Traffic Conflict Management Strategies at Intersections in Makassar City

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ABSTRACT

This study focuses on assessing traffic characteristics at four crossroads in the city of Makassar, employing a quantitative descriptive methodology. The analyzed parameters include traffic volume, road capacity, free flow speed, degree of saturation, road service level, and types and locations of traffic conflicts. The results indicate that the highest traffic volume occurs on crossings at each intersection, peaking on weekdays, particularly on Monday mornings. Most crossings are classified at road service level A, with a few of them placed in category B due to high Volume-to-Capacity (V/C) ratio. Traffic conflicts are caused by merging and crossing, influenced by driver behavior, vehicle type, and environmental conditions. Adaptive traffic light control, enhanced geometric designs, and road markings are thus required to reduce traffic congestion and enhance safety at crossings. The present study contributes to the development of efficient traffic control strategies in a metropolitan environment.

Keywords-traffic conflict; road intersection; road service level; traffic signal arrangement; Makassar City

I. INTRODUCTION

Transportation infrastructure is significant to the development of urban and rural areas, directly affecting accessibility and economic activity. Public transport systems in a metropolitan area support operational efficiency, improving traffic flow and minimizing congestion on highways [1]. Simultaneously, rural areas benefit from roads and transit facilities, which are needed for maintaining economic stability and enhancing quality of life [2]. These developments improve the interaction between urban and rural regions [3].

Regions with cooperative transportation system design produce a comprehensive framework that supports sustainable development objectives [4, 5]. For rural residents, effective coordination in transport networks leads to reduced costs and improved access to important services [6]. Furthermore, investing in transportation infrastructure contributes to robust economic networks and regional resilience against economic fluctuations [7]. Sustainable transport systems not only aim to reduce emissions from freight and commuter networks but also to effectively respond to community needs during disruptions [8].

Urban areas, such as Makassar city, are challenged by limited parking resources and an increased number of vehicles. Inefficient parking systems lead to traffic congestion, increased emissions, and driver frustration. These issues can be addressed by smart parking, as well as by integrating advanced recognition technologies for real-time monitoring and user assistance [9]. Moreover, noise pollution is considered a pressing environmental issue in rapidly developing cities [10]. In Makassar city, the implementation of Median U-Turns (MUTs) is a common strategy to regulate vehicle flow. To develop Intelligent Transportation Systems (ITS), adaptive

traffic control is dependent on accurate and real-time traffic data.

Parameters such as vehicle counts, density levels, congestion patterns, and intersection waiting times serve as the foundation for optimizing traffic flow and enhancing overall efficiency. Typically, traffic cameras are deployed to collect and process such information. However, their performance is often compromised by adverse environmental conditions. Additionally, regions with robust transportation systems have a greater capacity for industrial growth and agricultural productivity. Authors in [11] highlight that improving irrigation systems through integrations aligned with the Water-Energy-Food (WEF) nexus approach enhances agricultural outcomes and economic performance. Authors in [12] emphasize the role of transportation in facilitating regional economic activities through seamless trade and employment opportunities. Improved transport systems reduce travel times and enhance access to services, such as markets for agricultural products, positively impacting rural economies and contributing to a balanced regional development [13, 14]. Moreover, the integration of sustainable practices into transportation, such as the use of electric vehicles and public transit, aligns with global agendas for environmental sustainability and considers the environmental impacts of transportation [15].

Authors in [16] proposed urban planning strategies, including Transit-Oriented Development (TOD), to create environmentally sustainable urban landscapes in conjunction with more efficient transport systems. Furthermore, optimized urban rail transit systems reduce energy consumption and enhance sustainability objectives [17]. An effective transportation system can diminish travel time and expenses, facilitating improved access to work, education, and healthcare facilities, which are crucial for fostering economic development and social cohesion [18-20].

Intersections are important components of transportation systems, where multiple traffic streams converge. The configuration and operation of intersections influence traffic flow, safety, and efficacy. Intersections can be classified into: (a) at-grade intersections, where roads converge at the same elevation, and (b) grade-separated intersections or interchanges, which permit one road to be elevated above another to ensure uninterrupted flow. At-grade junctions are prevalent in urban environments and may cause increased congestion and potential safety risks due to direct contact between vehicles and pedestrians [21]. Conversely, grade-separated junctions reduce conflict points and enhance traffic efficiency by facilitating smoother transitions among various traffic flows [22]. Effective traffic management at intersections, including synchronized traffic lights, enables reducing delay times and enhancing traffic flow and safety for all road users [23]. Understanding the unique and complex aspects of traffic flow at junctions is significant for designing optimal signal timing and traffic management systems [24]. The implementation of such systems boosts traffic flow by adjusting signal timing in real-time according to prevailing traffic situations [25, 26]. Authors in [27, 28] indicated that examining traffic patterns at crossings leads to the recognition of distinct movement behaviors, which can guide the development of customized signal timing techniques. Additionally, the use of advanced technologies, including multi-agent reinforcement learning, demonstrates improved traffic light management by adapting to changing traffic demands [29].

