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# ANALYSIS OF TRAFFIC CONGESTION LEVELS ON GAJAYANA STREET, MALANG CITY USING THE PKJI METHOD 2023

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## ABSTRACT

*Traffic congestion at intersections and urban corridors is strongly influenced by road capacity, side frictions, and driver behavior. This study analyzes the traffic performance of Gajayana Street, Malang City, by evaluating traffic volume, road geometry, side frictions, travel speed, capacity, degree of saturation (DS), and Level of Service (LOS). Data were collected through field surveys and analyzed using the Indonesian Road Capacity Guidelines (PKJI 2023).The results show that the highest traffic volume occurs during peak hours between 16:15–17:15 WIB, reaching 2,030 PCU/hour. Side friction analysis indicated a weighted frequency of 146.9 events/hour, categorized as low, but still significant during peak demand. The average travel speed of light vehicles was 35.7 km/h. Under a two-way configuration, the DS reached 1.0, resulting in LOS F (unstable flow, heavy congestion). In contrast, the one-way configuration produced a DS of 0.68, corresponding to LOS B (stable flow). These findings suggest that traffic performance on Gajayana Street can be significantly improved through operational schemes such as one-way management, alongside measures to minimize side frictions and enhance driver compliance. The study highlights the importance of integrating infrastructure planning, traffic management, and behavioral interventions to achieve more efficient and sustainable urban mobility.*

***Keywords:*** *Traffic performance, Level of Service (LOS), capacity, side frictions.*

## Introduction

Congestion at intersections is influenced by driver violations. Educated drivers are less likely to commit violations and be involved in accidents compared to novice drivers. This is supported by research conducted by Shell et all [1]. According to [2] Nishida, drivers who have previously experienced accidents tend to be more cautious when driving. Meanwhile, Alonso et all [3] argue that drivers under the influence of alcohol exhibit more aggressive behavior compared to the general definition of aggression (e.g., shouting, insulting, and overtaking). The emotional violations were not initially anticipated but were attributed to the unfamiliar and potentially frustrating behaviors exhibited by AVs) [4].

Several factors influence driver violations at signalized intersections, including the number of approaches, speed, road width, speed at the intersection, and intersection width Al-Atawi [5]; There are three ways RLR-MC crossing the signalized intersection, i.e. (1) by Illegal maneuver (i.e. Illegal U-turn, contra-flow, prohibited left-turn), (2) by stopping first at or before the stop line, and (3) without stopping before the stop lin [6] (Manan) ,day of the week, installation of cameras, type of vehicle (two-wheeled or four-wheeled vehicles), traffic light cycle time (long or short), and type of traffic signal (with countdown timer or standard) (Kulanthayan et all [7]); the absence of an adaptive yellow signal (Lin & Cheng) [8] ; and gender (male or female) (Hezaveh et all) [9].

## Materials and Methods

According to PKJI 2023 [10], the capacity (C) for an undivided road type, 2/2-TT, is determined based on the total two-way traffic volume. The capacity for divided road types such as 4/2-T, 6/2-T, and 8/2-T is determined separately for each direction and per lane. The capacity (C) of a road segment in general can be calculated using the equation below:

$$C = C_0 \times FC_{LJ} \times FC_{PA} \times FC_{HS} \times FC_{UK} \quad (1)$$

Description:

C = It is the capacity of the road segment under observation, measured in PCU/hour. If the road segment conditions differ from the ideal conditions, then the value of C must be adjusted based on deviations from the ideal conditions in lane width or traffic lane (FCLJ), directional separation (FCPA), presence or absence of shoulder (FCHS), and city size (FCUK)..

Co = is the basic capacity of the ideal road segment condition, measured in SMP/hour.

FCLJ = is the capacity correction factor due to the difference in lane width or traffic lane from its ideal condition.

FCPA = is a capacity correction factor due to the separation of traffic directions (PA) and is only applicable for undivided road types.

