

IDENTIFICATION OF FACTORS CAUSING CONGESTION ON URBAN ROAD SECTIONS BASED ON SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Traffic congestion is understood as a major issue affecting travel time, fuel consumption, and environmental pollution. This research aims to analyze in detail the factors contributing to traffic congestion on urban road sections using a Systematic Literature Review (SLR) approach. Data were compiled from 24 national and international scientific articles published within the last ten years. Each identified factor was extracted into a worksheet and categorized into six main groups, ranging from traffic volume to rapid vehicle growth over time. The analysis reveals that traffic volume and vehicle growth rank first, accounting for approximately 25.0% of total occurrences, followed by road capacity and geometry at 23.7% (18 occurrences). Side friction accounted for 15 occurrences (19.7%). This study indicates that congestion on urban roads is primarily driven by an imbalance between travel demand and available road capacity, while roadside activities significantly impair performance. Proposed solutions include controlling side friction, regulating on-street parking, and managing roadside vehicle movements.

Keywords: Traffic congestion, urban road sections, side friction, road capacity, systematic literature review.

I. INTRODUCTION

Traffic congestion on highways is a common occurrence in almost every city across Indonesia. This condition arises when the number of vehicles traversing a particular road segment approaches or exceeds the road's carrying capacity, resulting in a sharp drop in travel speed and the formation of long queues. The rapid growth of private vehicle ownership relative to the expansion of road infrastructure is the primary driver of this disparity (U. Jilani, M. Asif, M. Rashid, 2023), (Kumar et al., 2021). In many cities, road widening is difficult to execute due to limited land availability and high land acquisition costs; thus, capacity issues must be addressed through alternative strategies.

The impacts of congestion extend beyond prolonged travel times. Research conducted in Mataram City demonstrates that higher saturation levels directly correlate with increased fuel waste incurred by road users (Mahendra, 2023). Similarly, a study along the Canggu Main Road quantified these economic losses by evaluating the additional operating costs borne by drivers due to intense roadside activity (I. G. A. Pramesta, I. G. N. N. Wismantara, 2022). At the urban scale, congestion significantly elevates exhaust emissions and degrades overall public productivity (Geroliminis, 2021).

Another frequently discussed factor is road capacity and geometric design, including the performance of intersections located at segment boundaries. Saturated intersections restrict traffic flow and trigger backups that propagate far upstream into feeding road segments (W. P. Zayu, S. Sarda, 2023). Performance evaluations using the Indonesian Road Capacity Guidelines (PKJI) and microsimulation models demonstrate that optimizing green light timing can effectively reduce delay, though such improvements often provide only partial relief when overall traffic demand continues to rise (dan D. H. A. Cahya, E. Gracia, D. Setijowarno, 2024), (Anggayeni et al., 2024).

Traffic congestion is also intrinsically linked to surrounding land-use patterns. Commercial districts, traditional markets, schools, and office complexes generate and attract massive trip volumes during peak hours (T. Nissa, A. Hidayat, R. A. Nugroho, 2024). Investigations in educational zones reveal sharp volume spikes during school drop-off and pick-up hours, accompanied by severe side friction caused by vehicles parking or stopping along shoulders (S. Meutia, S. M. Saleh, 2017).

