and protect infrastructure assets. In addition, performance-based fiscal incentives are suggested to stimulate logistics activity in disadvantaged areas.
Although the study is based on comprehensive quantitative data, it acknowledges limitations including the exclusion of qualitative road attributes such as surface quality, congestion, and intermodal integration. Future research should explore these dimensions, as well as incorporate spatial accessibility models, multimodal transport frameworks, and regional economic impact analyses.
In conclusion, the findings reinforce the strategic importance of district-level infrastructure in shaping national logistics outcomes. An evidence-based, equity-oriented approach to infrastructure planning is essential to reduce regional disparities, enhance supply chain efficiency, and support inclusive economic development across Indonesia.

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