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# Unveiling the Lost Time Value from Delays at Gajayana Intersection, Malang: A Traffic Delay Analysis

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**ABSTRACT :** The Gajayana Road Intersection in Malang City is a location where traffic congestion frequently occurs. This is due to its proximity to a supermarket and a densely populated area, as well as its function as the primary access route for road users travelling to educational institutions, campuses, commercial areas, and offices. The study was conducted to assess the performance of the intersection under existing conditions and to identify appropriate solutions. Data collection was performed through surveys based on CCTV recordings. The analysis process utilised the Indonesian Road Capacity Guidelines (PKJI) of 2023. The results of the intersection performance analysis under existing conditions revealed a service level of C. The maximum saturation degree was 0.9, and the minimum was 0.69. The maximum delay was 13.4, and the minimum was 11.53. After evaluating several alternative solutions, the chosen approach was the implementation of a Priority Intersection with one-way flow regulation, resulting in a service level of C. The maximum saturation degree was 0.84, and the minimum was 0.65. The maximum delay was 12.9, and the minimum was 11.11. The reduction in the value of lost time per annum due to delays at intersections, based on the UMR value and PDRB, was a maximum of 33.39% and a minimum of 32.77%.

**Keywords:** Traffic congestion, intersection performance, traffic delay, saturation degree, Priority intersection

## 1. INTRODUCTION

Urban traffic congestion remains a significant challenge worldwide, with profound implications for daily urban life, economic activity, and environmental sustainability. As cities continue to expand and urban populations grow, the stress on transportation networks intensifies, leading to more frequent and severe traffic bottlenecks. Efficient traffic management is essential for mitigating these challenges by improving travel times, reducing fuel consumption, and limiting the environmental impact of congested roads. In addition, well-managed transportation systems enhance the overall quality of life for urban residents, making the need for innovative and effective solutions in traffic management more urgent than ever.

Malang City, a rapidly growing urban center in Indonesia, illustrates the complexities of traffic congestion in the context of urbanization. The city's strategic importance as a hub for education, commerce, and administration attracts a constant influx of vehicles, contributing to severe traffic congestion at key intersections. Among these, the Gajayana Road Intersection, or Simpang Sardo, is particularly prone to traffic delays due to its location near residential and commercial areas, including the Sardo Supermarket. The intersection's central role in connecting road users to educational institutions, business centers, and office complexes makes it a critical point of interest for traffic management interventions.

Several factors exacerbate congestion at the Gajayana Road Intersection. The high traffic volume generated by local residents and nearby commercial activities, coupled with the limited road capacity and the physical constraints of the area, contribute to frequent bottlenecks. Furthermore, the lack of viable alternative routes and the difficulty of widening the existing infrastructure complicate efforts to alleviate traffic. These conditions underscore the importance of targeted solutions to improve traffic flow and enhance the efficiency of the intersection.

A review of the existing literature reveals that while there have been numerous studies on urban traffic management and intersection performance, few have focused on specific intersections in Malang City, particularly the Gajayana Road Intersection. Most studies tend to concentrate on larger metropolitan areas or offer generalized traffic models that do not account for the unique characteristics of specific urban intersections. This lack of localized research represents a significant gap in the literature, particularly in understanding how targeted interventions, such as one-way flow regulations or priority intersections, can improve traffic performance in Malang.  Especially related to the analysis of lost time value, due to delays at intersections, this is demonstrated in the research findings [1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11].

This study provides a detailed analysis of the Gajayana Road Intersection using real-time data from CCTV recordings and the Indonesian Road Capacity Guidelines (PKJI) of 2023. By conducting a localized performance analysis and evaluating the impact of specific traffic management interventions, this research fills a critical gap in the existing literature. The study’s focus on implementing a Priority Intersection with one-way flow regulation offers a novel approach to reducing traffic congestion at a key intersection in Malang City. The findings are expected to provide valuable insights for urban traffic planners and policymakers seeking to improve traffic flow, reduce delays, and enhance the overall efficiency of transportation systems in rapidly growing cities.

