

Structural Mechanisms of Urban Traffic Congestion in Dili, Timor-Leste

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ABSTRACT

Urban congestion in small developing capitals exhibits structural characteristics distinct from those observed in larger metropolitan regions. This study develops a perception-based Structural Equation Model (SEM) to analyze the dynamics of congestion formation in Dili, Timor-Leste. A cross-sectional survey of 1,001 active road users across five administrative sub-districts was conducted between January and March 2025. Four latent constructs were examined: population growth, vehicle growth, traffic flow conditions, and congestion. The measurement model demonstrated satisfactory reliability and validity, while the structural model confirmed that vehicle growth ($\beta = 0.51$, $p < 0.001$) and population growth ($\beta = 0.32$, $p < 0.001$) significantly influence traffic flow conditions, which in turn strongly determine congestion levels ($\beta = 0.78$, $p < 0.001$). The results reveal a full mediation structure, indicating that congestion emerges as an operational consequence of traffic flow instability rather than as a direct effect of demographic growth. The proposed framework offers a cost-effective analytical tool for congestion assessment in data-limited urban contexts and provides evidence to support demand-oriented transport policy strategies.

Keywords: urban congestion, motorization growth, traffic flow stability, Structural Equation Modeling, Dili

INTRODUCTION

Urban traffic congestion in small developing capitals represents a complex structural challenge rather than a mere consequence of inadequate infrastructure. In many emerging cities, such as Dili, Timor-Leste, rapid population growth and accelerating motorization create demand pressures that exceed the operational capacity of existing road networks. Dili is particularly vulnerable due to its linear coastal urban structure, reliance on a few main corridors, limited arterial redundancy, and modest public transport alternatives. These constraints render the road system highly sensitive to incremental increases in vehicle numbers, often leading to disproportionate operational disruptions and recurrent congestion. Between 2020 and 2024, private vehicle ownership in Dili increased by approximately 18% annually, while public transport coverage remains under 15% of daily trips, highlighting a growing modal imbalance and strong dependency on private motorized modes [1], [7], [12], [14], [16].

Such congestion has immediate socio-economic implications. Delays in traffic operations increase travel time, fuel consumption, and greenhouse gas emissions, while limiting accessibility to key commercial and institutional centers. Moreover, operational instability disproportionately affects economically productive age groups, who constitute the majority of daily commuters. The combination of spatial limitations, rapid motorization, and corridor dependency emphasizes the urgency of developing analytical frameworks that capture structural congestion mechanisms. Conventional approaches relying solely on infrastructure expansion are unlikely to provide sustainable solutions; instead, understanding the interactions among population growth, vehicle accumulation, and traffic flow performance is essential. By integrating perception-based data with structural modeling techniques, policymakers can identify operationally relevant interventions, such as demand management, traffic flow optimization, and coordinated urban planning strategies, tailored to the specific constraints of small developing capitals [1], [12], [14], [16].

Overall, Dili provides a representative case for examining structural congestion dynamics in a small capital city context. The city's unique combination of rapid motorization, corridor-dependent road networks, and limited public transport coverage creates operational pressures that differ significantly from large metropolitan regions. Therefore, analytical tools capable of assessing causal pathways and mediating mechanisms are crucial for evidence-based transport planning and policy formulation.

Previous studies on urban congestion have highlighted that in developing cities, population growth and motorization are stronger determinants of congestion than infrastructure limitations alone [1], [2], [14], [16], [17]. Rapid increases in vehicle ownership exacerbate traffic volume on primary corridors, frequently exceeding the operational efficiency of traffic management systems. Structural Equation Modeling (SEM) has emerged as a robust methodology to analyze the causal relationships among latent variables that contribute to traffic flow and congestion [2], [3], [4]. SEM allows for the simultaneous evaluation of measurement reliability and structural relationships, providing a comprehensive understanding of how demographic and motorization trends impact congestion. Perception-based indicators have been widely applied as reliable proxies in contexts with limited sensor infrastructure, enabling researchers to capture user-experienced traffic performance effectively [1], [12], [15].