FCHS = is a capacity correction factor due to the KHS conditions on roads equipped with shoulders or equipped with curbs and sidewalks of non-ideal sizes.

FCUK = is a capacity correction factor due to the size of the city being different from the ideal city size.

If the condition of the road segment being observed is the same as the ideal condition, then all capacity correction factors become 1.0, so C = C0.

### Research Steps

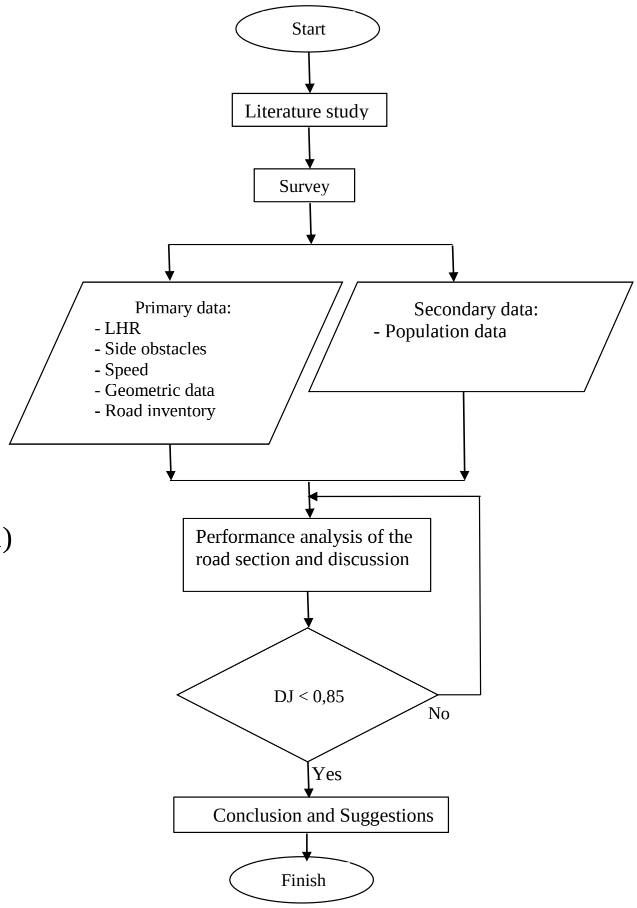



**Figure 1**. Research Steps

### Level of Service (LOS) of Roads

The level of service (LOS) of a road is its ability to perform its function. The calculation of the road's level of service can be done using the Level of Service (LOS) method. LOS is a qualitative measure that describes the traffic operational conditions on a road segment. In other words, the level of service is a measure that indicates the quality of service provided by a road under certain conditions. There are two definitions of the level of service for a road segment, according to Tamin in Anas et all [11]:

**Flow Dependent Level of Service.**

This relates to the operational speed/facilities of the road, which depends on the ratio of flow to capacity. Therefore, the level of service on a road depends on the traffic flow.

**Table 1.** Level of Service Values

| No | Level of Survice | V/C | Classification |
|---|---|---|---|
| 1 | A | < 0,60 | Free flow with low volume and high speed, drivers can choose their desired speed. |
| 2 | B | 0,60 < V/C < 0,70 | Stable flow with speed slightly limited by traffic, drivers still have freedom in choosing their speed. |
| 3 | C | 0,70 < V/C < 0,80 | Stable flow, speed controlled by traffic. |
| 4 | D | 0,80 < V/C < 0,90 | Flow is unstable, low speed. |
| 5 | E | 0,90 < V/C < 1,00 | Unstable flow, low and varying speeds, volume approaching capacity. |
| 6 | F | > 1,00 | Congested flow, low speed, volume exceeds capacity, frequent long-lasting congestion causing speed to drop to zero. |

## Result

### Secondary Data

Secondary data is data or information obtained from other sources related to the conducted research, as for the secondary data:a. Road section: Jl. Gajayana, Malang Cityb. Road type: a. 2 lanes 1 way (2/1) (from 07:00 to 18:00 WIB)b. 2 lanes 2 ways (2/2) (from 18:00 to 07:00 WIB)c. Road classification: Secondary collectord. Population: 849,667 people