The present state of roadways in Makassar city is highly congested, resulting in numerous issues for both vehicles and pedestrians. Most thoroughfares in Makassar city are two-way, either with or without a median. The contribution of the transportation sector to the GDP of Indonesia averages over 10% of the country's total GDP. The construction sector is a main driver of physical infrastructure development, which leads to accelerated economic and social progress, strengthening the country's global competitiveness.

II. METHODOLOGY

This research employs a quantitative descriptive method, utilizing numerical data systematically as an analytical tool to provide a general overview of the events of the research site. The study focuses on the city of Makassar, specifically the Tallo District at the intersection of Jl. Sunu, Jl. Teuku Umar, Jl. Galangan Kapal, and Jl. Gatot Subroto, as depicted by Figure 1.

Fig. 1. Research area map.

The data were collected at the research site, including traffic volume, road capacity, lateral obstructions, free flow speed, saturation level, road service level, and traffic conflicts. The collected data are processed to evaluate traffic performance and identify conflict types and locations at the intersections in the study area. For each road and intersection, these traffic indicators are analyzed in detail. The study also documents the types and locations of traffic conflicts observed in the study area. In addition, geometric and environmental conditions that influence the occurrence of traffic conflicts are examined.

III. RESULTS AND DISCUSSION

A. *Traffic Characteristics*

Based on the location of the survey camera, three crossings were examined: (a) Jl. Galangan Kapal and Jl. Teuku Umar, (b) Jl. Sunu and Jl. Teuku Umar, and (c) Jl. Gatot Subroto and Jl. Teuku Umar. The locations are photographically presented in Figures 2-4.

Fig. 2. Study area at the Jl. Sunu and Jl. Teuku Umar intersection.

Fig. 3. Study area at the JL. Teuku Umar intersection and JL. Gatot Subroto.

Fig. 4. Study area at the Jl. Galangan Kapal Intersection.

Traffic lights are located at all examined crossings except the intersection of Jl. Gatot Subroto and Jl. Teuku Umar lacks. Road markings are absent on Jl. Teuku Umar, Jl. Galangan Kapal, and Jl. Gatot Subroto.

Traffic flow is assessed every 15 min and later aggregated to produce hourly totals. The study categorizes the vehicles using the road segment into three categories: motorcycles, large vehicles, and light vehicles such as cars. At the junction of Jl. Galangan Kapal and Jl. Teuku Umar, the traffic volume is assessed throughout four lanes, as portrayed in Figure 5.

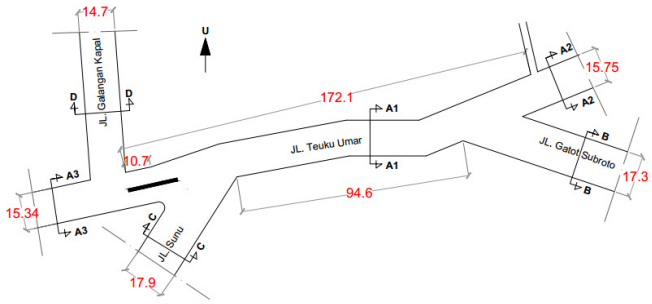

Fig. 5. Schematic representation of the study area.

Four types of crossings are studied between the two roads, as presented in Figure 6. The four figures illustrate the primary vehicle movement patterns at the intersection of Jl. Teuku Umar with the minor roads connected. Each diagram represents a different turning movement. That is, right-turn or left-turn movements either from the major road or from the intersecting minor streets. The red arrows indicate the direction of vehicle flow, while the black line highlights the major stream of traffic on Jl. Teuku Umar, which causes potential conflicts. These movements capture the primary interaction points at the intersection, where vehicles must yield or accept gaps in the main traffic flow, influencing delays, conflict intensity, and overall intersection performance. The traffic volume values are presented in Table I and Figure 7.

