DEVOTION
Journal of Research and Community Service
Volume 6, Number 2, February 2025
e-ISSN: 2797-6068 and p-ISSN: 2777-0915

Optimization of Traffic Light Settings on The Toll Overpass Segment of Sidodadi In Sidoarjo Regency

Helmi Riezki Latif, Risma Marleno, Haris Muhammadun
Universitas 17 Agustus 1945 Surabaya, Indonesia
helmi.riezki@gmail.com, rismamar@untag-sby.ac.id, haris@untag-sby.ac.id

KEYWORDS
traffic light effectiveness, road performance, degree of saturation, adaptive traffic control, sidodadi road

ABSTRACT
The optimization of traffic light settings plays a crucial role in managing vehicle flow, reducing congestion, and improving road performance, particularly in critical segments such as the toll overpass of Sidodadi in Sidoarjo Regency. This study focuses on addressing two key research questions: the impact of heavy vehicle traffic on intersection performance and the effectiveness of proposed strategies for long-term traffic management. Using the Indonesian Highway Capacity Manual (MKJI) 1997, traffic data during peak hours were analyzed to identify delays, degree of saturation, and service levels under existing traffic conditions. The findings revealed that the high volume of heavy vehicles significantly exacerbates delays and reduces intersection efficiency. To address this, two main strategies were proposed: restricting the operational hours of heavy vehicles and implementing dedicated heavy vehicle lanes. Additionally, long-term measures, including intersection redesign and the application of Adaptive Traffic Control Systems (ATCS), were evaluated. The results highlight the need for immediate interventions and continuous evaluation to ensure sustainable traffic flow and support regional mobility and economic growth.

INTRODUCTION

Traffic is a vital element in supporting community mobility and economic activities within a region. The efficiency of transportation systems is one of the key indicators of successful infrastructure development, directly affecting the smooth distribution of goods, time efficiency in travel, and road user convenience. However, the increasing number of vehicles and economic activities often outpaces the capacity of existing road infrastructure, leading to traffic issues, especially in areas with high vehicle volumes. One such area facing these challenges is Jalan Sidodadi, specifically at the Toll Overpass segment in Candi District, Sidoarjo Regency (Poernamasari et al., 2019; Yudanto et al., 2013).

Jalan Sidodadi serves as a strategic road connecting the local road network, arterial roads, and toll access. This location frequently experiences traffic congestion, particularly during morning and evening peak hours, due to the high volume of vehicles passing through. This condition results in significant delays, vehicle flow conflicts, and a decline in the road's Level of Service (LOS). According to the Indonesian Highway Capacity Manual (MKJI, 1997), the LOS in this location often falls into categories E and F, indicating unstable flow conditions to severe congestion (Sendow et al., 2023; Ulfah, 2018).

One effort to address this issue is the implementation of traffic lights. Traffic lights are designed to regulate vehicle flow, reduce conflicts between traffic streams, and minimize delays. However, the effectiveness of traffic lights heavily depends on cycle timing adjustments that must align with vehicle movement patterns during different operational hours, especially during peak times. Ineffective cycle timing configurations can lead to high delays, increased saturation levels, and reduced road performance efficiency (Herdiansyah & Atika, 2016; Indriani et al., 2024).

In addition to traffic light adjustments, other factors also contribute to traffic conditions on Jalan Sidodadi. One significant factor is the high proportion of heavy vehicles, such as trucks and buses, which have slower acceleration and require more space. These heavy vehicles exacerbate delays, particularly during busy hours. Road narrowing on the overpass segment is also a major factor causing increased congestion. Inconsistent road widths at several points force drivers to slow down, thereby extending delays and increasing the risk of traffic flow conflicts (Akçelik, 2005; Lumbanraja, 2018).

Side obstacles, such as illegal parking, vehicle activities entering and exiting facilities near the road, and pedestrian movement, further exacerbate congestion. These obstacles reduce the effective lane width available for vehicles, thereby decreasing road capacity. Thus, effective traffic management has become an urgent need to address these issues (Sagala, 2018; Utami et al., 2020).