### Primary Data

1. The daily traffic data and geometric road data for Gajayana Street can be seen in Table 2, Figure 2, and Figure 3 below:

**Table 2.** Gajayana Road Data in Malang City

| No | Time | Motor Cycle (MC) | | Low Vehicle (LV) | | High Vehicle (HV) | | Total | |
|---|---|---|---|---|---|---|---|---|---|
| | | Vehicle | Pcu / Hour | Vehicle | Pcu / Hour | Vehicle | Pcu / Hour | Vehicle | Pcu / Hour |
| 1 | 06.30-07.30 | 3046 | 761 | 642 | 642 | 34 | 42 | 3722 | 1445 |
| 2 | 06.45-07.45 | 3417 | 855 | 700 | 700 | 33 | 40 | 4151 | 1594 |
| 3 | 07.00-08.00 | 3591 | 898 | 770 | 770 | 32 | 38 | 4393 | 1706 |
| 4 | 07.15-08.15 | 3692 | 924 | 801 | 801 | 30 | 36 | 4523 | 1760 |
| 5 | 07.30-08.30 | 3827 | 957 | 834 | 834 | 32 | 38 | 4694 | 1829 |
| 6 | 11.00-12.00 | 3996 | 999 | 855 | 855 | 34 | 42 | 4885 | 1895 |
| 7 | 11.15-12.15 | 3883 | 971 | 922 | 922 | 30 | 36 | 4836 | 1929 |
| 8 | 11.30-12.30 | 3850 | 963 | 930 | 930 | 28 | 33 | 4808 | 1926 |
| 9 | 11.45-12.45 | 3660 | 915 | 870 | 870 | 24 | 29 | 4554 | 1814 |
| 10 | 12.00-13.00 | 3729 | 933 | 879 | 879 | 26 | 31 | 4634 | 1843 |
| 11 | 15.30-16.30 | 3602 | 901 | 868 | 868 | 26 | 31 | 4496 | 1800 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 12 | 15.45-16.45 | 3564 | 891 | 961 | 961 | 27 | 32 | 4552 | 1884 |
| 13 | 16.00-17.00 | 3492 | 874 | 1083 | 1083 | 30 | 36 | 4605 | 1992 |
| 14 | 16.15-17.15 | 3365 | 841 | 1158 | 1158 | 26 | 31 | 4549 | 2030 |
| 15 | 16.30-17.30 | 3495 | 874 | 1100 | 1100 | 29 | 35 | 4625 | 2009 |

From Table 2, it can be seen that the highest average daily traffic occurs between 16:15 and 17:15 WIB, with a volume of 2,030 PCU.