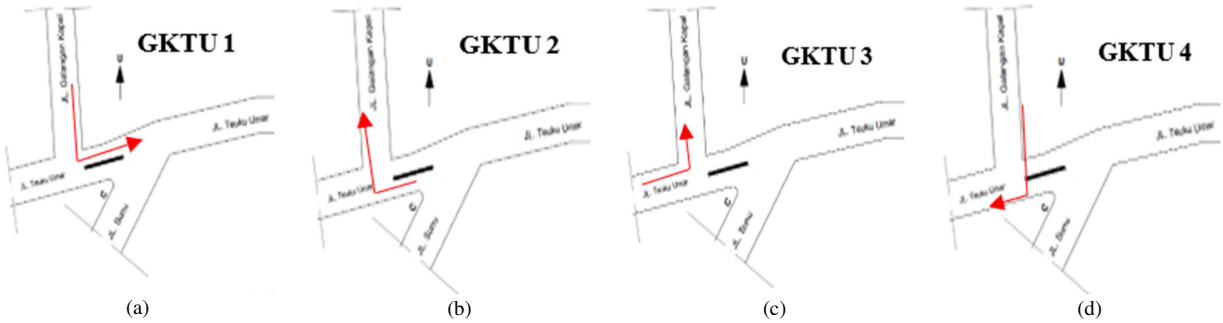

Fig. 6. Four types of crossings are under study at the intersection of Jl. Galangan Kapal –Jl. Teuku Umar, indicated with the red arrow: (a) GKTU 1, (b) GKTU 2, (c) GKTU 3, and (d) GKTU 4.

The obtained value for large vehicles is 1.3, whereas for motorcycles it is 0.5. Table I shows that the most congested traffic flow occurs on the GKTU 2 lane (Jl. Teuku Umar—Eastbound toward Jl. Galangan Kapal). On Monday, March 23,

2020, between 07:00 and 08:00, the maximum volume value is recorded (607.5 smp/h). Unlike weekend days, weekdays exhibit increased activity and volume during the morning [30].

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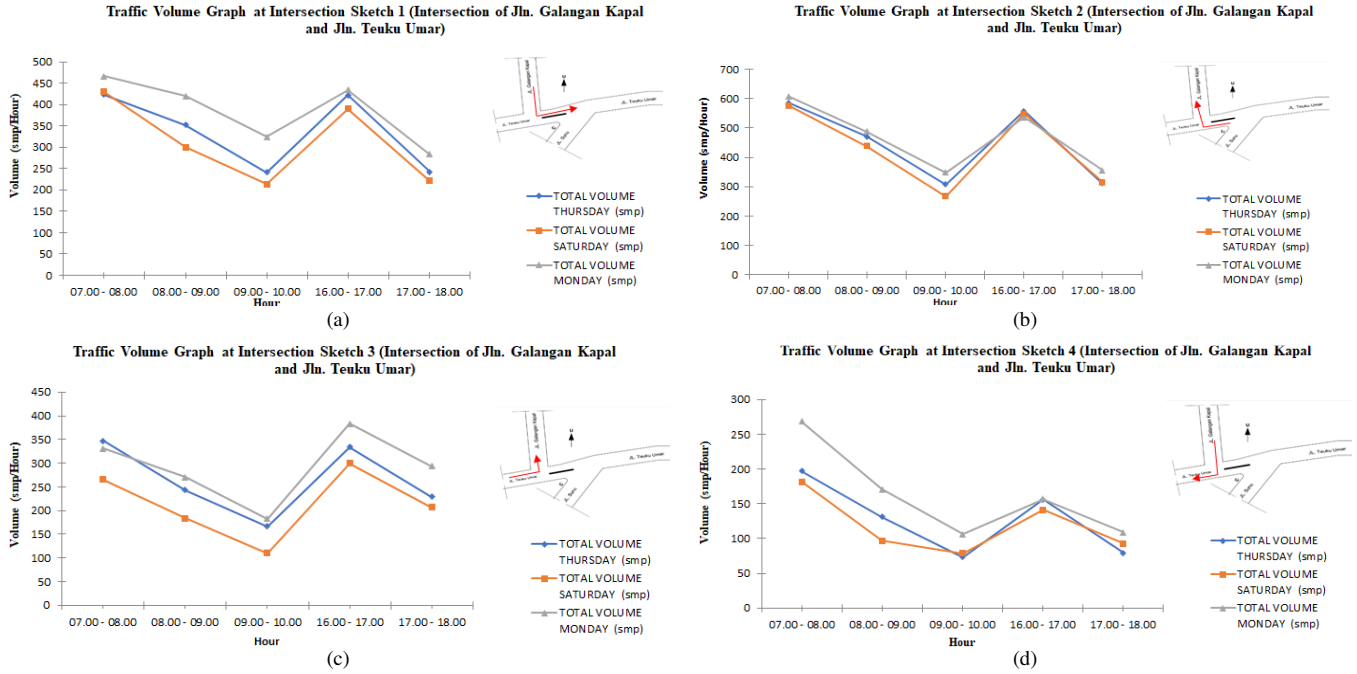

Fig. 7. Traffic volume against time at the intersection of Jl Galangan Kapal – Jl Teuku Umar: (a) GKTU 1, (b) GKTU 2, (c) GKTU 3, and (d) GKTU 4.