Research in small developing capitals demonstrates unique congestion dynamics due to corridor dependency, limited network redundancy, and constrained modal alternatives. Unlike large metropolitan regions with multimodal transport systems and alternative arterial routes, small capitals rely heavily on a few main roads, increasing vulnerability to traffic disruptions [7], [13], [16]. Prior studies in cities with similar conditions highlight the importance of modeling interdependencies among latent variables, rather than relying solely on conventional performance metrics such as volume-to-capacity ratios or travel delay indices [6], [14]. For instance, Da Cruz et al. [7] applied perception-based SEM in Dili to evaluate road Level of Service, showing that operational performance is strongly influenced by population and vehicle growth. Other studies confirm that traffic flow instability mediates the relationship between demographic pressure and congestion, emphasizing the need to capture indirect effects through structural modeling [2], [15], [16].

Despite these contributions, most empirical research remains concentrated on large metropolitan areas, leaving small capitals underrepresented. The literature indicates a knowledge gap regarding how operational traffic conditions mediate the impact of demographic and motorization growth on congestion in smaller urban contexts [2], [5], [7]. Additionally, studies integrating perception-based measures with SEM to model structural congestion mechanisms in data-limited cities are still limited, highlighting the need for frameworks adaptable to small developing capitals where sensor networks and real-time monitoring are scarce [12], [17]. Understanding these dynamics is critical to designing targeted interventions and formulating demand-oriented transport policies.

Research Gap, Novelty, and Objectives

Although SEM and perception-based approaches have increasingly been applied in urban congestion research, their application in small developing capitals remains limited. Most studies in developing countries focus on large metropolitan contexts, where alternative routes, multimodal networks, and sensor infrastructure are available [7], [13], [15], [16]. Existing models often assume a direct relationship between population or vehicle growth and congestion without testing whether traffic flow mediates these effects. This gap limits the practical applicability of such models in smaller cities with constrained road networks, where indirect pathways may significantly influence congestion formation. Moreover, data scarcity in these contexts necessitates models that can integrate perception-based inputs as reliable proxies for operational traffic performance [1], [12], [15].

This study addresses these research gaps by developing a perception-based SEM framework to examine structural mechanisms of urban congestion in Dili. The novelty lies in three dimensions: first, applying SEM to a small capital city characterized by corridor dependency and limited network redundancy, which has rarely been explored in the literature; second, empirically validating the mediating role of traffic flow conditions between demographic and motorization growth and

congestion formation; and third, providing a cost-effective analytical tool suitable for cities with minimal traffic monitoring infrastructure, enabling evidence-based planning and policy interventions. This approach advances understanding of congestion as an operational consequence of demand-flow imbalance, rather than solely as a demographic or infrastructure problem.

The primary objective of this study is to generate actionable insights that inform demand-oriented transport policies, operational management strategies, and urban mobility planning in small developing capitals. By focusing on the interactions among population growth, vehicle accumulation, and traffic flow conditions, this research contributes both theoretically and practically to congestion modeling in resource-constrained urban environments [12], [17], [19], [20]. The study also aims to extend perception-based SEM applications geographically, demonstrating their adaptability and relevance in a context where conventional traffic measurement tools are limited.

To visualize the research framework, Figure 1 presents a Structural Equation Model (SEM) illustrating how traffic flow conditions mediate the relationship between population growth, vehicle growth, and congestion formation in Dili. The diagram emphasizes that traffic flow instability acts as a key intermediary linking demographic and motorization pressures to urban congestion. This visualization underscores the indirect pathways that are crucial in small developing capitals, where limited network redundancy and corridor dependency amplify operational vulnerabilities. The model clearly depicts the full mediation effect: population growth and vehicle growth influence congestion indirectly through traffic flow conditions, highlighting the necessity of perception-based SEM in contexts with constrained data availability.