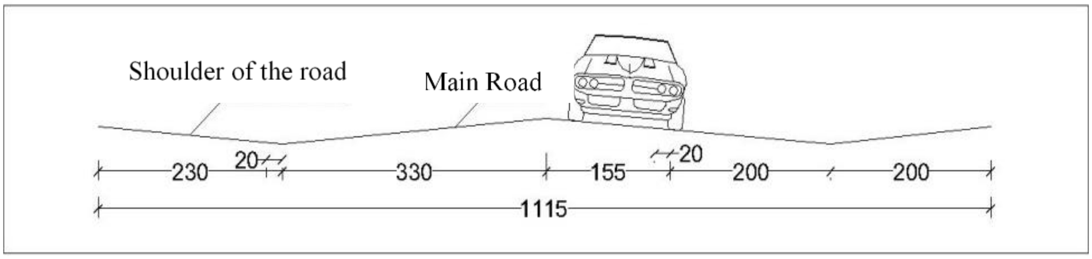



**Figure 2.** Cross-section of Gajayana Street in Malang City

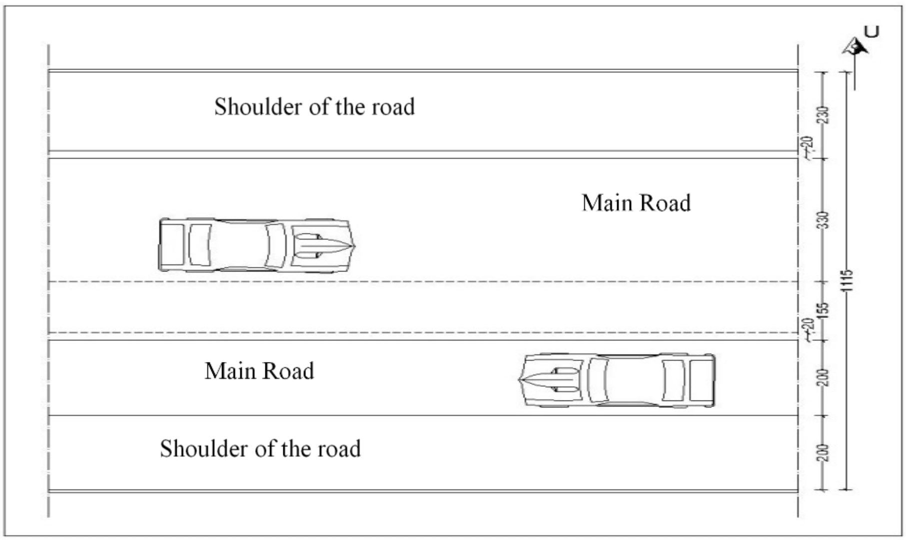



**Figure 3**. Map of Gajayana Street, Malang City

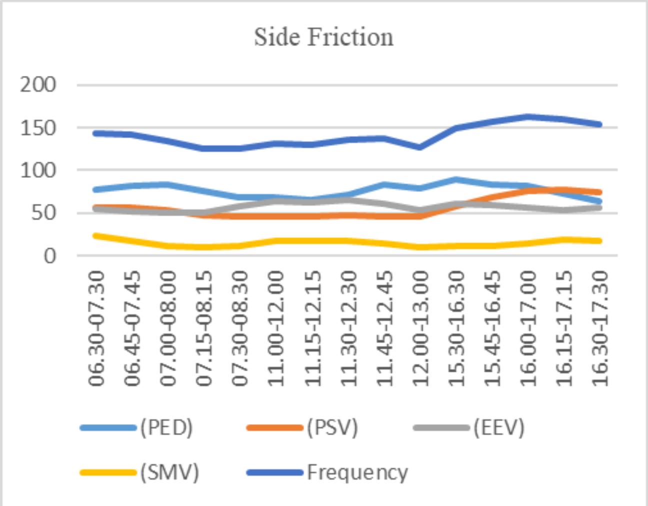
## Side Frictions

In determining side friction, the weighted frequency of events must be known. To obtain the weighted frequency value, each type of side friction event must be multiplied by its weighting factor. For more details, refer to Table 4.4.

The weighting factors for side friction are as follows:

a. Pedestrians (PED) = 0.5
b. Parked/Stopped Vehicles (PSV) = 1.0
c. Entering and Exiting Vehicles (EEV) = 0.7
d. Slow-moving Vehicles = 0.4




**Graphic 1**. Side Frictions

**Description:**
**PED** = Pedestrian
**PSV** = Parked/Stopped Vehicle
**EEV** = Entering and Exiting Vehicle
**SMV** = Slow-moving Vehicle
From the side friction survey conducted during peak hours, the highest result was recorded between 16:15 and 17:15, with a weighted frequency of events per 200 meters per hour amounting to **146.9**, which falls into the **low side friction** category.

**Speed Data**

Travel speed was calculated by sampling light vehicles (LV). Speed data was obtained through a survey conducted during peak hours, specifically from 16:15 to 17:15 WIB. The method used was **spot speed**, with a sample of 100 light vehicles.