TABLE I. TRAFFIC VOLUME AT THE INTERSECTION OF JL. GALANGAN KAPAL – JL. TEUKU UMAR

Crossing	Hour	Total volume		
		Thursday (smp/h)	Saturday (smp/h)	Monday (smp/h)
GKTU 1	07:00-08:00	423.6	429.8	466.1
	08:00-09:00	351.7	300.3	420.2
	09:00-10:00	241.5	212.9	324.5
	16:00-17:00	422.4	389.9	434.0
	17:00-18:00	241.9	221.2	283.4
GKTU 2	07:00-08:00	586.1	577.4	607.5
	08:00-09:00	471.7	438.6	488.1
	09:00-10:00	307.5	267.0	348.9
	16:00-17:00	558.8	549.5	536.0
	17:00-18:00	310.3	316.0	356.1
GKTU 3	07:00-08:00	347.3	265.9	330.7
	08:00-09:00	243.4	184.0	270.4
	09:00-10:00	166.7	109.9	182.5
	16:00-17:00	334.5	300.1	384.0
	17:00-18:00	229.0	207.4	293.3
GKTU 4	07:00-08:00	197.4	181.5	268.3
	08:00-09:00	131.1	97.0	171.0
	09:00-10:00	73.4	78.4	106.3
	16:00-17:00	156.2	141	156.7
	17:00-18:00	79.1	92.6	109.2

Furthermore, at the junction of Jl. Sunu and Jl. Teuku Umar, the traffic volume is assessed throughout six types of crossings, as depicted in Figure 8. The traffic volume values are presented in Table II and Figure 9. Specifically, the value for large vehicles is 1.3, whereas for motorbikes it is 0.5. According to Table II, the SNTU 6 lane (Jl. Teuku Umar Eastbound towards Westbound) presents the highest traffic volume of 1086.4 smp/h on Monday, March 23, 2020, between 7:00 and 8:00 AM. The same behavior is observed regarding weekdays and weekends.

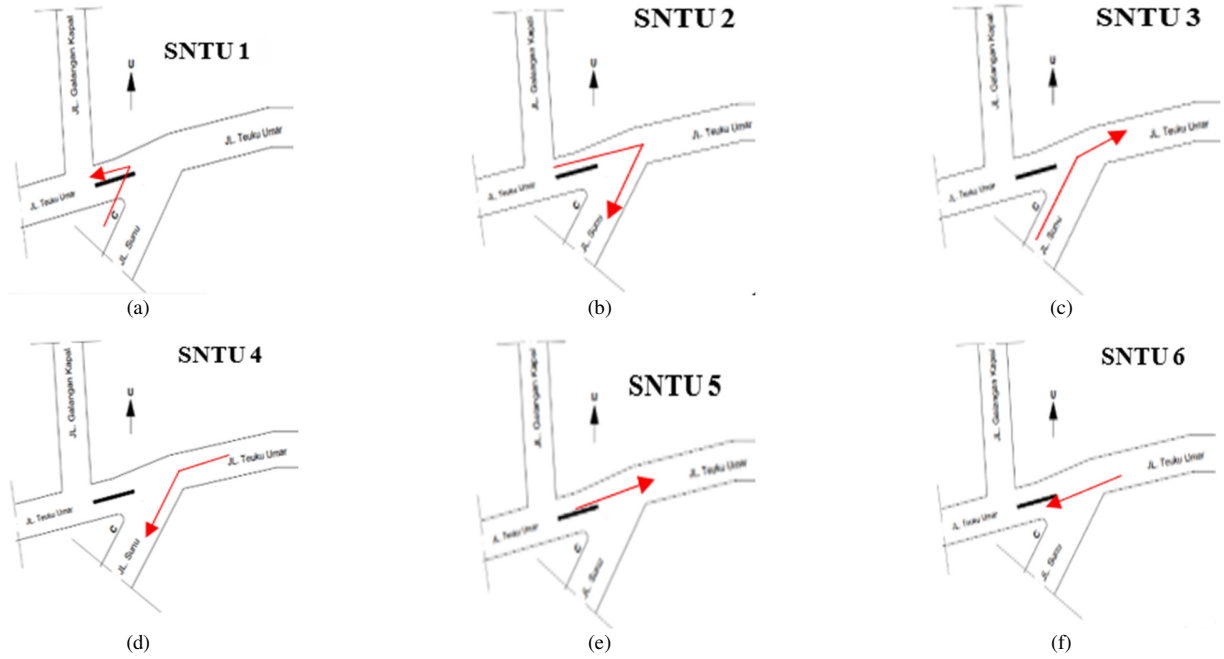

Fig. 8. Six types of crossings are under study at the intersection of Jl. Sunu and Jl. Teuku Umar: (a) SNTU 1, (b) SNTU 2, (c) SNTU 3, (d) SNTU 4, (e) SNTU 5, and (f) SNTU 6.