## 2. LITERATURE REVIEW

The evaluation of traffic performance at intersections is a multifaceted process that involves the assessment of various key metrics, including service level, intersection capacity, and time value. These elements are crucial for understanding and addressing congestion issues in urban environments. **Service level** is widely recognized as a qualitative indicator of traffic flow efficiency, representing the degree of comfort and convenience experienced by road users. It is typically measured through levels of service (LOS), which range from free-flowing conditions to highly congested scenarios. **Intersection capacity**, on the other hand, quantifies the maximum number of vehicles an intersection can handle within a given time frame under specific conditions. This measure is vital for identifying congestion points and designing interventions to improve traffic throughput. Finally, **time value** encompasses the economic and social costs of delays, highlighting the importance of minimizing traffic disruptions to enhance productivity and reduce unnecessary expenses. Together, these concepts provide a comprehensive framework for analyzing and optimizing intersection performance, which is essential for developing effective traffic management strategies.

### 2.1. Service Level

The determination of the desired service level aims to establish the appropriate level of service for a road segment and/or intersection [12]. This process requires meeting several key performance indicators, including the volume-to-capacity ratio of the road, speed limits that are set based on local conditions, travel time, freedom of movement, safety, security, orderliness, smoothness of traffic flow, and driver perceptions of traffic conditions. These indicators ensure that the selected service level reflects both the operational efficiency of the road network and the quality of experience for road users, allowing for a balanced approach to traffic management.  The level of service at intersections is classified into:

a. Service level A, with a delay condition of less than 5 seconds;
b. Service level B, with a delay condition of more than 5 seconds to 15 seconds for the vehicle;

c. Service level C, with a delay condition between more than 15 seconds to 25 seconds for the vehicle;
d. Service level D, with a delay condition of more than 25 seconds to 40 seconds for the vehicle;
e. Service level E, with a delay condition of more than 40 seconds to 60 seconds for the vehicle;
f. Service level F, with a delay condition of more than 60 seconds.

Effective traffic management relies on determining the desired level of service at intersections across various types of road networks to ensure optimal performance and mobility. In the primary road network system, the desired level of service is essential to maintain the smooth functioning of roads according to their designated roles. Primary arterial roads, which handle high-capacity traffic movement, are required to achieve a minimum service level of B. Similarly, primary collector roads, responsible for linking arterial roads to local streets, must also meet a service level of B to support seamless connectivity. For primary local roads, which provide access to residences and businesses, a service level of C is necessary, while toll roads must achieve a minimum service level of B to facilitate uninterrupted long-distance travel. These standards help to balance traffic demand and road capacity, ensuring safety and efficiency.

In the secondary road network system, the determination of service levels is equally important for maintaining road performance and traffic flow. Secondary arterial roads and secondary collector roads, which serve medium to high traffic volumes, are required to achieve a minimum service level of C. Meanwhile, secondary local roads and environmental roads, which handle lower traffic volumes and provide access to residential and environmental areas, must meet a minimum service level of D. These service level requirements form a structured approach to traffic management, ensuring that even roads within the secondary network can fulfill their functions effectively while preserving mobility and safety within the broader transportation system.
Delays at intersections without traffic signals, which are a common feature in both primary and secondary road networks, are primarily caused by the interaction between vehicles from conflicting directions. These delays can be categorized into two main types. The first is traffic delay, defined as the waiting time caused by interactions between vehicles. Main road traffic delay refers to the average waiting time for vehicles entering the intersection from the primary road, while minor road traffic delay pertains to the average delay experienced by vehicles entering from secondary roads. The second type of delay, geometric delay, arises from the deceleration and acceleration of vehicles as they approach or leave the intersection, whether influenced by other vehicles or not [13].

### 2.2. Intersection Capacity

Intersection capacity analysis considers the effects of traffic flow conditions, intersection geometry, and surrounding environmental factors, all based on empirical data. The analysis results should align with the application of these empirical values and not depend on priority rules such as the obligation to stop before entering the intersection or to yield to vehicles from other directions.