**Steps for surveying and calculating spot speed:**

a) Determine the starting and ending points of the vehicle's journey over a 200-meter segment.
b) Record the license plate of the vehicle as it passes the starting point and simultaneously start the stopwatch.
c) When the vehicle reaches the endpoint, record the time it took to travel between the two points using the stopwatch.
d) Repeat steps b and c until 100 samples are obtained.
e) Calculate the average speed of the light vehicles using the formula found in the literature review:

**V = S / T**

Where:
**V** = Speed (km/h)
**S** = Distance (km)
**T** = Travel Time (hour)

**Example Calculation:**
V = (200 × 0.001) / (20 × 3600)
V = 0.2 / 72000
V = **36 km/h**
The result from the average speed survey of light vehicles is **35.7 km/h**. The full calculation can be found in the appendix.

**Analysis of Existing Road Segment Performance**

The analysis of capacity and degree of saturation for the year 2012, using calculation forms and PKJI 2023, is as follows:

**Total Flow (Q)**

Traffic volume refers to the number of vehicles passing through a road segment within one hour. The traffic volume data was taken from the peak hour average daily traffic (ADT), measured in PCU/hour. The calculation can be found in form JK II of PKJI 2023 in the appendix, while the value of traffic volume (Q) is presented in the following table.

**Table 3.** Data Volume of Traffic on Gajayana

| Road Condition | Traffic Volume Value (Q) (pcu/hour) |
|---|---|
| 2 way (morning) | 2030 |
| 1 way (afternoon) | 1952 |

**Capacity (C)**

Road segment capacity can be calculated using the equation provided in the literature review:

The calculation of road capacity can be seen in Forms JK I, II, and III of PKJI 2023 in the appendix. The steps for calculating capacity (C) are as follows:

a) **Basic capacity ($C_0$)** from Table 4.1:

For undivided two-lane roads: $C_0$ = 2800 (total both directions)

For one-way roads: $C_0$ = 1700 per lane

b) **Lane width adjustment factor (FCLJ)** from Table 4.3:

For undivided two-lane roads: FCLJ = 0.87 (total both directions)

For one-way roads: FCLJ = 0.92 per lane

c) **Directional separation adjustment factor (FCSP)** from Table 4.4:

For undivided two-lane roads: FCSP = 0.88

For one-way roads: FCSP = 1.00

d) **Side friction adjustment factor (FCHS)** from Tables 4.5 and 4.6:

With side friction of 167, categorized as low

For shoulder width > 2 m:

Undivided roads: FCHS = 0.97

One-way roads: FCHS = 0.97

e) **Urban size adjustment factor (FCUK)** from Table 4.7:

With a population of 0.8 million: FCUK = 0.94

**Resulting in:**

a) **Two-way road capacity:**

$C = 2800 \times 0.87 \times 0.88 \times 1.00 \times 0.94$

C = **2015 PCU/hour**

b) **One-way road capacity:**

$C = 1700 \times 0.92 \times 1.00 \times 0.97 \times 0.94 \times 2$

C = **2852 PCU/hour**

**Degree of Saturation (DS)**

The degree of saturation is calculated using the equation provided in the literature review:

$$DS = Q / C$$

Where:

DS = Degree of Saturation

Q = Traffic Volume (PCU/hour)

C = Capacity (PCU/hour)

The calculation of the degree of saturation can be found in Form UR-3 of MKJI 1997 in the appendix. The results of the DS calculation are as follows:

a) **DS (two-way)** = 2030 / 2015 = **1.0**

b) **DS (one-way)** = 1952 / 2852 = **0.68**

**Level of Service (LOS)**

The Level of Service (LOS) is determined based on **Regulation of the Minister of Transportation No: KM 14 Year 2006**.