TABLE II. TRAFFIC VOLUME AT THE INTERSECTION OF JL. SUNU – JL. TEUKU UMAR

Crossing	Hour	Total volume		
		Thursday (smp/h)	Saturday (smp/h)	Monday (smp/h)
SNTU 1	07:00-08:00	644	569.4	694
	08:00-09:00	456.4	396.3	536.5
	09:00-10:00	413.8	324.9	461.9
	16:00-17:00	581.7	457.6	613.3
	17:00-18:00	511.2	309	497.7
SNTU 2	07:00-08:00	336.3	372.1	355.2
	08:00-09:00	308.4	359.3	291.3
	09:00-10:00	268.4	281.3	232.7
	16:00-17:00	417.2	405.7	413.7
	17:00-18:00	357	272.9	332.5
SNTU 3	07:00-08:00	216.3	174.3	239.1
	08:00-09:00	138.3	139.5	175.4
	09:00-10:00	138.5	123.5	158.2
	16:00-17:00	210	159.8	234.3
	17:00-18:00	156.1	138.1	194.6
SNTU 4	07:00-08:00	498.3	420.6	538.4
	08:00-09:00	463.8	366.9	454.5
	09:00-10:00	405.4	305.5	384.1
	16:00-17:00	702.5	555.4	710.2
	17:00-18:00	611.7	411.8	569.4
SNTU 5	07:00-08:00	470.7	454.3	507.6
	08:00-09:00	410.5	391.8	463.9
	09:00-10:00	326.5	331.1	403.2
	16:00-17:00	531.5	557.4	528.2
	17:00-18:00	392.9	413	414.4
SNTU 6	07:00-08:00	986.1	991.1	1086.4
	08:00-09:00	862.7	698.9	817.2
	09:00-10:00	721.6	609.5	691.5
	16:00-17:00	793.6	925.2	977.2
	17:00-18:00	668.6	782.9	748.4