Modern technologies, such as Adaptive Traffic Control Systems (ATCS), offer long-term solutions to enhance the effectiveness of traffic lights. ATCS enables automatic cycle timing adjustments based on real-time traffic data. This technology can optimize road performance by reducing delays, improving vehicle flow, and preventing severe congestion (Marpaung, 2019; Noval et al., 2018). Additionally, infrastructure improvements, such as road widening or adding lanes, can be implemented to increase road capacity and mitigate congestion risks at the overpass segment of Jalan Sidodadi. The importance of periodic evaluations of traffic light performance cannot be overlooked (Milenia, 2023). Continuous monitoring and data collection on traffic conditions provide a strong basis for adjusting traffic light cycle timings according to actual conditions on the ground. Furthermore, educating and raising awareness among road users about compliance with traffic regulations, such as stopping at red lights and using lanes appropriately, are essential steps to support smoother vehicle flow.

Traffic congestion, especially in critical areas such as the toll overpass of Sidodadi in Sidoarjo Regency, is becoming increasingly problematic due to the rising volume of vehicles. The existing traffic light settings are not adequately addressing the congestion, leading to long delays, particularly during peak hours. This situation affects the overall road performance and impacts mobility, which is essential for both local economic activities and daily commuting. Given these pressing issues, it is urgent to assess and optimize traffic light settings to alleviate congestion and improve road efficiency in the region.

Although previous studies have explored traffic management and the optimization of traffic signals, few have specifically focused on the performance of intersections with high volumes of heavy vehicles and varying road conditions, such as the Sidodadi toll overpass segment. There is limited research on how traffic light cycle adjustments, especially during peak times, influence congestion and road capacity in areas experiencing significant fluctuations in traffic flow. This study seeks to fill this gap by evaluating the current traffic light system and proposing targeted interventions for improving traffic flow at this specific location.

This research introduces a novel approach by examining the effectiveness of traffic light settings, including cycle timing adjustments, in mitigating congestion on a toll overpass segment that experiences heavy vehicle traffic. The use of Adaptive Traffic Control Systems (ATCS) and strategies such as the construction of dedicated lanes for heavy vehicles are proposed as long-term solutions. Unlike previous studies, this research combines real-time traffic data analysis with advanced simulation techniques to assess the performance of traffic lights and identify optimal settings for reducing delays and improving road service levels.

This study aims to evaluate the effectiveness of traffic lights in reducing congestion and improving road performance on Jalan Sidodadi, as well as to provide recommendations and alternative solutions to enhance traffic performance in the area. By analyzing the current traffic situation, the research intends to offer insights into how traffic management strategies can be optimized to address existing issues.

The benefits of this research are threefold: for the author, it fulfills the graduation requirements for the Master of Civil Engineering program at the Faculty of Engineering, Universitas 17 Agustus 1945 Surabaya, while also enriching the author’s knowledge of traffic management. For the university, this research contributes to the body of scientific literature in the field of traffic management and serves as a valuable resource for future studies, particularly in transportation and road performance analysis. For stakeholders in traffic management, especially the Sidoarjo Regency Government, the study provides practical insights for planning and regulation, addressing road narrowing issues that cause traffic delays and congestion, and offering a deeper understanding of local traffic challenges.

Literature Review

General Definitions and Terminology

Understanding or defining general terms related to intersection performance is crucial to make the study easier to comprehend for readers. Below are several key terms used in this research. According to various literature, these traffic-related terms are essential in analyzing intersection performance:

1. Intersection Leg:
   An intersection leg refers to the part of an intersection functioning as an approach for vehicles entering or exiting. This term is significant in analyzing vehicle flow patterns at intersections.
2. Three-Legged Intersection (T-Intersection):
   A T-intersection is an intersection with three legs. This type of intersection is commonly used to connect a major road with a minor road, facilitating simpler traffic flows compared to intersections with more legs.
3. Main Road:
   The main road is the most critical route in an intersection. In a T-intersection, the continuing road is typically designated as the main road to ensure smooth vehicle movement along this path.
4. Minor Road:
   A minor road is the secondary road in a T-intersection that does not continue. It typically serves as an access road rather than a primary route.
5. Approach:
   An approach is the entry point for vehicles at an intersection leg. The approach plays a vital role in determining the capacity and efficiency of an intersection.
6. Approach Width:
   The approach width refers to the paved width of an approach, measured at its narrowest point and used by moving traffic. It is an essential factor in evaluating the capacity of an approach in an intersection.
7. Intersection Type:
   Intersection type is a code that indicates the number of legs and the number of lanes on both the minor and main roads of an intersection.
8. Total Flow (Qtot):
   Total flow represents the number of motor vehicles passing through an intersection, expressed in vehicles per hour or passenger car units (PCU) per hour.
9. Passenger Car Unit (PCU) Factor:

The PCU factor is a conversion factor used to translate the motor vehicle flow from vehicles per hour into passenger car units per hour.

10. Degree of Saturation (DS):
    Degree of saturation is the ratio between the total flow and the intersection capacity. This ratio evaluates whether an intersection can accommodate the current traffic volume.
11. Delay:
    According to the Manual Kapasitas Jalan Indonesia (MKJI, 1997), delay is the additional travel time required by vehicles to pass through an intersection. Delay is measured in seconds per passenger car unit (PCU).
12. Traffic Delay:
    Traffic delay refers to the average delay experienced by all motor vehicles entering an intersection. It is expressed in seconds per passenger car unit (PCU) and serves as one of the primary indicators in evaluating intersection performance (HCM, 2016).

Traffic Flow Calculation

Traffic flow at an intersection is divided into several directions of movement according to traffic conditions and can be depicted in the form of a sketch. Here is an example of a traffic condition sketch:

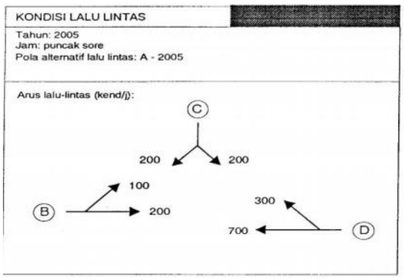

Figure 1 Traffic Condition Sketch Source: MKJI, 1997

The input data needed in calculating intersection traffic with units of vehicles/hour must be adjusted with the smp factor, namely the conversion value of vehicles/hour to passenger car units smp/hour. The following are the conversion values for motor vehicles.

Capacity Calculation

A signalized intersection is an intersection consisting of several arms and equipped with traffic light signal settings. Based on MKJI 1997, the purposes of using traffic light signals at intersections include:

1. To avoid intersection congestion due to traffic flow conflicts, so that a certain capacity can be maintained, even during peak traffic conditions.
2. To provide an opportunity for vehicles and/or pedestrians from (small) intersection roads to cut through the main road.
3. To reduce the number of traffic accidents due to collisions between vehicles from opposing directions.

For most road facilities, traffic capacity and behavior are primarily a function of geometric conditions and traffic demands. By using signals, designers or engineers can distribute capacity to various approaches by allocating green time to each approach (Nugroho et, al (2020).

The use of signals with three-color lights (green, yellow, red) is applied to separate the lanes of conflicting traffic movements in the time dimension. This is an absolute necessity for traffic movements coming from intersecting roads = major conflicts (Febriani, 2020). Signals can also be used to separate turning movements from opposing straight traffic, or to separate turning traffic movements from pedestrians crossing = secondary conflicts. The sequence of signal changes with a two-phase system, including the definition of cycle time, green time and inter-green period, with the formula:

IG (time between green) = yellow + all red (Formula 2.1)
Source: MKJI, 1997

Traffic phases are stages or time periods set in the traffic light cycle at an intersection to control the flow of vehicles and pedestrians. Each phase gives priority to a particular direction of traffic or group of road users. Here are some common phases in a traffic light system, namely the Green Phase is that vehicles in a certain direction are allowed to move, the Yellow Phase is that the light will soon turn red. Vehicles must prepare to stop, and the Red Phase is that vehicles must stop (Marleno et al., 2019).