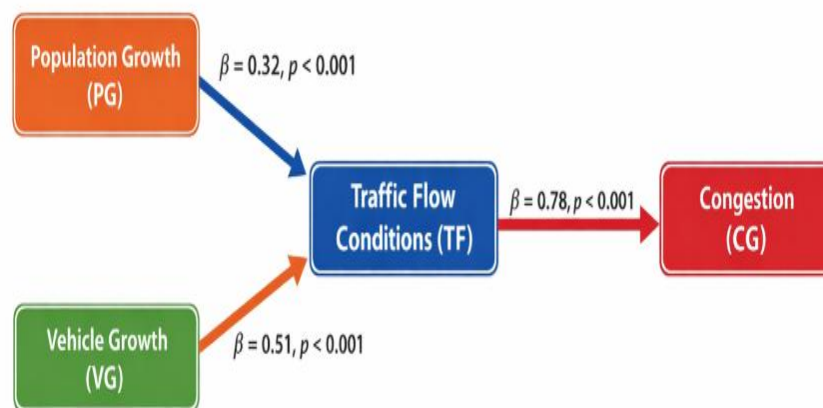


Figure 1. Structural Equation Model of Perception-Based Urban Congestion in Dili. (Source: Authors' Survey, 2025)

RESEARCH METHODS

Research Design

This study adopted a quantitative research framework using a cross-sectional survey design to examine the structural mechanisms underlying urban traffic congestion. A cross-sectional approach allows for the simultaneous measurement of latent constructs and the evaluation of causal relationships within a defined time frame, making it appropriate for Structural Equation Modeling (SEM) applications [4].

A perception-based analytical framework was selected to represent demand-side dynamics and operational traffic performance, particularly in urban environments where comprehensive sensor-based traffic monitoring systems are limited. Prior studies demonstrate that perception indicators can serve as reliable proxies for assessing congestion and traffic flow performance in developing city contexts [1], [12], [15].

Structural Equation Modeling (SEM) was employed to estimate both the measurement properties of latent constructs and the structural relationships among demographic growth, motorization trends,

traffic flow conditions, and congestion levels [2], [4]. This approach enables the identification of indirect and mediating mechanisms explaining how increases in travel demand translate into operational instability and congestion formation.

Study Area

The empirical analysis was conducted in Dili, the capital city and primary administrative and economic center of Timor-Leste. As the country's principal urban hub, Dili concentrates government institutions, commercial districts, educational facilities, and the majority of daily commuting flows. These characteristics make it a representative setting for investigating urban congestion mechanisms in small developing capitals.

Dili exhibits a predominantly linear coastal urban structure, with limited alternative arterial routes and minimal network redundancy. The city's transport system is highly corridor-dependent, increasing its sensitivity to incremental vehicle growth and traffic disruptions. Public transport coverage remains modest, reinforcing reliance on private motorized vehicles.

To ensure spatial representation, five administrative sub-districts Dom Aleixo, Vera Cruz, Nain Feto, Cristo Rei, and Metinaro were included in the survey framework. These areas encompass major residential zones, commercial centers, and institutional clusters, reflecting diverse mobility patterns and congestion exposure across the city [14], [16].

Given its rapid motorization growth, constrained road network structure, and limited modal alternatives, Dili provides an appropriate case for examining structural congestion dynamics in small developing capital cities.

Data Collection

Primary data were collected through a structured questionnaire survey conducted between January and March 2025. A total of 1,001 valid responses were obtained from active road users, including private car drivers, motorcycle riders, and public transport passengers. Participants were selected based on their regular engagement in daily travel activities within the study area to ensure experiential relevance.

A stratified purposive sampling technique was applied. Stratification was based on the five administrative sub-districts to ensure proportional geographic representation. Within each stratum, purposive selection was implemented to include respondents with consistent exposure to urban traffic conditions. This sampling strategy aligns with established perception-based congestion modeling approaches in developing urban contexts [1], [15].

The achieved sample size exceeds commonly recommended minimum thresholds for SEM analysis, thereby enhancing parameter stability, statistical power, and the reliability of Maximum Likelihood Estimation (MLE) procedures [4].

All latent variables were measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Questionnaire items were designed to capture perceptions related to four constructs: population growth (PG), vehicle growth (VG), traffic flow conditions (TF), and congestion (CG). The measurement design follows established practices in perception-based transportation research [12], [15].

Data Analysis

Data were analyzed using Structural Equation Modeling (SEM) with AMOS software. The analytical procedure followed a two-stage modeling approach: (1) validation of the measurement model and (2) estimation of the structural model [2], [4].

Measurement Model Evaluation

Confirmatory Factor Analysis (CFA) was conducted to verify whether observed indicators adequately represented their respective latent constructs. Internal consistency reliability and construct reliability were assessed to ensure that measurement items consistently reflected the theoretical dimensions under investigation [4].