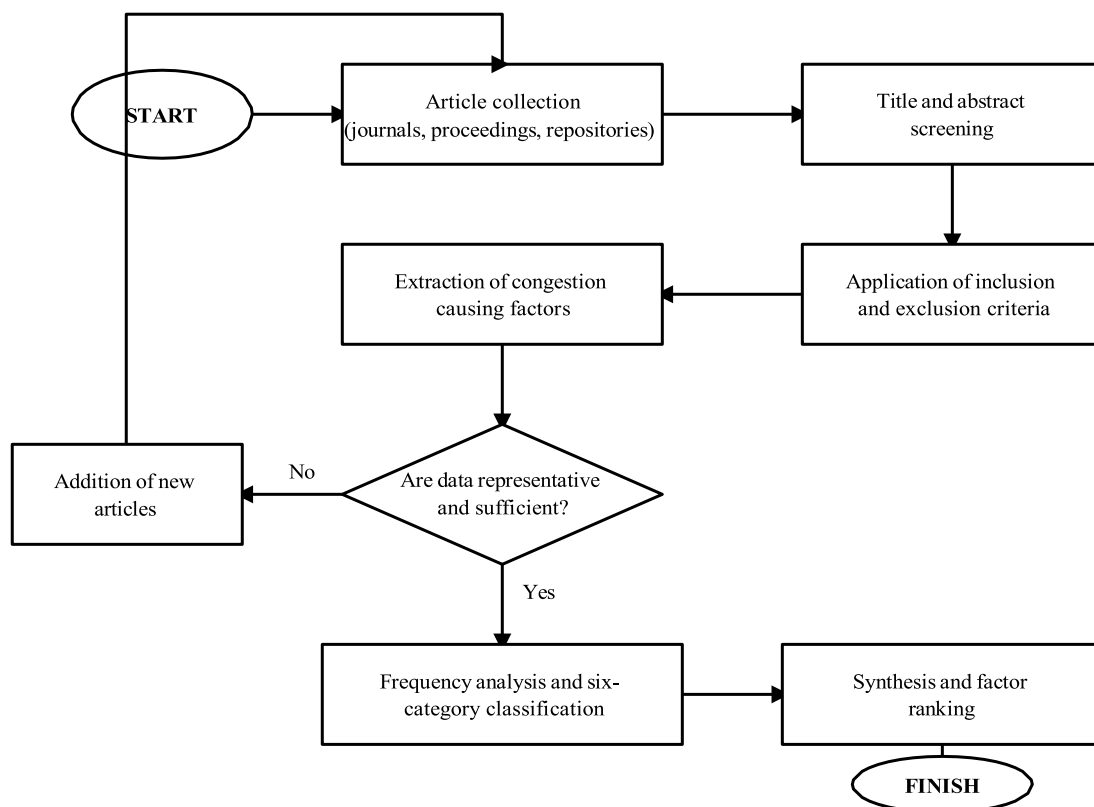
Human behavior plays a critical role as well. Indiscriminate parking, poor compliance with traffic signs and pavement markings, and sudden stops to drop off or pick up passengers severely disrupt flow quality (Wijanarko et al., 2025), (Halim, 2023). Studies in the I Gusti Ngurah Rai Road corridor even rank driver attitudes and habits as equal in significance to the physical condition of the roadway (Dewanti, 2025).

II. RESEARCH METHODOLOGY

Data sources comprised scientific articles published in national and international journals, conference proceedings, and university institutional repositories. Literature searches were conducted using keywords such as *traffic congestion*, *road section performance*, *side friction*, *degree of saturation*, *urban traffic congestion*, and *side friction*. The publication timeframe was restricted to the past ten years to ensure findings remain relevant to contemporary urban traffic conditions.

Three inclusion criteria were established: First, the article must analyze factors causing congestion or degrading section/intersection performance in urban areas. Second, the article must provide sufficient data or discussion to extract concrete factors. Third, full-text access must be available. Articles focusing exclusively on predictive technology without addressing root causes, duplicate papers, and non-urban studies were excluded. Following screening, 24 articles were selected for detailed analysis.

Each selected paper was reviewed, and the cited congestion factors were extracted into an Excel spreadsheet for quantitative tracking. Extracted factors were then grouped into six distinct categories: traffic volume and vehicle growth, road capacity and geometry, side friction, land use and trip generation, traffic management and engineering, and road user behavior. Categorization was based on thematic similarities among findings across study locations. The research workflow is summarized in Figure 1.



Data analysis was conducted using frequency synthesis. The number of articles addressing each category was tabulated and divided by total factor occurrences across all categories to calculate percentages. Individual papers could contribute to multiple categories if they identified more than one cause, resulting in total occurrences exceeding the sample size of 24 articles. Higher occurrence frequencies reflect greater emphasis within the reviewed literature.

When article coverage was deemed insufficient to provide a representative synthesis, the collection and filtering cycle was repeated until data saturation was met. Following frequency calculations, findings were synthesized to examine inter-category relationships and compare trends against existing national and international body of knowledge.

III. RESULT AND DISCUSSION

Based on factor extraction across the 24 eligible articles, all identified causes of congestion were mapped into six distinct categories. This classification structures the discussion by consolidating conceptually identical factors despite minor descriptive variations. Table 1 outlines the distribution of categories across the reviewed literature.

