Smart City

Volume 4
Issue 2 *Reimagining Urban Transport: Innovations in Smart Mobility Solutions*

Article 6

6-25-2024

Impact of Auxiliary Markings on Intersection Safety

Mhd Tommy Franata
Universitas Indonesia, mhdtommyf@gmail.com

Martha Leni Siregar
Universitas Indonesia, martha.leni@ui.ac.id

Andyka Kusuma
Universitas Indonesia, andyka.k@ui.ac.id

Recommended Citation

Franata, Mhd Tommy; Siregar, Martha Leni; and Kusuma, Andyka (2024) "Impact of Auxiliary Markings on Intersection Safety," *Smart City*: Vol. 4: Iss. 2, Article 6.
DOI: 10.56940/sc.v4.i2.6
Available at: https://scholarhub.ui.ac.id/smartcity/vol4/iss2/6

Impact of Auxiliary Markings on Intersection Safety

Cover Page Footnote

This research extends our sincere appreciation and gratitude for the collaborative efforts between the Traffic Corps of the Indonesian National Police (Korps Lalu Lintas POLRI) and the Faculty of Engineering, University of Indonesia (Fakultas Teknik Universitas Indonesia), as delineated in Agreement No. B/22/IV/2016 and 197/PKS/FT/UI/2016 regarding the Organization of Education, Training, Research, and Expertise Support. This partnership has significantly advanced human resource development, knowledge dissemination, and expertise enhancement, particularly in traffic management and transportation. We deeply appreciate the dedication of all involved parties, whose commitment and collaborative spirit have fostered the success and mutual benefit derived from this agreement. May this acknowledgment serve as a testament to our fruitful collaboration, and we eagerly anticipate continued cooperation and further milestones in our shared pursuit of excellence.

THE IMPACT OF IMPLEMENTING ASSISTIVE MARKINGS ON INTERSECTION SAFETY IMPROVEMENT

[1]Mhd Tommy Franata*, [1]Martha Leni Siregar, and [1]Andyka Kusuma

[1]Civil Engineering Department, Faculty of Engineering, Universitas Indonesia

**Correspondence: martha.leni@ui.ac.id*

ABSTRACT

The rapid growth of motorcycle vehicles coupled with inadequate traffic discipline contributes to an escalating rate of traffic accidents and casualties. This study investigates the efficacy of auxiliary road markings in enhancing traffic safety and intersection performance along Lieutenant Sutopo Street, Promoter Street, and Boulevard BSD East in South Tangerang, Indonesia. Employing the Traffic Conflict Technique (TCT), the research evaluates safety enhancements and service level alterations subsequent to the installation of road markings. Preliminary observations highlight significant safety concerns and traffic conflicts at the intersection. Consequently, auxiliary road markings are strategically installed to regulate driver behavior, enhance lane discipline, and improve visibility. Post-installation observations revealed a significant decrease in total vehicle conflicts, though the percentage of severe conflicts slightly increased. Initially rated as Level of Service (LOS) F with high delays, the LOS remained the same post-marking installation but with reduced delays. Further cycle time adjustments improved the LOS to E, indicating a substantial overall reduction in delays. The findings suggest that although auxiliary road markings effectively reduce traffic conflicts and improve intersection performance, additional measures are necessary to address the severity of these conflicts. The study offers valuable insights into the effectiveness of road safety interventions, supporting broader strategies for improving traffic management and safety in urban areas.

Keywords*: Auxiliary Road Markings; Intersection; Intersection level of services; Manual on uniform traffic control devices; Swedish traffic conflict technique.*

INTRODUCTION

Traffic safety is a crucial aspect of traffic engineering to achieve the goals of safe, comfortable, and economical traffic management (Mahardianto, 2015). This includes adherence to traffic regulations such as following speed limits, obeying traffic signs and road markings, and using safety equipment like seat belts. Furthermore, ensuring traffic safety involves courteous behavior on the road, such as respecting pedestrian rights, giving priority to emergency vehicles, and avoiding alcohol or drug use while driving. Ideal traffic conditions reflect safe, orderly, and smooth traffic flow, which allows people to live, grow, and thrive productively, making traffic the lifeblood of society (Chrysnanda, 2017).