Convergent validity was evaluated by examining standardized factor loadings and the proportion of variance explained by each construct. Discriminant validity was assessed to confirm that latent variables were empirically distinct from one another [3], [4]. Establishing measurement validity was essential prior to testing the hypothesized structural relationships [2].

Structural Model Estimation

After confirming the adequacy of the measurement model, structural relationships among latent constructs were estimated using the Maximum Likelihood Estimation (MLE) method, which is widely applied in SEM-based transportation studies [2], [4].

Model fit was evaluated using multiple goodness-of-fit indices, including:

- Chi-square (χ^2)
- CMIN/DF ratio
- Root Mean Square Error of Approximation (RMSEA)
- Comparative Fit Index (CFI)
- Tucker Lewis Index (TLI)

The use of multiple fit indices provides a comprehensive assessment of model adequacy and reduces dependence on a single statistical criterion [4].

This two-stage SEM procedure enables a rigorous examination of both measurement validity and the structural pathways linking demographic growth, motorization trends, traffic flow instability, and congestion outcomes in small developing capitals [13], [15].

RESULTS AND DISCUSSION

Descriptive Analysis

Descriptive analysis provides an initial overview of respondent characteristics and travel patterns, forming the empirical basis for interpreting perceived congestion in Dili. The distribution of respondents by gender, age group, and primary travel mode is presented in Table 1.

Table 1. Respondent Characteristics

Variable	Frequency	Percentage (%)
Gender		
Male	612	61.1
Female	389	38.9
Age Group		
18–25 years	214	21.4
26–35 years	348	34.8
36–45 years	267	26.7
>45 years	172	17.1
Primary Travel Mode		
Motorcycle	528	52.8
Private Car	318	31.8
Public Transport	102	10.2
Others	53	5.2

(Source: Authors' Survey, 2025)

Table 1 indicates that male respondents (61.1%) and individuals aged 26–35 years (34.8%) dominate daily road usage. This age group represents the economically active population with high commuting intensity, consistent with findings in urban mobility studies highlighting that productive-age groups contribute most significantly to traffic volume [1], [2].

Regarding travel mode, motorcycles account for more than half of respondents (52.8%), followed by private cars (31.8%). The predominance of private motorized modes reflects strong dependency on individual transport and limited public transport competitiveness, a pattern commonly observed in developing Southeast Asian cities experiencing rapid motorization growth [14], [16], [17].

Public transport usage remains relatively low (10.2%), indicating that the current system has not yet become a primary mobility option. Similar structural conditions have been documented in developing urban contexts where inadequate service coverage, reliability, and integration reduce public transport attractiveness [5], [11], [20].

These descriptive findings reinforce the structural premise of this study: motorization growth intensifies traffic demand, increasing pressure on road network performance and contributing to congestion formation [7], [13].

Model Analysis / Main Finding

The structural model was estimated to examine causal relationships among four latent constructs: Population Growth (PG), Vehicle Growth (VG), Traffic Flow Conditions (TF), and Congestion (CG). Standardized path coefficients are presented in Table 2.

Table 2. Structural Path Estimates

Path	Standardized Coefficient (β)	C.R.	p-value
PG $\rightarrow$ TF	0.32	5.12	<0.001
VG $\rightarrow$ TF	0.51	8.47	<0.001
TF $\rightarrow$ CG	0.78	12.63	<0.001

(Source: Authors' Analysis, 2025)

Table 2 shows that both population growth and vehicle growth significantly influence traffic flow conditions. Vehicle growth exerts the strongest effect ($\beta = 0.51$), indicating that motorization escalation is the dominant driver of traffic instability in Dili. This finding aligns with previous studies emphasizing the critical role of rapid vehicle ownership growth in shaping congestion dynamics in developing cities [2], [14], [17].

Traffic flow conditions strongly determine congestion levels ($\beta = 0.78$), suggesting that congestion primarily emerges as a consequence of operational degradation rather than direct demographic expansion. High Critical Ratio (C.R.) values and p-values below 0.001 confirm statistical significance at the 99% confidence level.