These traffic phases are designed to optimize traffic flow and improve safety at intersections. The first function is fulfilled by the yellow time, while the second is fulfilled by the all-red time which is useful as a clearing time between the two phases (Daksa & Prastyanto, 2019). All-red time and yellow time are generally applied in advance and do not change during the operating period. If the green time and cycle time are also set in advance, then the signal is said to be operated in a fixed-time control manner.

Table 1. Conversion of Heavy Vehicles, Light Vehicles And Motorbikes To Passenger Car Units

Vehicle Type	Emp for approach type	
	Protect	Against
Heavy Vehicles (HV)	1.3	1.3
Light Vehicles (LV)	1	1
Motorbike (MC)	0.2	0.4

Level of Service

Intersection service or Level of Service (LoS) is a descriptive description of the condition of an intersection. In this study, the level of road service used refers to the Regulation of the Minister of Transportation number 96 of 2015 concerning traffic engineering management. The following are the criteria for the level of intersection service.

Table 2. Level of Intersection Service

Level of Service *Level of Service* (LoS)	**Delay** (det/smp)
A	5
B	5-15
C	15-25
D	25-40
E	40-60
F	>60

Source: Permenhub, 2015

Minimum Standard of Service Level

Minimum standards at intersections are used as a reference for the minimum service that can be provided by an intersection. The following are minimum standards that are classified based on the function of the main road that is passed.

Table 3. Minimum Intersection Service Level

Road Function	Level of Service Intersection *Level of Service* (LoS)
Primer	
Primary Arterial Road: B	B
Primary Collector Road: B	B
Primary Local Road: C	C
Secondary Roads	
Secondary Arterial Road: C	C
Secondary Collector Road: C	C
Secondary Local Road: D	D
Residential Road: D	D

Source: Permenhub, 2015

From this basis, it can be determined to carry out traffic simulations to find out the minimum handling that needs to be achieved, with the hope that traffic management can overcome road performance to provide the best service to road users.

RESEARCH METHOD

The research design consists of three main stages: the preparation stage, implementation stage, and compilation stage. In the preparation stage, objectives, problem type, research scope, solution ideas, required data, and survey tools are determined. The implementation stage involves conducting preliminary and literature surveys, collecting secondary data, carrying out primary surveys such as traffic and road capacity mapping, processing data, analyzing performance, and drawing conclusions. Finally, the compilation stage organizes the research findings to facilitate readers' understanding and fulfill graduation requirements. The study focuses on vehicle traffic crossing Jalan Sidodadi, overpass segment, Sidodadi Village, Candi District, Sidoarjo Regency, East Java. It was conducted in 2024 to collect basic data, including traffic counting surveys and supporting data. Data collection procedures include gathering traffic volume data through a five-day survey (three weekdays, two weekends) during peak hours, grouping vehicles based on their type, measuring road dimensions such as the effective width of the road body and shoulder, and gathering road capacity data from both field surveys and secondary sources like the population of Sidoarjo from BPS and road maps from the Transportation Agency. Traffic volume data is then converted into passenger car units (PCU) using the 1997 MKJI guidelines, and the road section's performance is analyzed by calculating the degree of saturation and intersection capacity, employing simulation techniques to determine the intersection cycle time for a three-arm signalized intersection on the overpass segment.

RESULTS AND DISCUSSION

The analysis of the Sidodadi Road section's performance was conducted based on traffic data collected during morning, afternoon, and evening peak hours. The key parameters examined included delay (seconds/smp), degree of saturation (DS), and Level of Service (LOS), following the Indonesian Road Capacity Manual (MKJI, 1997) guidelines. During the morning peak hour, the East Arm experienced a delay of 48 seconds/smp with a DS of 0.620, indicating conditions approaching capacity with unstable traffic flow. In comparison, the West Arm had a higher delay of 67 seconds/smp with a DS of 0.870, reflecting severe congestion nearing saturation.