### 2.2.1. Intersection Capacity Calculation (C)

The intersection capacity (C) is the total incoming traffic flow from all arms of the intersection. It is calculated by multiplying the basic capacity ($C_o$) by correction factors that account for environmental differences compared to ideal conditions. The following equation can be applied for calculating intersection capacity [13]:

$$C = C_O \times F_{LP} \times F_M \times F_{UK} \times F_{HS} \times F_{BKi} \times F_{Bka} \times F_{Rmi} \text{ (cur/hour)} \quad (1)$$

With:
$C$ = Intersection Capacity
$C_O$ = basic capacity value
$F_{LP}$ = approach width adjustment factor
$F_M$ = major road median adjustment factor
$F_{UK}$ = city size adjustment factor

$F_{HS}$ = adjustment factor for road environment, side obstacles and vehicles not motorized
$F_{Bki}$ = left turn adjustment factor
$F_{BKa}$ = right turn adjustment factor
$F_{Rmi}$ = minor road flow ratio adjustment factor

### 2.2.2. Basic Capacity ($C_0$)

The basic capacity ($C_0$) is empirically determined from ideal intersection conditions, which include an average lane width (LRP) of 2.75 m, no median, a city population size between 1 and 3 million people, moderate side obstacles, and a left-turn ratio (RBKi) and right-turn ratio (RBKa) of 10%. The minor road flow ratio (Rmi) is 20%, with qKTB = 0. The $C_0$ value of the intersection is shown in the following table:

Table.1 Basic capacity of T-junction and 4-way Intersection

| **Intersection Type** | **$C_0$ (pcu/hour)** |
|---|---|
| 322 | 2700 |
| 324 | 3200 |
| 344 | 3200 |
| 422 | 2900 |
| 424 | 3400 |

### 2.2.3. Intersection Type:

The type of intersection is classified based on the number of arms and the number of lanes on both major and minor roads. Each intersection is assigned a three-digit code representing these characteristics, as detailed in Table 2-2. The number of arms is the number of arms for incoming or outgoing traffic or both.

Table 2. Intersection Type Codes

| **Code Intersection Type** | **Number of arms Intersection** | **Number of lanes minor road** | **Number of lanes major road** |
|---|---|---|---|
| 322 | 3 | 2 | 2 |
| 324 | 3 | 2 | 4 |
| 422 | 4 | 2 | 2 |
| 424 | 4 | 2 | 4 |

### 2.2.4. Determination of Average Approach Width:

The correction factor for the average approach width (FLP) can be calculated according to the following equation:

For intersection Type 422: $F_{LP} = 0.70 + 0.0866\ L_{RP}$
For intersection type 424 or 444: $F_{LP} = 0.61 + 0.0740\ L_{RP}$

For intersection Type 322: $F_{LP} = 0.73 + 0.0760\ L_{RP}$
For intersection type 324 or 344: $F_{LP} = 0.62 + 0.0646\ L_{RP}$

### 2.2.5. Median Correction Factor for Major Roads:

A median is classified as wide if it is at least 3.0 meters, allowing passenger vehicles to safely take cover without disrupting traffic flow. Median classification and correction factors for major roads are listed in Table 3 below. This correction is only applied to major roads with four lanes.

Table 3. Median correction factors on major roads, $F_M$

| **Intersection Condition** | **Median type** | **Correction factor, $F_M$** |
|---|---|---|
| There are no medians on major roads | There isn't any | 1.00 |
| There is a wide median on major roads < 3m | Narrow median | 1.05 |
| There is a wide median on major roads ≥ 3m | Wide median | 1.20 |

### 2.2.6. City Size Correction Factor (FUK):

Larger cities tend to have more aggressive driving behaviors, which can increase intersection capacity. The $F_{UK}$ correction factor varies according to the population size of the city. The $F_{UK}$ value can be found in the following table:

Table 4. City size correction factor ( $F_{UK}$ )

| City size | Population, million people | $F_{UK}$ |
|---|---|---|
| Very small | < 0.1 | 0.82 |
| Small | 0.1 – 0.5 | 0.88 |
| Currently | 0.5 – 1.0 | 0.94 |
| Big | 1.0 – 3.0 | 1.00 |
| Very large | >3.0 | 1.05 |

### 2.2.7. Road Environment Correction Factors:

Factors such as road environment, side obstacles, and the presence of non-motorized vehicles are combined into a single side resistance correction factor ($F_{HS}$). These factors account for the influence of the road environment and activities around the intersection on basic capacity.