The high growth of Motorcycle and vehicles without traffic discipline leads to an increasing number of traffic accidents and casualties. Typically, the primary factors contributing to high traffic accident rates are human factors (such as high speed, inattention, fatigue) and the low discipline of drivers (Marsaid et al., 2013). Traffic accidents, often referred to as vehicle accidents, involve one or more vehicles on the road, resulting in vehicle damage, injuries, or even fatalities caused by human, environmental, and vehicle factors. According to the World Health Organization (WHO), traffic accidents are a major global public health issue, causing millions of deaths and injuries annually. The 2018 Global Status Report on Road Safety by WHO reported that approximately 1.35 million people die each year due to traffic accidents, and traffic injuries are the leading cause of death among the productive age group of 5-29 years. This report also highlights that factors such as speed, alcohol consumption, seat belt use, and helmet use significantly impact the likelihood and severity of road accidents, emphasizing the importance of effective safety measures and awareness campaigns to reduce these incidents (World Health Organization, 2022).

In Indonesia, traffic accidents at intersections are a serious concern due to these points being prone to conflicts between drivers, increasing the risk of accidents. Improving road infrastructure and raising public awareness about good traffic behavior are crucial steps in addressing this issue. One solution that needs to be researched is the impact of the implementation of auxiliary markings at intersections on traffic safety and service levels, particularly at the intersection of Letnan Sutopo Street - Promoter Street - East BSD Boulevard Street in South Tangerang. This study aims to analyze the characteristics of traffic accidents at this intersection and the impact of implementing auxiliary markings on improving traffic safety and intersection service levels based on delays at the intersection legs.

METHODS

The methodology for assessing the impact of auxiliary markings on intersection safety begins with a detailed identification of the problem. This involves analyzing existing traffic accident reports and identifying the specific safety issues and traffic conflicts at the intersection of Jl. Letnan Sutopo, Jl. Promoter, and Jl. Boulevard BSD Timur in South Tangerang. Once the problem areas are identified, primary data collection is conducted through direct observation of driver behavior at the intersection. This initial observation aims to document the current traffic conditions, including instances of non-compliance with traffic rules, common conflict points, and the overall flow of vehicles and pedestrians.

Following the initial data collection, auxiliary road markings are strategically installed at the intersection. These markings are designed to guide driver behavior, improve lane discipline, and enhance the visibility of traffic controls. After the installation, another round of primary data collection is conducted through further observation of driver behavior. This post-installation observation period aims to capture any changes in traffic patterns, compliance with the new markings, and any reduction in traffic conflicts or accidents.

The data collected before and after the installation of the auxiliary markings is then analyzed using the Traffic Conflict Technique (TCT), which helps identify and evaluate potential conflict points and near-miss incidents that could lead to accidents. Additionally, The Level of Service (LOS) at the intersection is assessed to determine the impact on traffic flow efficiency. This involves analyzing parameters such as vehicle delay, queue length, and overall intersection capacity.

The survey conducted at the intersection of Jl. Letnan Sutopo, Jl. Promoter, and Jl. Boulevard BSD Timur aimed to provide a clear depiction of various traffic conflicts at the location, including identifying potential conflicts that could lead to accidents. The survey aimed to understand the relationship between the types of conflicts and the traffic characteristics at this intersection, providing a comprehensive understanding of traffic dynamics and potential risks in the area.

The intersection is located in Lengkong East Warehouse, Serpong District, South Tangerang City, and is part of the Bumi Serpong Damai development area managed by the South Tangerang City Government and the developer Sinar Mas Land. The roads at this intersection are divided with medians in all four directions and are classified as urban roads. The surrounding area includes residential housing, shops, a gas station, Motorbike and car workshops, and a Precision Traffic Police Post along the road median. Each camera monitored by a surveyor recorded vehicles and the timing of conflicts from the direction opposite the surveyor's location.