In the afternoon peak hour, both arms exhibited more stable traffic conditions compared to the morning. The East Arm showed a reduced delay of 46 seconds/smp with a DS of 0.595, while the West Arm had a delay of 48 seconds/smp with a DS of 0.621, both remaining within stable conditions. However, during the evening peak, the East Arm's delay increased to 64 seconds/smp with a DS of 0.850, signaling conditions approaching saturation. Conversely, the West Arm showed improvement with a delay of 44 seconds/smp and a DS of 0.540, indicating smoother traffic flow.

From the Level of Service (LOS) perspective, during the morning peak, the East Arm was at LOS D, indicating near-capacity conditions, while the West Arm was at LOS E, signifying significant congestion. In the afternoon peak, both arms were at LOS C, reflecting stable traffic flow with acceptable delays. However, during the evening peak, the East Arm experienced a decline to LOS E, while the West Arm improved to LOS C compared to the morning.

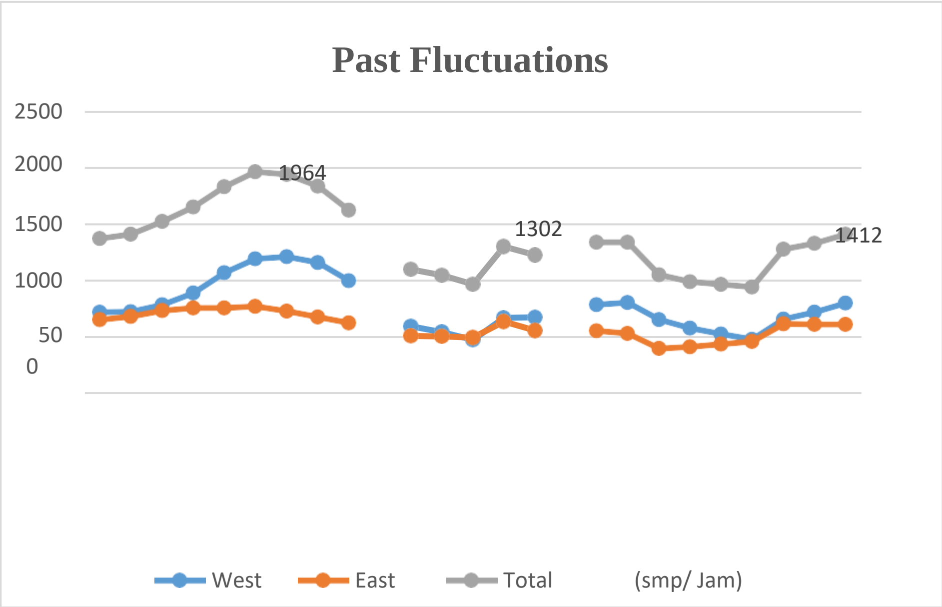

Figure 2. Traffic Fluctuation Graph
Source: Data Analysis, 2024

From Graph 2, it can be seen that the Traffic Fluctuation Graph on the Sidodadi Road Section shows that the highest total traffic volume is during the morning peak hours 07.15 - 08.15 totaling 1,964 smp/hour, during the afternoon peak hours 11.45-12.45 totaling 1,302 smp/hour and the evening peak hours 18.00 - 19.00 totaling 1,412 smp/hour. The largest vehicle composition (split mode) is MC totaling 86%, LV totaling 10%, and MHV totaling 4%. To determine the capacity of a road section with the application of traffic lights, input data is used in the form of saturated flow (S), adjusted green time (g), and cycle time (c) and is carried out on each arm which in this study uses the direction of vehicle movement entering the Sidodadi Road section overpass segment.

Table 4. Saturation Current (S) Current Condition

Leg	Saturation Flow Rate (S) Under Current Conditions							
	Adjustment Factors							Adjusted Value pcu/hour green
	Basic Capacity (So)	City Size Adjustment Factor FCS	Side Friction Factor FSF	Gradient Factor FG	Parking Facto FP	Right Turn Factor FRT	Left Turn Factor	S
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9=2*3*4*5*6*7*8)
East	2100	1	0.89	0,96	1	1.00	1.00	1,794
West	2100	1	0.89	0,96	1	1.00	1.00	1,794