Table 1. Distribution of congestion factor categories across 24 reviewed articles

No	Ref	Researcher Name(s)	Traffic Volume	Capacity & Geom.	Side Friction	Land Use	Traffic Mgt.	Driver Behav.
1	[1]	U. Jilani, M. Asif, M. Rashid, A. A. Siddiqui	x	x			x	x
2	[2]	M. M. Rahman, S. Najaf, M. G. Fields, J. C. Thill	x	x		x	x	
3	[3]	C. V. Beojone, N. Geroliminis	x				x	x
4	[4]	B. Priambodo, A. Ahmad, R. A. Kadir	x				x	
5	[5]	A. Kumar, S. Das	x	x		x	x	x
6	[6]	I. Wijanarko, M. A. Ridlo	x	x	x	x		x
7	[7]	T. Dewanti	x	x	x			x
8	[8]	R. Halim, et al.	x		x	x		x
9	[9]	W. P. Zayu, S. Sarda, W. Boy	x	x			x	
10	[10]	A. Cahya, E. Gracia, D. Setijowarno, D. Hartanto	x	x			x	
11	[11]	T. Nissa, A. Hidayat, R. A. Nugroho, R. S. Putra	x	x		x		
12	[12]	R. Rohani, I. W. Suteja, H. Hasyim, M. Mahendra	x	x	x		x	
13	[13]	N. Fuadana, Maslina		x	x			x
14	[14]	S. Kurniawan, L. Sriharyani		x	x			
15	[15]	S. Meutia, S. M. Saleh, Azmeri	x		x	x		
16	[16]	O. K. Putri, A. Herison	x	x	x			

17	[17]	Z. N. Raudah, W. Kushartomo, Najid	x	x	x			
18	[18]	A. S. Amal, A. A. Darmawan, A. N. Adibah, C. Saleh	x	x	x			
19	[19]	N. P. R. Anggayeni, K. R. Agastya, I. W. W. A. Tunas		x			x	

No	Ref	Researcher Name(s)	Traffic Volume	Capacity & Geom.	Side Friction	Land Use	Traffic Mgt.	Driver Behav.
20	[20]	N. Z. Awaludin, Wahidin, D. D. Apriliano	x	x	x			
21	[21]	I. G. A. Pramesta, I. G. N. N. Wismantara, D. A. P. A. G. Putri	x		x	x		
22	[22]	I. N. A. Purnata, M. Mahendra	x	x	x			
23	[23]	W. Ridwan, F. Rosyad		x	x			
24	[24]	A. Mustofa, N. Hidayah			x			x
Total Occurrences			19	18	15	7	9	8

Note: Checkmark (x) indicates that the cited article addresses the corresponding category.

A total of 76 factor occurrences were extracted from the 24 articles. This count exceeds the total number of papers because most studies cited multiple root causes within their respective study areas. A summary of frequencies, percentages, and relative rankings is presented in Table 2.

Table 2. Ranking of congestion factor categories on urban road sections

No	Factor Category	Frequency	Percentage	Rank
1	Traffic Volume and Vehicle Growth	19	25.0 %	Rank 1
2	Road Capacity and Geometry	18	23.7 %	Rank 2
3	Side Friction	15	19.7 %	Rank 3
4	Traffic Management and Engineering	9	11.8 %	Rank 4
5	Road User Behavior	8	10.5 %	Rank 5
6	Land Use and Trip Generation	7	9.2 %	Rank 6
Total Factor Occurrences		76	100 %	-

“**Traffic volume and vehicle growth** appeared 19 times (25.0%), ranking first. This finding aligns with fundamental traffic theory, as congestion fundamentally represents demand exceeding infrastructure supply. Several studies recorded saturation degrees above 1.0 during

peak hours, confirming that demand exceeded maximum operational capacity (Herison, 2018), (N. Z. Awaludin, Wahidin, 2024), (Mahendra, 2023). Unless rapid vehicle growth is countered by demand management, supply-side improvements will offer only temporary relief.

Road capacity and geometry ranked second with 18 occurrences (23.7%). Narrow carriageways, absence of medians, dysfunctional shoulders, and unbalanced intersection approaches reduce real-world operational capacity well below design capacity (Z. N. Raudah, W. Kushartomo, 2021), (A. S. Amal, A. A. Darmawan, A. N. Adibah, 2023). This explains why two road segments with identical traffic volumes can exhibit vastly different levels of service.

Side friction ranked third with 15 occurrences (19.7%). This factor was most prevalent along road segments adjacent to markets, commercial strips, and educational zones. On-street parking was identified as the most severe side friction component, directly curtailing effective lane width (R. Rohani, I. W. Suteja, H. Hasyim, M. Mahendra, 2026), (Sriharyani, 2018), (Lantang et al., 2025). Certain studies highlighted a full level-of-service drop resulting solely from localized parking and loading activities (Maslina, 2026).

Traffic management and engineering accounted for 9 occurrences (11.8%). This includes signal timing control, one-way system implementation, heavy vehicle time restrictions, and access point management. Simulation results across several intersections demonstrate that optimizing green splits reduces delay and queue length, although highly saturated approaches remain at low service levels (D. H. A. Cahya, E. Gracia, D. Setijowarno, 2024), (Anggayeni et al., 2024).