Table 5. Types of road environment

| Type Environment Road | Criteria |
|---|---|
| Commercial | Land used for interest commercial, for example shops, houses dining, office, with road enter direct Good for pedestrians or vehicle. |
| Settlement | Land used for place stay with road enter direct Good for pedestrians or vehicle. |
| Access limited | Land without road enter direct or very limited, for example Because exists barrier physique; access must through road side. |

Table 6. Criteria for side resistance classes

| Obstacle Class Side | Criteria |
|---|---|
| Tall | The departing flow at the entry and exit points of the intersection is disrupted and reduced due to roadside activity along the approach. For example, there are public transportation activities such as picking up and dropping off passengers or |

|  |  |
|---|---|
|  | waiting in the parking lot, pedestrians and/or street vendors along or passing the approach, vehicles leaving/entering the side of the approach. |
| Currently | The flow of departures at the entry and exit points of the intersection is slightly disrupted and slightly reduced due to roadside activity along the approach |
| Low | The flow departs at the entry and exit points of the intersection disturbed and not reduced by side obstacles. |

Table 7. $F_{HS}$ as a function of road environment type, side obstacles, and $R_{KTB}$

| Type Environment road | Obstacle side | $F_{HS}$ For $_{KTB}$ R value |  |  |  |  |  |
|---|---|---|---|---|---|---|---|
|  |  | 0.00 | 0.05 | 0.10 | 0.15 | 0.20 | ≥0.25 |
| Commercial | Tall | 0.93 | 0.88 | 0.84 | 0.79 | 0.74 | 0.70 |
|  | Currently | 0.94 | 0.89 | 0.85 | 0.80 | 0.75 | 0.70 |
|  | Low | 0.95 | 0.90 | 0.86 | 0.81 | 0.76 | 0.71 |
| Settlement | Tall | 0.96 | 0.91 | 0.86 | 0.82 | 0.77 | 0.72 |
|  | Currently | 0.97 | 0.92 | 0.87 | 0.82 | 0.77 | 0.73 |
|  | Low | 0.98 | 0.93 | 0.88 | 0.83 | 0.78 | 0.74 |
| Access limited | Tall/ Currently/ Low | 1.00 | 0.95 | 0.90 | 0.85 | 0.80 | 0.75 |

### 2.2.8. Left-Turning Flow Ratio Correction Factor (FBKi):

The correction factor for left-turning flow (FBKi) can be calculated using following equation:

$$F_{BKi} = 0.84 + 1.61\ R_{BKi} \qquad (2)$$

With:

RBKi is the left turn ratio.

### 2.2.9. Right-Turning Flow Ratio Correction Factor ($F_{BKa}$):

The correction factor for right-turning flow ($F_{BKa}$) can be determined using the following equation:

For Four-way intersection: $F_{BKa} = 1.0$

$$\text{For T-Junction: } F_{BKa} = 1.09 - 0.922 \qquad (3)$$

With:

$R_{BKa}$ is the right turn ratio

### 2.2.10. Degree of Saturation (DJ):

The degree of saturation (DJ) is a critical metric in intersection performance, and it can be calculated implementing the following equation:

$$DJ = q / C \qquad (4)$$

With:

DJ is the degree of saturation.

C is the intersection capacity, in PCU/hour.

q is all motor vehicle traffic flow from all intersection arms entering the intersection in units of SMP/hour.

### 2.2.11. Delay (T):

Delays at intersections arise from two primary sources: traffic delay ($T_{LL}$) and geometric delay ($T_G$). Traffic delay ($T_L$L) results from interactions between vehicles in the traffic flow and is calculated for all intersections, as well as for major and minor roads separately. Geometric delay ($T_G$) is caused by the deceleration and acceleration of vehicles when turning at intersections or stopping. The total delay (T) can be calculated using equation. T is calculated using the following equation:

$$T = TLL + TG \quad (5)$$

$T_{LL}$ is the average traffic delay for all motorized vehicles entering the intersection from all directions, it can be calculated using the following equation:

$$\text{For } DJ \le 0.60: T_{LL} = 2 + 8.2078\ DJ - (1 - DJ)2 \quad (6)$$
$$\text{For } DJ > 0.60: T_{LL} = 1.0504(0.2742 - 0.2042\ DJ) - (1 - DJ)2 \quad (7)$$