Importantly, once traffic flow conditions are incorporated into the structural model, neither population growth nor vehicle growth exhibits a direct significant effect on congestion. This confirms a full mediation structure, meaning that congestion occurs indirectly through deterioration of traffic flow stability. Such mediation mechanisms have been highlighted in SEM-based urban traffic studies, where operational variables act as intermediaries between demand growth and congestion outcomes [3], [15], [16].

Figure 2 illustrates the full SEM of perception-based urban congestion in Dili. The diagram visually confirms the mediation pathways:

- Population Growth $\rightarrow$ Traffic Flow Conditions $\rightarrow$ Congestion
- Vehicle Growth $\rightarrow$ Traffic Flow Conditions $\rightarrow$ Congestion

The absence of direct arrows from population growth and vehicle growth to congestion indicates that their effects are entirely transmitted through traffic flow conditions.

Total effect analysis further reveals that vehicle growth has the largest overall influence on congestion (0.440), followed by population growth (0.319). This highlights that rapid motorization exerts disproportionate pressure on the operational stability of the road network in small developing capitals [14], [17].

Thus, congestion in Dili should be interpreted as an operational instability outcome triggered by escalating vehicle demand rather than as a purely demographic phenomenon.

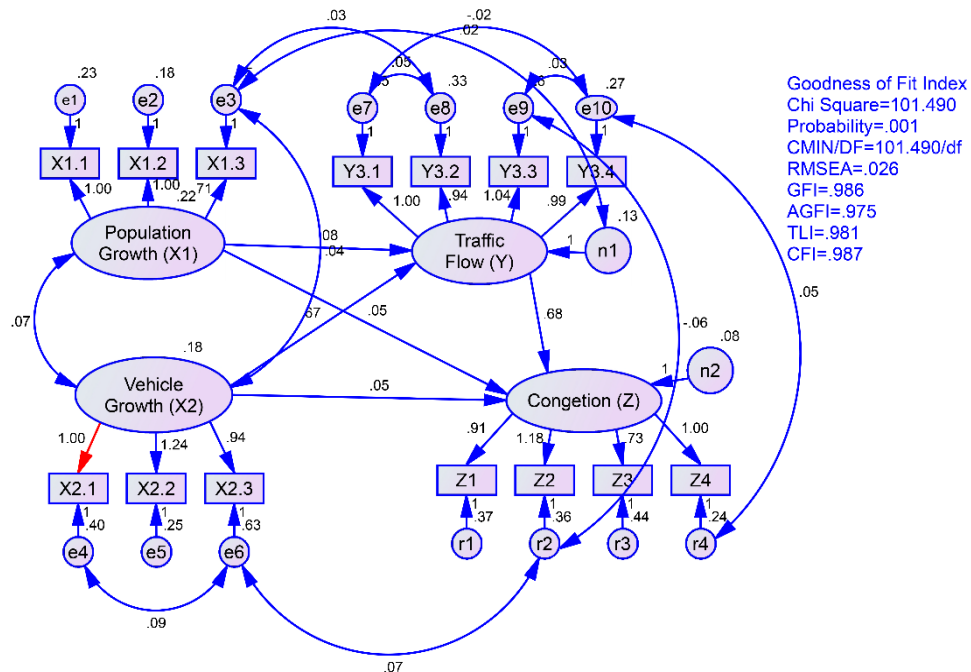


Figure 2. Structural Equation Model of Perception-Based Urban Road Congestion (Source: Authors' Analysis, 2025)

Structural Path Results and Model Fit Evaluation

Model adequacy was assessed using multiple goodness-of-fit indices, following established SEM evaluation guidelines [4].

Table 3. Goodness-of-Fit Indices

Fit Index	Recommended Cut-off	Model Result	Evaluation
Chi-square (χ^2)	Smaller is better	101.490	Acceptable*
Probability	≥ 0.05	0.001	Marginal
CMIN/DF	≤ 5.00	1.490	Good
RMSEA	≤ 0.08	0.026	Good
CFI	≥ 0.90	0.987	Excellent
TLI	≥ 0.90	0.981	Excellent

*Chi-square is sensitive to large sample sizes ($n = 1,001$).

(Source: Authors' Analysis, 2025)

Although the chi-square probability is marginal ($p < 0.05$), this outcome is common in large-sample SEM analyses due to the sensitivity of the chi-square statistic to sample size [4]. Therefore, evaluation should rely on multiple indices rather than a single criterion.