Gajayana Street, which functions as a secondary collector road, must have a minimum LOS of **C**. Based on Table 2.15, the Level of Service of Gajayana Street under various conditions is as follows:

**Table 4.** Level of Survice jalan Gajayana

| Condition | Degree of Saturation | Level of Survice |
|---|---|---|
| Two way | 1,0 | F |
| One Way | 0,68 | B |

## Discussion

The analysis of Gajayana Street in Malang City reveals critical insights into traffic performance, particularly during peak hours. The highest recorded traffic volume occurred between 16:15 and 17:15 WIB, reaching 2,030 PCU/hour. This volume coincides with the highest side friction frequency (146.9 events/hour), which indicates that external disturbances such as pedestrian movement, parked vehicles, and vehicles entering/exiting significantly contribute to congestion. Although classified as low side friction, its effect becomes more pronounced during peak traffic conditions.

The calculated average travel speed of light vehicles was 35.7 km/h, which aligns with typical urban secondary collector roads but still indicates moderate congestion when compared with ideal conditions. The degree of saturation (DS) for the two-way configuration reached 1.0, indicating that demand equals or exceeds capacity, resulting in Level of Service (LOS) F. This reflects unstable flow, long delays, and frequent congestion. Conversely, the one-way configuration produced a DS of 0.68, categorized as LOS B, which reflects relatively stable conditions with only slight limitations on speed choice. These findings suggest that the operational efficiency of Gajayana Street is highly dependent on its traffic management system. The one-way configuration significantly improves traffic flow, reducing saturation and providing a better service level. This result is consistent with previous research that emphasizes the importance of road geometry, traffic control measures, and behavioral aspects of drivers in influencing intersection and corridor performance [5][6][7].

Additionally, driver violations remain a crucial factor in traffic flow performance. Literature shows that factors such as driver education [1], prior accident experiences [2], emotional and aggressive driving tendencies [3], as well as signal types and cycle lengths [7], all shape driver compliance at intersections. In the case of Gajayana Street, where congestion coincides with high traffic volumes, strategies to minimize violations—such as enforcement through cameras, adaptive signal control, or countdown timers—may enhance compliance and reduce unsafe behaviors.

Overall, this study highlights that road performance is not only influenced by physical capacity but also by side frictions and human behavior. The improvement of LOS from F to B under different operational schemes demonstrates that strategic traffic management interventions can alleviate congestion significantly. However, sustainable solutions should integrate infrastructure adjustments, behavioral interventions, and stricter enforcement to ensure long-term improvements in traffic safety and efficiency.

**Interpretation of Findings**

The analysis of Gajayana Street highlights the interplay between road capacity, side frictions, and driver behavior in determining traffic performance. The results show that traffic conditions vary significantly depending on road operation schemes.

First, the two-way road configuration resulted in a degree of saturation (DS) of 1.0, which places the road at Level of Service (LOS) F. This indicates that traffic demand has reached or exceeded capacity, creating unstable conditions with frequent congestion and delays. Such conditions not only reduce travel efficiency but also increase the risk of aggressive driving and traffic violations.

In contrast, the one-way operation produced a DS of 0.68 or LOS B, reflecting a stable traffic condition where drivers retain flexibility in choosing speeds. This suggests that traffic flow efficiency is strongly influenced by directional management. Converting roads to one-way operation, particularly during peak hours, appears to be an effective strategy to reduce congestion.

The survey of side frictions further supports this conclusion. While the overall friction level was categorized as low, peak-hour disturbances—especially pedestrian movements, parked vehicles, and entry/exit maneuvers—coincided with the highest traffic volumes. This overlap indicates that even low levels of side friction can exacerbate congestion during peak hours.

The average speed of light vehicles, measured at 35.7 km/h, confirms moderate traffic performance. Although the speed is acceptable for an urban secondary collector, it reflects the influence of both congestion and side frictions compared to the ideal free-flow conditions.

These findings align with prior research emphasizing the role of both physical road capacity and behavioral aspects of drivers in shaping traffic conditions. Violations at intersections, inadequate enforcement, and limited infrastructure for pedestrians or parked vehicles amplify congestion problems. Therefore, the study underscores that improving traffic flow requires not only physical interventions (capacity and geometry) but also behavioral and regulatory measures (enforcement, education, and signal management).