Traffic delay for major roads ($T_{LLma}$) is the average traffic delay for all motorized vehicles entering an intersection on a major road, which can be calculated using the following equation:

For DJ ≤0.60:

$$T_{LLma} = 1.8000 + 5.8234\ DJ - (1 - DJ)1.8 \quad (8)$$

For DJ >0.60:

$$T_{LLma} = 1.0503(0.3460 - 0.2460\ DJ) - (1 - DJ)1.8 \quad (9)$$

Traffic delay for minor roads ($T_{LLmi}$) is the average traffic delay for all motorized vehicles entering the intersection of minor roads, determined from $T_{LL}$ and $T_{LLma}$, calculated using the following equation:

$$T_{LLmi} = (q_{KB} \times T_{LL} - q_{ma} \times T_{LLma}) / q_{mi} \quad (10)$$

With:
qKB is the total flow of motorized vehicles entering the intersection, in PCU/hour.
qma is the flow of motorized vehicles entering the intersection of major roads, in SMP/hour.

$T_G$ is the average geometric delay of all intersections, it can be calculated using the following equation:
For DJ<1:

$$T_G = (1 - DJ) \times \{6\ RB + 3\ (1 - RB)\} + 4\ DJ \text{ (sec/SMP)} \quad (11)$$

For DJ≥1:
$T_G$ = 4 seconds/SMP
With:
RB is the ratio of turning flow to the total motor vehicle flow at the intersection

### 2.2.12. Queue Opportunities (Pa):

The probability of queue formation (Pa) is expressed as a percentage and can be determined according to the following equation:
Upper limit of opportunities:

$$P_a = 47.71\ DJ - 24.68\ DJ2 + 56.47\ DJ3 \quad (12)$$

Lower limit of opportunity:

$$P_b = 9.02\ DJ + 20.66\ DJ2 + 10.49\ DJ3 \quad (13)$$

## 2.3. Time Value

The concept of the value of time refers to the amount of money an individual is willing to pay (or save) in exchange for reducing travel time by one unit. Typically, this value is directly proportional to per capita income, maintaining a fixed ratio to income levels. The underlying assumption is that travel time remains constant over time when compared to consumer spending patterns [14].

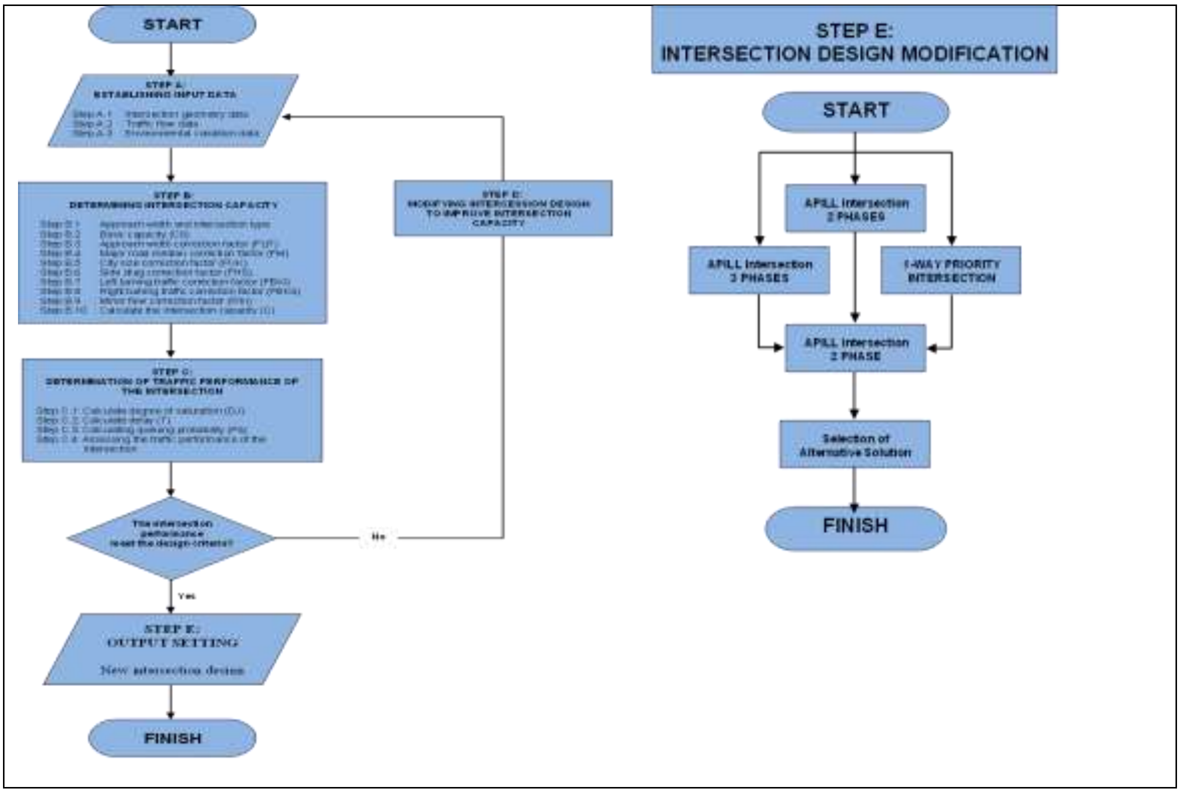
In this study, the value of time is assessed using the Income Method (Income-Approach). This method focuses on two key factors: the Gross Regional Domestic Product (GRDP) and the regional minimum wage (UMR). These factors are applied to individuals' work time in a year, assuming that time spent working translates directly into income. The value of travel time is calculated based on this relationship, following the formula provided in the following Equation:

$$NW = (GRDP / \text{Annual working time}) \tag{14}$$

In this study, it is assumed that each vehicle carries an average of two passengers. According to 2022 data, Malang City's Gross Regional Domestic Product (GRDP) amounted to IDR 84,807,430,000,000, with a population of 846,130 people. The annual working hours are set at 2,080 hours, based on an 8-hour workday over a 5-day workweek. For 2023, the regional minimum wage in Malang City is recorded at IDR 3,194,143.98. These data points serve as the basis for calculating the value of travel time in the city's transportation network.

## 3. METHODOLOGY

The methodology of this study involved a comprehensive data collection process utilizing a survey based on CCTV recordings at the observed intersections. This approach enabled the accurate observation and measurement of traffic flow, vehicle counts, and delays. The subsequent analysis was conducted using the 2023 Indonesian Road Capacity Guidelines (PKJI), which provides a standardized framework for evaluating road and intersection performance. The steps of the analysis, as outlined in the accompanying flowchart shown in Fig. 1, ensure that the results are consistent with national traffic management practices, offering insights into intersection capacity, delays, and overall efficiency.



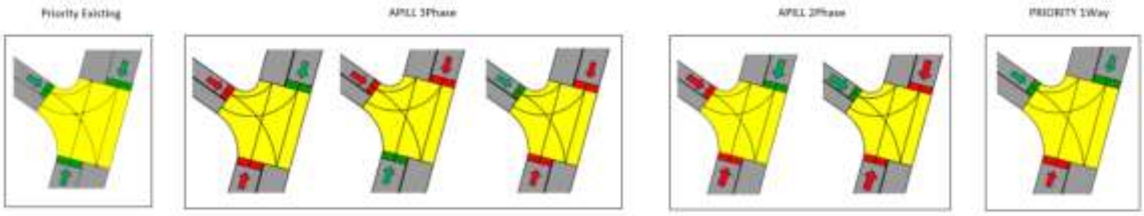


Figure 1. Intersection Performance Analysis Process

The research was conducted at the intersection of Gajayana Road, specifically at the Gajayana Road - Simpang Gajayana intersection, located in Malang City. This intersection serves as a critical juncture within the city's road network, facilitating traffic flow between residential, commercial, and educational areas. Its strategic location and high traffic volume make it an ideal case study for evaluating intersection performance and identifying potential improvements. The observed location, intersection configuration, and traffic condition of the intersection provides a visual reference for the analysis, illustrated in Fig. 2 and Fig.3 respectively.