The CMIN/DF value (1.490) indicates very good model parsimony. RMSEA (0.026) suggests minimal approximation error, while CFI (0.987) and TLI (0.981) demonstrate excellent incremental fit. Collectively, these indicators confirm that the proposed structural model adequately represents the covariance structure of the observed data, consistent with SEM applications in transportation research [2], [4], [7], [13], [17].

Comparison with Previous Studies

The dominance of motorization growth found in this study supports the argument that congestion in Dili is fundamentally demand-driven. Incremental vehicle accumulation destabilizes traffic flow, particularly along corridors lacking modal alternatives and network redundancy. Similar dynamics have been reported in developing urban environments experiencing rapid motorization [14], [17].

These findings also align with the induced demand perspective, which argues that infrastructure expansion alone may not provide sustainable congestion relief if vehicle ownership continues to increase [6]. Without demand management measures, additional capacity may eventually be absorbed by growing traffic volumes.

The identified mediation structure further clarifies that demographic expansion does not directly generate congestion; instead, it amplifies traffic demand, which then degrades operational stability. Comparable mediation mechanisms have been observed in SEM-based congestion models in developing contexts [13], [15], [16].

Therefore, the present findings strengthen the theoretical understanding of congestion as an operational outcome of demand flow imbalance and provide empirical evidence supporting demand oriented and operational traffic management strategies in small developing capital cities.

CONCLUSION

This study shows that rapid growth in vehicle ownership and population significantly affects traffic flow stability in Dili. As more vehicles use the road network, operational disruptions increase and congestion risks become higher. The imbalance between traffic demand and road capacity reduces the efficiency of the urban transport system. The findings indicate that congestion in Dili is mainly caused by traffic operational problems rather than infrastructure limitations alone. High vehicle volumes compared to road capacity create unstable traffic conditions, leading to repeated delays and inefficiencies. Among the structural factors examined, vehicle growth is the most influential contributor to congestion, highlighting the need to manage motorization trends alongside population growth in urban transport planning. The perception-based Structural Equation Modeling (SEM) approach used in this research effectively explains the complex dynamics of urban congestion. By combining user perceptions with operational variables, the model provides a practical analytical tool for transport evaluation and policy development, even in conditions with limited data.

Overall, congestion in small developing capitals such as Dili is largely an operational issue driven by rapid motorization and demand capacity imbalances, rather than purely a demographic or infrastructure problem.

POLICY IMPLICATIONS

1. **Vehicle Demand Management:** Regulatory measures to control private vehicle growth, such as licensing restrictions, vehicle quotas, or congestion pricing, should be prioritized to mitigate traffic instability.
2. **Traffic Flow Optimization:** Operational strategies including signal coordination, corridor management, lane discipline enforcement, and real-time traffic monitoring can enhance traffic flow stability and reduce congestion.
3. **Public Transport Enhancement:** Expanding reliable, affordable, and integrated public transport services can reduce reliance on private vehicles, thereby alleviating congestion pressures.

4. Integrated Land-Use and Transport Planning: Coordinating land-use policies with transport planning is essential to prevent excessive travel demand concentration along key corridors and to promote balanced urban mobility.

In conclusion, urban congestion in Dili emerges primarily from operational instability induced by rapid vehicle demand, rather than from infrastructure deficits alone. A perception-based SEM approach provides a cost-effective and analytically rigorous framework to guide evidence-based urban transport policy formulation in small developing capitals.

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REFERENCES:

- [1] S. Hasan, M. Hoque, and N. I. Khan, "Perception-based modeling of congestion in a developing city context," *Int. J. Transp. Sci. Technol.*, vol. 9, no. 4, pp. 355–370, 2020, doi: 10.1016/j.ijtst.2020.03.002.
- [2] A. Raj and P. Vedagiri, "Modeling urban traffic congestion using structural equation modeling," *J. Transp. Eng., Part A: Syst.*, vol. 148, no. 2, p. 04021089, 2022, doi: 10.1061/JTEPBS.0000597.
- [3] C. Fornell and D. F. Larcker, "Evaluating structural equation models with unobservable variables and measurement error," *J. Mark. Res.*, vol. 18, no. 1, pp. 39–50, 1981, doi: 10.1177/002224378101800104.
- [4] J. F. Hair, W. C. Black, B. J. Babin, and R. E. Anderson, *Multivariate Data Analysis*, 8th ed. Boston, MA: Cengage Learning, 2019.
- [5] D. Banister and Y. Berechman, *Transport and Urban Development*. London: Routledge, 2023.
- [6] R. Cervero, "Congestion, road investment, and induced demand: A review," *Transp. Res. Rec.*, vol. 2119, no. 1, pp. 1–10, 2009, doi: 10.3141/2119-01.
- [7] M. R. M. Da Cruz, D. M. P. Wedagama, P. A. Suthanaya, and A. A. G. A. Yana, "Perception-based model of urban road level of service in Dili, Timor-Leste," *Civil Eng. Archit.*, vol. 13, no. 5, pp. 3656–3667, 2025, doi: 10.13189/cea.2025.130514.
- [8] D. A. Hensher and K. J. Button, *Handbook of Transport and the Environment*. Elsevier, 2015.
- [9] I. G. N. A. Putra and P. A. Suthanaya, "Analisis kinerja lalu lintas pada ruas jalan perkotaan di Kota Denpasar," *J. Tek. Sipil*, vol. 17, no. 2, pp. 85–94, 2021, doi: 10.9744/jts.17.2.85-94.
- [10] J.-P. Rodrigue, C. Comtois, and B. Slack, *The Geography of Transport Systems*, 5th ed. London: Routledge, 2020.
- [11] V. R. Vuchic, *Urban Transit Systems and Technology*. Hoboken, NJ: Wiley, 2007.
- [12] I. G. K. Widiana and D. M. P. Wedagama, "Pemodelan tingkat pelayanan jalan perkotaan berdasarkan persepsi pengguna jalan," *J. Tek. Sipil*, vol. 16, no. 1, pp. 1–10, 2020, doi: 10.9744/jts.16.1.1-10.
- [13] X. Zhang and Y. Chen, "Urban traffic congestion modeling using structural equation modeling: A developing country perspective," *Transp. Res. Part A*, vol. 150, pp. 345–360, 2021, doi: 10.1016/j.tra.2021.06.012.
- [14] M. Wang, J. Sun, and L. Li, "Motorization growth and congestion dynamics in emerging cities," *J. Transp. Geogr.*, vol. 102, 2022, doi: 10.1016/j.jtrangeo.2022.103376.

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- [15] R. Kumar and S. V. Kumar, "Perception-based assessment of urban congestion using SEM," *Sustain. Cities Soc.*, vol. 85, 2022, doi: 10.1016/j.scs.2022.104084.
- [16] T. Nguyen and H. Pham, "Demand-side determinants of congestion in Southeast Asian cities," *Case Stud. Transp. Policy*, vol. 11, no. 3, pp. 1000–1012, 2023, doi: 10.1016/j.cstp.2023.100936.
- [17] W. Hussain, S. Ahmad, dan R. Sharma, "Traffic congestion and mitigation strategies in developing urban contexts: empirical evidence and policy implications," *Sustainable Cities and Society*, vol. 109, 2024, doi: 10.1016/j.scs.2024.105548.
- [18] C. Urrutia-Mosquera, L. Flórez-Calderón, Y. Cortés, R. Troncoso, dan M. Lufin, "Impact of urban facilities spatial inequality on sustainable travel mode," *PLoS ONE*, vol. 19, no. 10, e0308610, 2024, doi: 10.1371/journal.pone.0308610.
- [19] D. Hussain, A. Jamal, A. Farooq, M. Almoshaogeh, F. Alharbi, dan D. Farooq, "Evaluation of traffic congestion mitigation techniques using an entropy-TOPSIS integrated method," *Scientific Reports*, vol. 16, 5036, 2026, doi: 10.1038/s41598-026-35814-w.
- [20] M. Al-Farouq dan T. Nguyen, "Investigating factors influencing the adoption of intelligent public transport systems for congestion reduction in developing cities," *Transportation in Developing Economies*, vol. 11, art. 30, 2025, doi: 10.1007/s40890-025-00253-1.