Road user behavior was recorded 8 times (10.5%). Unregulated stopping, low compliance with road markings and signs, and aggressive queue-jumping at intersections exacerbate traffic conflicts [6], [7]. Although often treated as a secondary cause, its impact on flow continuity is direct and difficult to resolve through physical infrastructure alone.

Land use and trip generation ranked last with 7 occurrences (9.2%). Its relatively low frequency does not diminish its systemic importance; land-use dynamics operate at the planning level and constitute the root cause of high volumes and side friction (T. Nissa, A. Hidayat, R. A. Nugroho, 2024), (S. Meutia, S. M. Saleh, 2017), (I. G. A. Pramesta, I. G. N. N. Wismantara, 2022). Unregulated land-use conversion into commercial centers without traffic impact assessments imposes severe long-term burdens on surrounding networks. A percentage comparison of all six categories is illustrated in Figure 2

**RANKING OF CONGESTION FACTOR CATEGORIES BASED ON ANALYSIS OF
24 ARTICLES**

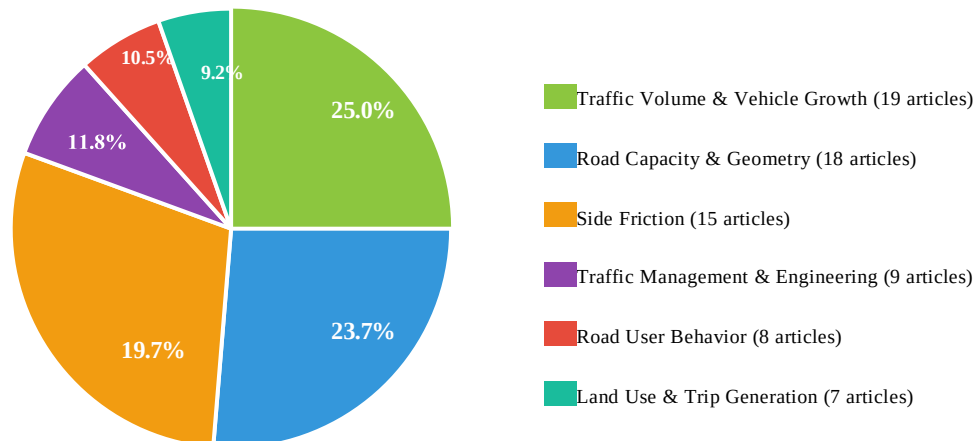


Figure 2. Percentage distribution of congestion factor categories

The overarching pattern is highly distinct. The top three categories—traffic volume, road capacity, and side friction—account for 68.4% of all factor occurrences. These elements are tightly interrelated: high traffic volume imposes extreme strain on capacity-constrained roads, while operational capacity is further degraded by unchecked roadside friction. In essence, urban road congestion in Indonesia is predominantly a compound result of these three intersecting issues rather than an isolated cause.

These findings mirror international studies that identify vehicle growth and infrastructure constraints as primary drivers of urban congestion (U. Jilani, M. Asif, M. Rashid, 2023), (M. M. Rahman, S. Najaf, M. G. Fields, 2022), (Kumar et al., 2021). However, Indonesian literature assigns significantly greater weight to side friction. This distinction stems from the specific characteristics of Indonesian urban corridors, which feature high-density mixed land use alongside a high proportion of motorcycles in the traffic stream.

Based on these insights, interventions should prioritize immediate, high-impact low-cost measures. Enforcing parking bans, reorganizing street vendors, and controlling access points can restore effective road capacity without heavy capital investment. Subsequent phases should focus on signal optimization and lane management at saturated junctions. Over the long term, controlling trip generation via rigorous traffic impact assessments and public transit expansion remains essential to prevent demand growth from overwhelming capacity gains.

IV. CONCLUSION

The identified factor categories interact dynamically and simultaneously; consequently, mitigating urban congestion cannot rely on a single isolated policy.

Regulating side friction and reorganizing on-street parking represent immediate, highly efficient interventions that deliver substantial short-to-medium-term benefits. These measures lay the groundwork for long-term policies aimed at preventing newly restored road capacity from being immediately absorbed by uninterrupted vehicle growth.

This study is limited by the sample size of 24 reviewed articles and the reliance on occurrence frequency as the primary metric. Frequency reflects how often a factor is highlighted in the literature, rather than its exact quantitative weight in the field. Future research should expand the article corpus and integrate multi-criteria decision models, such as the Analytical Hierarchy Process (AHP) or factor analysis, to quantitatively weigh each cause and better support traffic engineering priority setting.

V. ACKNOWLEDGMENTS

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