**Comparison with Prior Work**

The findings of this study are consistent with and extend previous research on traffic performance, driver behavior, and violations at intersections.

First, the observed differences in road performance between two-way and one-way operations support the conclusion of Al-Atawi (2014) [5], who found that intersection geometry and traffic control strongly influence red-light violations and congestion levels. Similarly, Abdul Manan et al. (2019) [6] emphasized the role of intersection design and signalization in shaping motorcyclist compliance in Malaysia. The present study confirms that operational schemes, such as one-way conversion, can significantly improve the Level of Service (LOS) in urban corridors.

Second, the role of driver behavior in exacerbating congestion aligns with earlier findings. Shell et al. (2015) [1] demonstrated that driver education reduces violations and accidents, while Nishida (2015) [2] showed that drivers with prior accident experience tend to drive more cautiously. In contrast, Alonso et al. (2019) [3] and Cegarra et al. (2025) [4] highlighted that emotional and aggressive driving behaviors, including interactions with autonomous vehicles, can increase risky maneuvers. The congestion observed on Gajayana Street during peak hours, despite relatively low side friction, suggests that driver impatience and violations may amplify the negative effects of high volumes.

Third, the influence of external factors such as signal type and cycle length also echoes prior work. Kulanthayan, Phang, and Hayati (2007) [7] showed that longer signal cycles and the absence of enforcement increase the likelihood of violations. Although this study did not directly measure signal compliance, the findings suggest that enforcement measures (e.g., cameras, countdown timers, adaptive yellow signals) could further improve performance, supporting conclusions drawn by Lin & Cheng as well as Hezaveh et al. (2018) [8] in relation to user behavior under different traffic control conditions.

Finally, the measured travel speed of 35.7 km/h and LOS outcomes align with Tamin (2000) and PKJI (2023) [9], which provide benchmarks for evaluating urban road performance. The comparison highlights that Gajayana Street operates at suboptimal service levels during peak hours under two-way operations, but achieves acceptable performance with one-way flow.

Overall, this study reinforces prior evidence that both **infrastructure design** and **human factors** are critical determinants of traffic performance. It contributes by providing a case-specific analysis in Malang City, demonstrating how operational schemes and side frictions interact with driver behavior to influence road service levels.

**Implications**

The findings of this study carry several important implications for traffic management and urban transport planning in Malang City:

**Traffic Management Strategies**

The significant improvement in Level of Service (LOS) from F under two-way conditions to B under one-way operation highlights the importance of adaptive traffic management. Policymakers should consider implementing one-way traffic schemes during peak hours to reduce congestion and improve mobility.

**Infrastructure Planning**

Road capacity alone is not sufficient to ensure smooth traffic flow. The influence of side frictions, such as pedestrians, parked vehicles, and entering/exiting vehicles, demonstrates the need for better infrastructure design. Providing dedicated pedestrian crossings, on-street parking management, and controlled access points could minimize interruptions to main traffic flow.

**Behavioral Interventions**

Since driver violations contribute significantly to congestion, interventions should go beyond infrastructure. Public awareness campaigns, driver education, and stricter law enforcement (e.g., red-light cameras, countdown timers, and adaptive signal control) can improve driver compliance and reduce risky behaviors.

**Policy and Regulation**

Local transportation authorities should adopt regulations that enforce the minimum required LOS for collector roads, as stipulated in national guidelines. By doing so, performance monitoring can ensure that roads remain within acceptable service levels, and corrective measures can be taken promptly when thresholds are exceeded.

**Urban Mobility and Sustainability**

Improved traffic flow not only benefits travel time but also contributes to broader sustainability goals. Reducing congestion lowers fuel consumption, emissions, and accident risks. This aligns with sustainable transport development agendas and provides long-term benefits to public health and environmental quality.