From Table 4, it can be seen the magnitude of the saturation flow in the current condition which is stated in units of passenger cars per hour with a value of 1,794 pcu/hour. The performance of the road section is the ability of the road section to serve the traffic flow that occurs, the performance results are in the form of a degree of saturation (DS). The performance of the Sidodadi Road section with the current traffic light is as follows:

Table 5. Current performance of Sidodadi Road Traffic Light

Peak Hour	Leg	Traffic Flow (smp/hour) Q	Capacity (smp/hour) C	Degree of Saturation DS (Q/C)	Delay (seconds/smp) DT
Morning	East	513	897	0,620	48
	West	719	897	0,870	67
Afternoon	East	492	897	0,595	46
	West	513	897	0,621	48
Evening	East	703	897	0,850	64
	West	446	897	0,540	44

Based on Table 5, the current performance of the Sidodadi road traffic light during peak hours shows varying levels of delay and degrees of saturation. During the morning peak hours, the eastbound direction experiences a delay of 48 seconds per smp with a degree of saturation (DS) of 0.620, while the westbound direction faces a higher delay of 67 seconds per smp with a DS of 0.870. In the afternoon peak hours, the eastbound direction shows an improved delay of 46 seconds per smp with a DS of 0.595, and the westbound direction records a delay of 48 seconds per smp with a DS of 0.621. However, during the evening peak hours, the eastbound direction sees an increased delay of 64 seconds per smp with a DS of 0.850, whereas the westbound direction improves with a delay of 44 seconds per smp and a DS of 0.540.

The analysis reveals that the current traffic light cycle timing is insufficient to fully accommodate the variation in traffic patterns, especially during the morning and evening peak hours. High delays are evident in the westbound leg during the morning and the eastbound leg during the evening, which result in a Level of Service (LOS) in category E. To address this issue, optimizing the traffic light cycle timing is crucial, with adjustments tailored to the traffic volume on each leg. Implementing advanced technologies such as Adaptive Traffic Control System (ATCS) could provide a more dynamic solution by automatically adjusting the cycle timing based on real-time traffic data, thereby improving traffic flow efficiency.

Furthermore, the high proportion of heavy vehicles during the morning and evening peak hours exacerbates delays, particularly in the westbound leg. Heavy vehicles require larger spaces and exhibit slower acceleration, which significantly raises the degree of saturation. Limiting the operational hours of heavy vehicles during peak times or allocating dedicated lanes for them could mitigate conflicts and improve overall traffic flow. Additionally, the road narrowing on the overpass segment is a major factor contributing to delays, particularly in the eastbound leg during the evening. To alleviate this, road widening or adding lanes in this segment could enhance road capacity and reduce congestion risks.

Regular traffic monitoring is vital to detect changes in traffic patterns and reevaluate the traffic light settings. Data obtained from monitoring can support the development of strategies to adjust traffic light cycles to align with real-world conditions.

This approach ensures that traffic arrangements remain relevant to the dynamic demands of vehicle flows, ultimately supporting smoother mobility and improving road user safety.

Table 6. Recapitulation of Current Capacity Conditions

Peak Hour	Leg	Traffic Flow (smp/hour) Q	Capacity (smp/hour) C	Degree of Saturation DS (Q/C)	Delay (seconds/ smp) DT
Morning	East	513	723	0,770	35
	West	719	1071	0,671	30
Afternoon	East	492	897	0,548	23
	West	513	897	0,572	25
Evening	East	703	1071	0,656	29
	West	446	723	0,617	28

From Table 6. it can be seen that the current performance of the Sidodadi Traffic Light road during the morning peak hour towards the east with a delay of 35 sec/smp DS 0.770 while towards the west with a delay of 30 sec/smp DS 0.671. at the afternoon peak hour towards the east with a delay of 23 sec/smp DS 0.548 while towards the west with a delay of 25 sec/smp DS 0.572. at the evening peak hour towards the east with a delay of 29 sec/smp DS 0.656 while towards the west with a delay of 28 sec/smp DS 0.617.