Figure 2. Research Location

Figure 3. Traffic conditions
(Source: https://malangkota.go.id)

## 4. RESULT & DISCUSSION

A thorough evaluation of the Gajayana Road intersection's traffic performance under current conditions has been carried out. This analysis is essential to assess the intersection's level of service, congestion patterns, and delays affecting road users. Key metrics, including vehicle flow, delays, and saturation levels, were examined to provide a detailed overview of the intersection's operational efficiency. The results are presented in the accompanying tables and figures, forming the basis for further discussion on possible improvements and effective traffic management strategies.

Table 8. Results of traffic performance analysis at intersections in existing conditions

| Day | Time | Level Of Service (LOS.) | | | |
|---|---|---|---|---|---|
| | | APILL 3Phase | APILL 2Phase | PRIORITY 1Way | Priority Existing |
| Monday | Morning | D | C | C | C |
| | Afternoon | C | E | C | C |
| | Afternoon | D | D | C | C |
| | Morning | D | C | C | C |

| | | | | | |
|---|---|---|---|---|---|
| Saturday | Afternoon | C | D | C | C |
| | Afternoon | C | C | C | C |
| Sunday | Morning | D | D | C | C |
| | Afternoon | C | E | C | C |
| | Afternoon | D | C | C | C |

The analysis results, as presented in Table 8 above, indicate that the maximum degree of saturation at the intersection is 0.9, which exceeds the acceptable threshold of 0.85. This suggests the need for improvements to enhance intersection performance. The current level of service (LOS) is classified as Level C, which is still within acceptable limits. According to Appendix V of Malang City Regional Regulation Number 6 of 2022 concerning the Regional Spatial Planning for 2022-2042, the Gajayana Road intersection is categorized within the hierarchy of secondary arterial roads, while the intersecting road belongs to the secondary collector road hierarchy, based on PKJI 2023. The intersection itself is classified as a Type 322 intersection. Referring to the Regulation of the Minister of Transportation of the Republic of Indonesia Number PM 96 of 2015, the minimum acceptable level of service for intersections is Level C. The subsequent section presents proposed solutions to improve the intersection's performance, as summarized in the following table.

Table 9. Results of traffic performance analysis at alternative solution intersections

| Alternative Solutions | | APILL 3Phase | APILL 2Phase | PRIORITY 1Way | Priority Existing |
|---|---|---|---|---|---|
| Average Delay | Maximum | 31.69 | 49.10 | 12.90 | 13.40 |
| | Minimum | 21.85 | 19.96 | 11,11 | 11.53 |
| | Average | 26.58 | 32.88 | 12.28 | 12.53 |
| DJ.( Deg Saturation ) | Maximum | 0.84 | 0.88 | 0.84 | 0.90 |
| | Minimum | 0.79 | 0.79 | 0.65 | 0.69 |
| | Average | 0.82 | 0.83 | 0.77 | 0.80 |
| Level Of Service (LOS.) | Highest | C | C | C | C |
| | Lowest | D | E | C | C |
| | Condition | C | C | C | C |

The analysis of the time lost due to delays at the observed intersection, along with potential alternative solutions, has been evaluated by incorporating factors such as the Gross Regional Domestic Product (GRDP) and the Regional Minimum Wage (UMR). The findings, which quantify the economic impact of these delays and suggest possible improvements, are illustrated in the Fig. 4 and Fig. 5 below. This analysis provides a comprehensive view of how delays at the intersection affect both traffic efficiency and economic productivity.