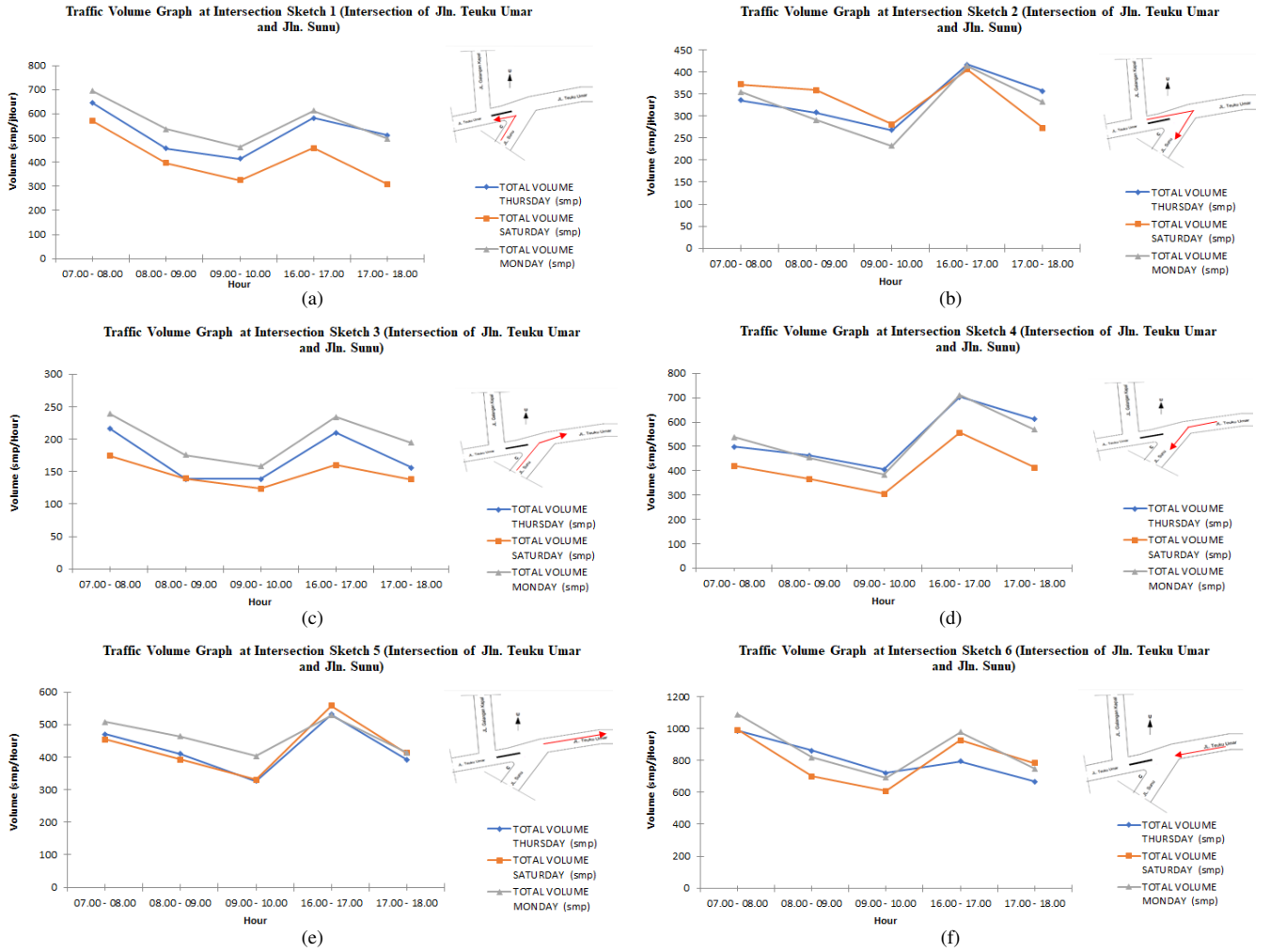

Fig. 9. Traffic volume against time at the intersection of Jl Sunu – Jl Teuku Umar: (a) SNTU 1, (b) SNTU 2, (c) SNTU 3, (d) SNTU 4, (e) SNTU 5, and (f) SNTU 6.

Moreover, at the intersection of Jl. Teuku Umar and Jl. Gatot Subroto, four types of crossings are assessed, as illustrated in Figure 10. The traffic volume values are presented in Table III and Figure 11. Table III exhibits that the GSTU 1 crossing has the highest traffic volume values. The maximum volume (583.6 pcu/h) is observed on Monday, March 23, 2020, at 07:00-08:00 am.

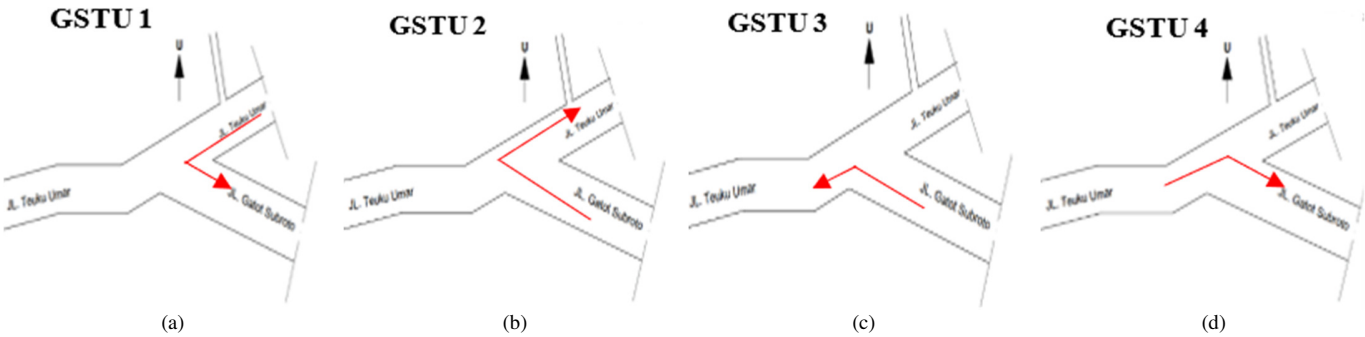

Fig. 10. Four types of crossings are under study at the intersection of Jl. Teuku Umar and Jl. Gatot Subroto: (a) GSTU 1, (b) GSTU 2, (c) GSTU 3, and (d) GSTU 4.