In this study, the performance analysis of the Sidodadi Road section at the Toll Overpass segment was conducted based on two main research questions: to assess the effectiveness of traffic light implementation in reducing congestion and improving road performance, and to provide alternative solutions and recommendations for improving traffic performance at the location. Based on the analysis results, during the morning peak hour, the East Arm experienced a delay of 48 seconds/smp with a degree of saturation (DS) of 0.620, indicating a condition close to capacity, with traffic flow starting to become unstable. On the other hand, the West Arm had a higher delay of 67 seconds/smp with a DS of 0.870, reflecting a severe level of congestion nearing saturation. This indicates that the current traffic light cycle timing does not effectively accommodate the variation in traffic volume, especially during the morning peak.

During the afternoon peak hour, the traffic performance improved, with lower delays on both arms. The East Arm recorded a delay of 46 seconds/smp with a DS of 0.595, while the West Arm showed a delay of 48 seconds/smp with a DS of 0.621. Both arms were at Level of Service (LOS) C, indicating stable traffic flow with delays that were still within acceptable limits.

However, during the evening peak, the East Arm experienced an increase in delay to 64 seconds/smp with a DS of 0.850, indicating conditions approaching saturation. In contrast, the West Arm showed improvement with a delay of 44 seconds/smp and a DS of 0.540, indicating relatively smooth traffic flow. This condition suggests the need for further adjustments to the traffic light cycle, especially for the East Arm during the evening peak.

From the LOS perspective, during the morning peak, the East Arm was at LOS D, indicating traffic conditions approaching capacity, while the West Arm was at LOS E, reflecting significant congestion. During the afternoon peak, both arms showed better performance with LOS C, indicating stable traffic flow. However, during the evening peak, the East Arm experienced a decline in performance to LOS E, while the West Arm improved to LOS C, suggesting that the traffic light cycle timing needs to be adjusted to accommodate the dynamic traffic patterns.

Based on these results, it can be concluded that the implementation of traffic lights on Sidodadi Road, at the Toll Overpass segment, has had a positive impact on reducing congestion, but the timing of the light cycles still requires further evaluation and adjustments. The high delays during the morning and evening peak hours, especially on the West and East Arms, indicate that the current cycle timing is not optimal for handling high traffic volumes. Therefore, more precise cycle adjustments should be made, particularly during peak hours, by considering the vehicle volume on each arm. The use of an Adaptive Traffic Control System (ATCS) can be a solution to automatically adjust the light cycle based on real-time traffic data, improving vehicle flow efficiency and reducing delays.

Additionally, heavy vehicles, particularly during peak hours on the West Arm, further exacerbate congestion. Limiting the operational hours of heavy vehicles or providing dedicated lanes for them could help mitigate their negative impact on traffic flow. The narrowing of the road at the overpass segment is also a significant factor contributing to increased delays and congestion. Therefore, widening the road or adding lanes in this segment should be considered to increase road capacity and reduce the risk of further congestion.

Overall, the findings of this study suggest that although the implementation of traffic lights has played a role in reducing congestion, the traffic light cycle timing needs to be adjusted to significantly improve road performance. Such adjustments would not only reduce delays and congestion but also enhance the safety and comfort of road users. Therefore, integrated short-term and long-term solutions, such as the use of ATCS and infrastructure improvements, should be implemented promptly to ensure smooth traffic flow and support economic growth in Sidoarjo Regency.

CONCLUSION

Based on the data analysis and discussion, it can be concluded that traffic lights play a crucial role in regulating vehicle flow, enhancing road user safety, and reducing congestion. In Alternative 1, improvements to cycle times successfully alleviated traffic during peak hours; however, significant delays persisted, particularly in the morning from the east direction, with delays of 35 seconds per SMP and a Level of Service (LOS) D, indicating approaching instability and delays exceeding 25 to 40 seconds. To address these issues, Alternative 2 proposes the construction of a new overpass with a planned width of 6 meters. Analysis showed that during the morning peak, the existing overpass recorded the highest degree of saturation (DS) at 0.398 with LOS B, reflecting stable flow with limited speed variations, while the new overpass during the evening peak from the east recorded a DS of 0.430 and LOS B, indicating stable conditions with minor speed constraints. Although traffic light adjustments in Alternative 1 yielded some improvements, significant delays during peak hours necessitate infrastructure enhancements such as the proposed overpass to optimize traffic flow and minimize congestion, underscoring the need for continuous evaluation and upgrading of traffic management systems.