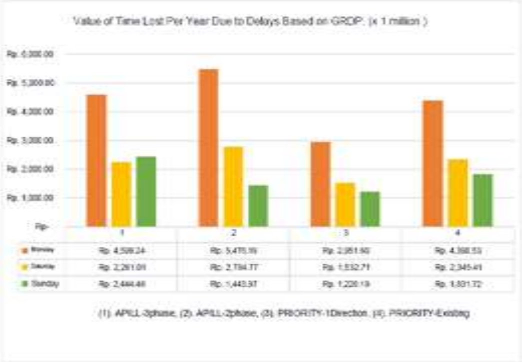


Figure 4. Value of Time Lost Due to Delays Based on GRDP

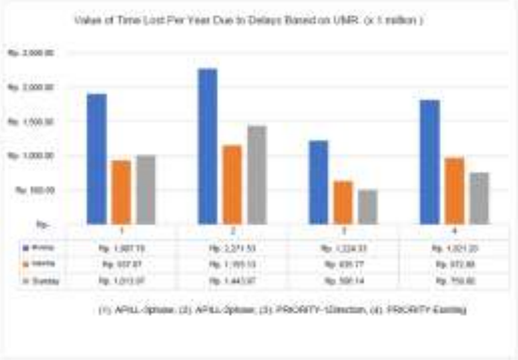


Figure 5. Value of Time Lost Due to Delays Based on UMR

The data presented in the table and figure above reveal a substantial decrease in the value of lost time due to delays when comparing the current intersection conditions with those proposed for the Priority Intersection. Specifically, the introduction of vehicle flow diversion and the widening of the minor road approach contribute to a notable reduction in lost time, ranging from 32.77% to 33.39%, with an average reduction of 33.08%. This indicates that the proposed modifications significantly enhance traffic flow and minimize delays.

Additionally, the improvements in traffic efficiency are further evidenced by the reduction in delay-related costs. By alleviating congestion and optimizing vehicle movement, the proposed changes not only decrease the time spent waiting at the intersection but also lower the overall economic impact associated with traffic delays. This underscores the value of implementing such traffic management strategies to achieve better operational performance and cost savings.

Moreover, the effectiveness of the proposed Priority Intersection modifications is reflected in various metrics, including the degree of saturation, delay times, service level, and queue lengths. The substantial reductions in these metrics further validate the anticipated benefits of the proposed improvements. Consequently, the data supports the conclusion that the Priority Intersection approach represents a viable solution for enhancing traffic efficiency and reducing the negative impacts of delays at the intersection.

## 5. CONCLUSIONS AND SUGGESTIONS

### 2.4. Conclusion

This study evaluated various traffic management solutions for improving the performance of the Gajayana Road intersection, including alternatives such as APILL with three phases, APILL with two phases, and a Priority Intersection with one-way flow control. After careful analysis, the Priority Intersection with one-way flow control was selected as the most effective solution. This configuration, coupled with medium vehicle flow control restricted to weekends, achieved a notable enhancement in traffic conditions.

Under the proposed Priority Intersection model, the service level improved to C, reflecting an optimized balance between traffic demand and roadway capacity. The analysis revealed a maximum degree of saturation of 0.84 and a minimum of 0.65, indicating a significant reduction in congestion compared to existing conditions. Additionally, the maximum and minimum delays were reduced to 12.9 seconds and 11.11 seconds, respectively, demonstrating the efficacy of the one-way flow control in minimizing wait times at the intersection.

Furthermore, the implementation of the Priority Intersection resulted in a substantial decrease in the value of lost time due to delays. The reduction in lost time, based on the Regional Minimum Wage (UMR) and Gross Regional Domestic Product (GRDP), ranged from a maximum of 33.39% to a minimum of 32.77%, with an average reduction of 33.08%. This reduction underscores the significant economic benefits of the proposed traffic management strategy, highlighting its effectiveness in enhancing overall traffic efficiency and reducing delay-related costs.

In conclusion, the Priority Intersection with one-way flow control presents a viable solution for addressing traffic congestion and improving intersection performance. The findings of this study provide valuable insights for traffic management authorities and policymakers, offering a data-driven approach to optimizing traffic flow and minimizing delays at critical urban intersections.

### 2.5. Suggestion

To enhance the effectiveness of traffic management strategies, future research should focus on exploring the impact of road network loading at intersections. Investigating how varying levels of road network loading influence intersection performance can provide valuable insights into optimizing traffic flow and reducing congestion. This research could involve developing and testing advanced models that account for dynamic traffic conditions, peak-hour variations, and different traffic management strategies. By understanding how road network loading affects intersection functionality, planners and engineers can design more resilient and adaptive traffic systems.

Additionally, examining the interactions between road network loading and various traffic control measures, such as signal timing, lane configurations, and priority systems, could yield significant findings. Future studies could explore how these factors collectively influence traffic delays, safety, and overall road network efficiency. Such research would contribute to a deeper understanding of intersection dynamics and inform the development of innovative solutions to enhance traffic management practices. Prioritizing this area of research will be crucial for advancing urban transportation systems and addressing the growing challenges of congestion and travel efficiency.

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***INFO***

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