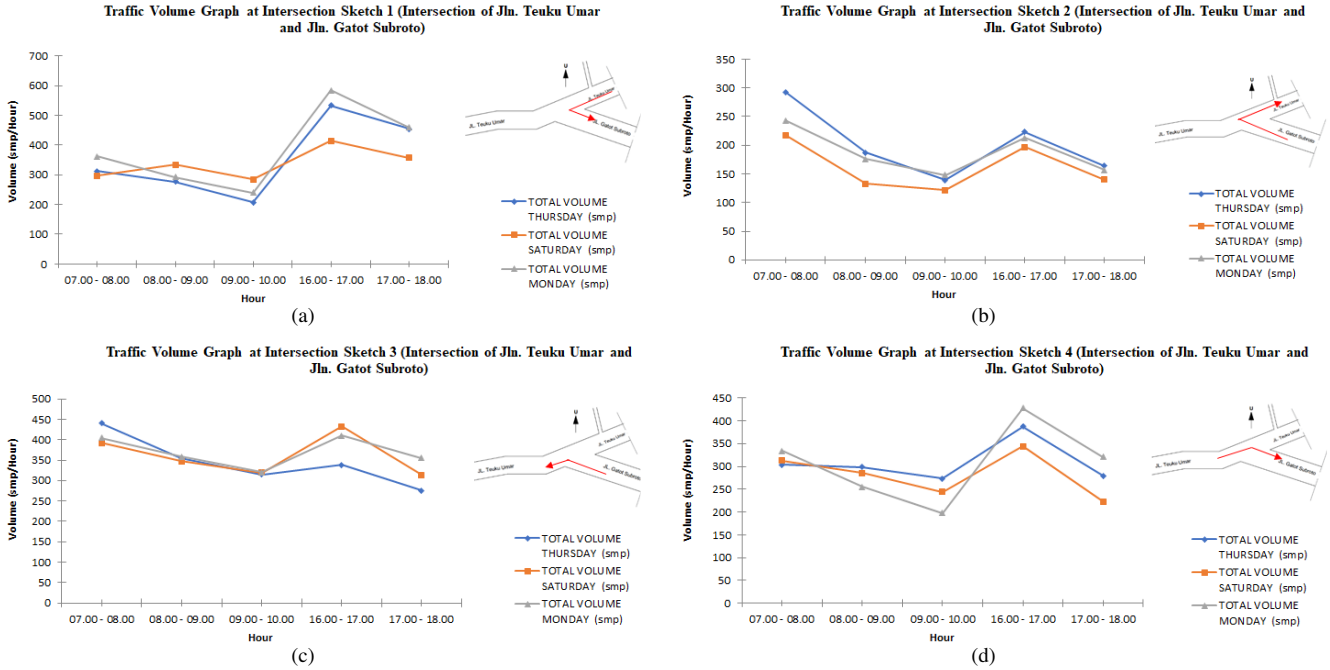

Fig. 11. Traffic volume against time at the intersection of Jl Teuku Umar – Jl Gatot Subroto: (a) GSTU 1, (b) GSTU 2, (c) GSTU 3, and (d) GSTU 4.

TABLE III. TRAFFIC VOLUME AT THE INTERSECTION OF JL. TEUKU UMAR - JL. GATOT SUBROTO.

Crossing	Hour	Total volume		
		Thursday (smp/h)	Saturday (smp/h)	Monday (smp/h)
GSTU 1	07:00-08:00	311.9	296.8	361
	08:00-09:00	277.4	334.2	292
	09:00-10:00	207.1	285.2	240.2
	16:00-17:00	533.5	414.1	583.6
	17:00-18:00	454.2	356.6	459.4
GSTU 2	07:00-08:00	292.5	217.3	242.9
	08:00-09:00	187.6	133.2	175.8
	09:00-10:00	139.1	121.9	148.1
	16:00-17:00	223.2	197	212.7
	17:00-18:00	164.4	140.4	156.9
GSTU 3	07:00-08:00	440.6	391.9	404.9
	08:00-09:00	353.6	347.3	358.3
	09:00-10:00	315.1	318.7	320.1
	16:00-17:00	337.7	431.9	410
	17:00-18:00	275	314.1	354.6
GSTU 4	07:00-08:00	303.4	313.2	334.1
	08:00-09:00	298.8	285.5	255.3
	09:00-10:00	273.3	244	197.4
	16:00-17:00	387.5	344	427.8
	17:00-18:00	279.4	223.1	320.8

B. Traffic Conflict Analysis

This section of the study focuses on traffic conflicts, addressing traffic issues individually based on the intersection's location. Traffic lights are an effective solution to eliminate issues such as traffic disputes that frequently arise, leading to congestion. Figures 12 and 13 present the installation of traffic lights at the study area. According to Figure 12, automobiles traveling from Jl. Teuku Umar (west, red arrow) turn left toward Jl. Galangan Kapal, whereas vehicles traveling from Jl. Teuku Umar (east, green arrow) turn right, resulting in a merging confrontation. Additionally, vehicles approaching Jl. Galangan Kapal make a right turn onto Jl. Teuku Umar (westbound, green arrow), whilst vehicles and multiple motorcycles originating from Jl. Teuku Umar (eastbound, red arrow) turn right onto Jl. Galangan Kapal. The two blue arrows depict the straight movement from the east and west directions along Jl. Teuku Umar. As illustrated in Figure 13, vehicles approaching from Jl. Teuku Umar (westward, yellow arrow) turn right into Jl. Sunu, whereas other vehicles and numerous motorcycles originating from the east proceed directly westward along Jl. Teuku Umar (blue arrow). Automobiles approaching Jl. Teuku Umar (westbound, yellow arrow) turn right onto Jl. Sunu. Other vehicles originating from Jl. Sunu

make a right turn onto Jl. Teuku Umar, heading east, as depicted by the yellow arrow.

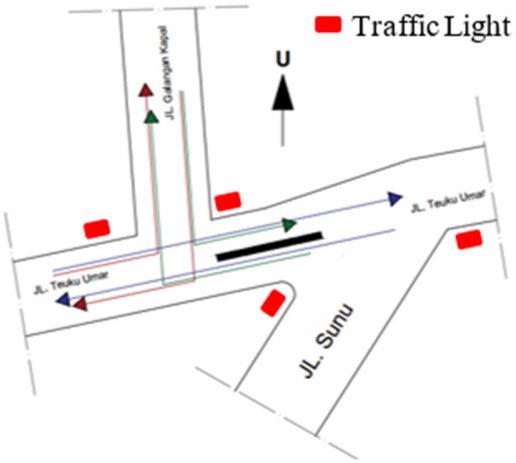

Fig. 12. Graphical representation of the intersection traffic conflicts of Jl. Galangan Kapal – Jl. Teuku Umar. The red rectangle indicates the traffic lights.