**Future Research Directions**

Further studies should investigate the long-term effects of traffic management strategies, including how changes in signal design, road widening, or public transport improvements interact with driver behavior. Such research will provide a more comprehensive basis for future urban mobility planning.

**Limitations**

Although this study provides useful insights into the performance of Gajayana Street, several limitations should be acknowledged:

**Geographical Scope**

The research focused only on one road segment in Malang City. As a result, the findings may not fully represent traffic conditions on other road types or locations with different geometric, socioeconomic, or enforcement characteristics.

**Time of Observation**

Traffic surveys were conducted during specific peak hours. While this captures critical congestion periods, it may not fully reflect variations throughout the day, weekdays versus weekends, or seasonal traffic fluctuations.

**Driver Behavior Measurement**

The study primarily inferred driver behavior from traffic volume, side friction, and LOS data. Direct behavioral analysis (e.g., observation of specific violations such as red-light running, speeding, or aggressive maneuvers) was not conducted. This limits the ability to precisely link violations with congestion outcomes.

**Influence of Traffic Control Devices**

Although prior studies highlight the role of signal types, countdown timers, and enforcement technologies, this study did not evaluate their direct effects on compliance or performance. The absence of this analysis restricts the understanding of how control measures interact with traffic flow on Gajayana Street.

**Data Limitations**

The speed survey was based on a sample of 100 light vehicles. While sufficient for estimation, it may not fully capture the diversity of vehicle types and driving styles. Similarly, side friction measurements were limited to certain periods and may not reflect dynamic variations across time.

**Longitudinal Analysis**

The research did not account for changes in traffic patterns over time, such as population growth, urban development, or new transportation policies. Therefore, the results provide a snapshot rather than long-term trends in road performance.

**Future Work**:

Building on the findings and limitations of this study, several avenues for future research are recommended.

**Broader Geographic Coverage**

Expanding the study to include multiple road segments and intersections in Malang City or other urban areas would provide a more comprehensive understanding of traffic performance under different conditions.

**Extended Observation Periods**

Future studies should capture traffic data across different times of the day, weekdays versus weekends, and even seasonal variations. This would help identify recurring congestion patterns and provide more robust recommendations for traffic management.

**Direct Behavioral Analysis**

Observing and quantifying specific driver violations such as red-light running, speeding, or aggressive maneuvers would allow researchers to directly link driver behavior with congestion and safety outcomes, rather than inferring behavior from flow data alone.

## Conclusion

This study evaluated the traffic performance of Gajayana Street in Malang City by analyzing traffic volume, side frictions, speed data, capacity, degree of saturation (DS), and Level of Service (LOS). The results demonstrate that traffic conditions on this road segment vary significantly depending on its operational scheme.

Under a two-way configuration, the road operates at a DS of 1.0, corresponding to LOS F, which indicates unstable flow and frequent congestion during peak hours. Conversely, the one-way configuration yields a DS of 0.68, categorized as LOS B, which reflects stable flow with only minor speed limitations. This comparison clearly shows that one-way operation significantly improves traffic performance.

Side friction analysis revealed that although classified as low, disturbances such as pedestrian crossings, parked vehicles, and entry/exit maneuvers amplify congestion when traffic volumes peak. Meanwhile, the average speed of light vehicles was recorded at 35.7 km/h, confirming that actual travel performance is below ideal free-flow conditions.

Overall, the findings highlight that traffic flow is influenced not only by physical capacity but also by driver behavior and roadside activities. Improvements in traffic management such as adaptive signal control, enforcement of violations, and operational schemes like one-way flow can enhance efficiency and safety. In addition, better infrastructure planning to reduce side frictions and stricter policy implementation are essential to achieving sustainable urban mobility.

This research contributes to the growing body of knowledge on urban traffic management by providing a case-specific analysis in Malang City. The insights gained can support policymakers, engineers, and planners in designing strategies to improve road performance, reduce congestion, and promote safer, more efficient transportation systems

## Acknowledgements

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