REFERENCES

Akçelik, R. (2005). Capacity and performance analysis of roundabout metering signals. *TRB National Roundabout Conference, Vail, Colorado, USA*, 22–25.

Daksa, S. T., & Prastyanto, C. A. (2019). Analisis Pemilihan Jenis Perkerasan Jalan untuk Perbaikan Kerusakan Perkerasan Jalan di Jalan Harun Thohir, Kecamatan Gresik, Kabupaten Gresik, Jawa Timur. *Jurnal Transportasi: Sistem, Material, dan Infrastruktur*, *2*(1), 11–15.

Herdiansyah, M. I., & Atika, L. (2016). Pengaturan Lampu Lalu Lintas Menggunakan Pendekatan Sistem Pakar. *Jurnal Ilmiah Matrik*, *18*(3), 241–250.

Indriani, P. P., Puspasari, N., & Akbar, R. Z. (2024). Optimalisasi Durasi Lampu Lalu Lintas Pada Persimpangan Jalan Rajawali-Tingang Menggunakan PKJI 2023. *AGREGAT*, *9*(2), 1185–1189.

Lumbanraja, N. (2018). *Optimasi Pengaturan Lampu Lalu Lintas pada Simpang Bersinyal dengan Menggunakan Software Vissim*. Universitas Sumatera Utara.

Marleno, R., Witjaksana, B., & Oetomo, W. (2019). Analysis of Risk Mitigation of Development of Flood Control Reservoir of Jadi Village Tuban District. *Journal of Physics: Conference Series*, *1364*(1), 12053.

Marpaung, F. (2019). Optimalisasi Pengaturan Traffic Light di Persimpangan Kota Medan. *Jurnal Keluarga Sehat Sejahtera*, *17*(1), 11–23.

Milenia, C. D. (2023). *Optimalisasi Pengaturan Lampu Lalu Lintas Simpang Glugur Dan Simpang Bambu II Dengan Menggunakan Software VISSIM*. UNIMED.

Noval, C., Virgono, A., & Saputra, R. E. (2018). Optimasi Lampu Lalu Lintas Cerdas Menggunakan Metode Webster. *eProceedings of Engineering*, *5*(3).

Poernamasari, I., Tumilaar, R., & Montolalu, C. E. J. C. (2019). Optimasi Pengaturan Lampu Lalu Lintas dengan Menggunakan Metode Webster (Studi Kasus Persimpangan Jalan Babe Palar). *d'CARTESIAN: Jurnal Matematika dan Aplikasi*, *8*(1), 27–35.

Sagala, V. (2018). Optimasi Pengaturan Lalulintas Raya Gedangan dengan Penerapan Algoritma Welch-Powel dan Bilangan Khromatik. *Limits: Journal of Mathematics and Its Applications*, *15*(1), 79–88.

Sendow, E. S., Sulistyaningsih, M., & Monoarfa, J. F. (2023). Optimasi Waktu Tunggu Lampu Lalu Lintas dengan Mengaplikasikan Teori Graf dan Metode Webster. *Journal on Education*, *6*(1), 2272–2284.

Ulfah, C. (2018). *Optimasi Pengaturan Lampu Lalu Lintas Kota Medan Menggunakan Graf dan Metode Webster*. Universitas Sumatera Utara.

Utami, W. D., Naufal DS, A., & Intan, P. K. (2020). Optimasi waktu tunggu lampu lalu lintas pada simpang lima krian-sidoarjo menggunakan algoritma welch-powell. *Jurnal Matematika*, *2*(1), 1–6.

Yudanto, A. Y., Apriyadi, M., & Sanjaya, K. (2013). Optimalisasi Lampu Lalu Lintas dengan Fuzzy Logic. *Ultimatics: Jurnal Teknik Informatika*, *5*(2), 58–62.