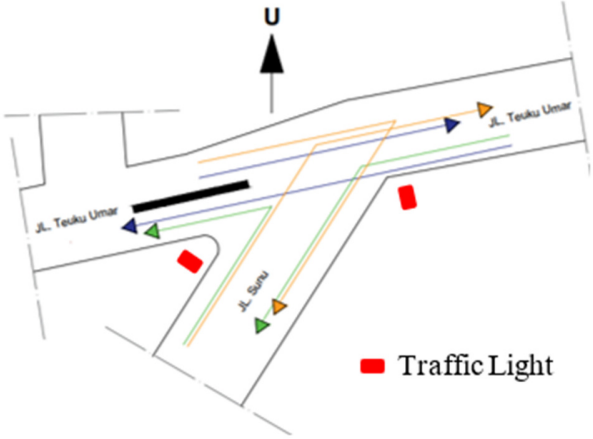

Fig. 13. Graphical representation of the intersection traffic conflicts of Jl. Sunu – Jl. Teuku Umar. The red rectangle indicates the traffic lights.

On the contrary, the junction of Jl. Teuku Umar and Jl. Gatot Subroto lacks traffic signals, leading to reduced traffic flow at this intersection compared to the other two junctions. The initial conflict arises when vehicles from Jl. Teuku Umar (westbound, green arrow) turn right onto Jl. Gatot Subroto, intersecting with motorbikes from Jl. Teuku Umar (eastbound, yellow arrow) turning left onto Jl. Gatot Subroto. This dispute is referred to as a mutual merging conflict. The volume of vehicular traffic from the eastern segment of Jl. Teuku Umar surpasses that of the other lanes, since it serves as the exit from the Reformasi Toll Road. The second merging issue arises when vehicles from Jl. Gatot Subroto making a left turn into Jl. Teuku Umar (heading west, yellow arrow) encounter a vehicle proceeding straight from the east on Jl. Teuku Umar towards the west (blue arrow).

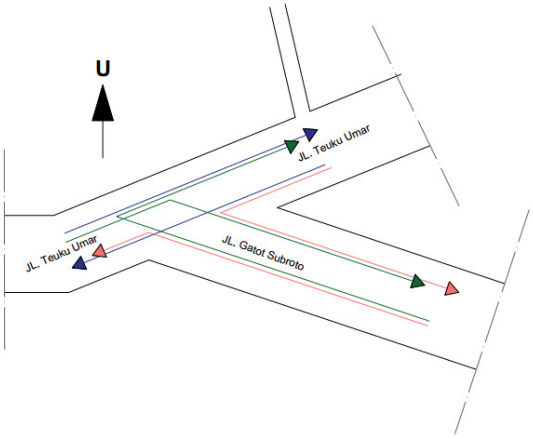

Fig. 14. Graphical representation of the intersection traffic conflicts of Jl. Teuku Umar – Jl. Gatot Subroto.

The initial crossing conflict arises when a vehicle from Jl. Gatot Subroto turns right into Jl. Teuku Umar (heading east) and encounters a vehicle moving straight from the East on Jl. Teuku Umar towards the West. To mitigate these conflicts and enhance traffic efficiency and safety at the intersection, improved traffic management is necessary, including the installation of traffic signals or modifications to the geometric configuration of crossings.

IV. CONCLUSION

Traffic conditions throughout Jl. Teuku Umar presented a variety of maximum traffic volume values across different crossings. During the peak hour on Monday, March 23, 2020 (07:00–08:00 AM), the GKTU 2, SNTU 6, and GSTU 1 crossings recorded traffic volumes of 607.5 smp/h, 1086.4 smp/h, and 583.6 pcu/h, respectively. The highest traffic capacity was observed at the intersection of Jl. Teuku Umar and Jl. Gatot Subroto (3458.54 pcu/h), compared to 2942.34 pcu/h at the intersection of Jl. Galangan Kapal and Jl. Sunu. Similarly, the highest free-flow speed was recorded at Jl. Teuku Umar and Jl. Gatot Subroto, reaching 45.9 km/h, which is higher than the 42.3 km/h observed at Jl. Galangan Kapal and Jl. Sunu. Based on the Volume-to-Capacity (V/C) ratio, most lanes operate at a level of service A, indicating stable traffic conditions. However, SNTU 1 and SNTU 6 fall under category B, in which V/C ratios range between 0.21 and 0.44. Finally, the predominant traffic conflicts at the intersections studied are merging and crossing conflicts, mostly influenced by driver behavior, vehicle characteristics, and environmental conditions.

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