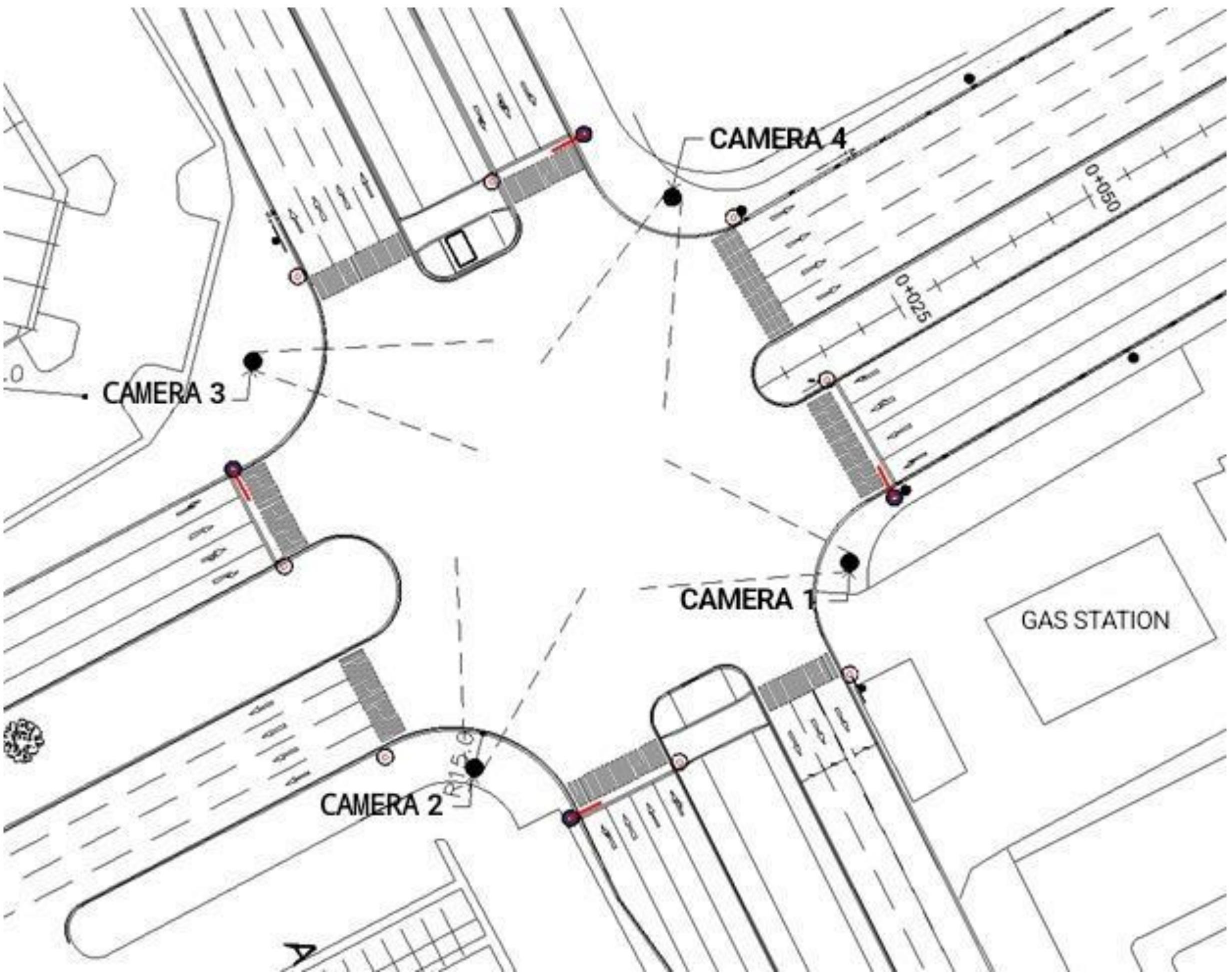

Figure 1 Survey Illustration of Study Location

Surveyors installed and monitored handycam cameras and noted near-miss incidents to the right of the lane at the intersection of Jl. Letnan Sutopo - Jl. Promoter - Jl. Boulevard BSD Timur. The survey was conducted on January 26 and February 20, 2024, between 4:00 PM and 7:00 PM, both before and after the installation of road markings. These times were chosen because they represent peak hours on weekdays. Despite the limitations of the handycams, which could not be placed higher than 1.5 meters and the less supportive intersection conditions, the recordings were clear and detailed enough for further analysis.

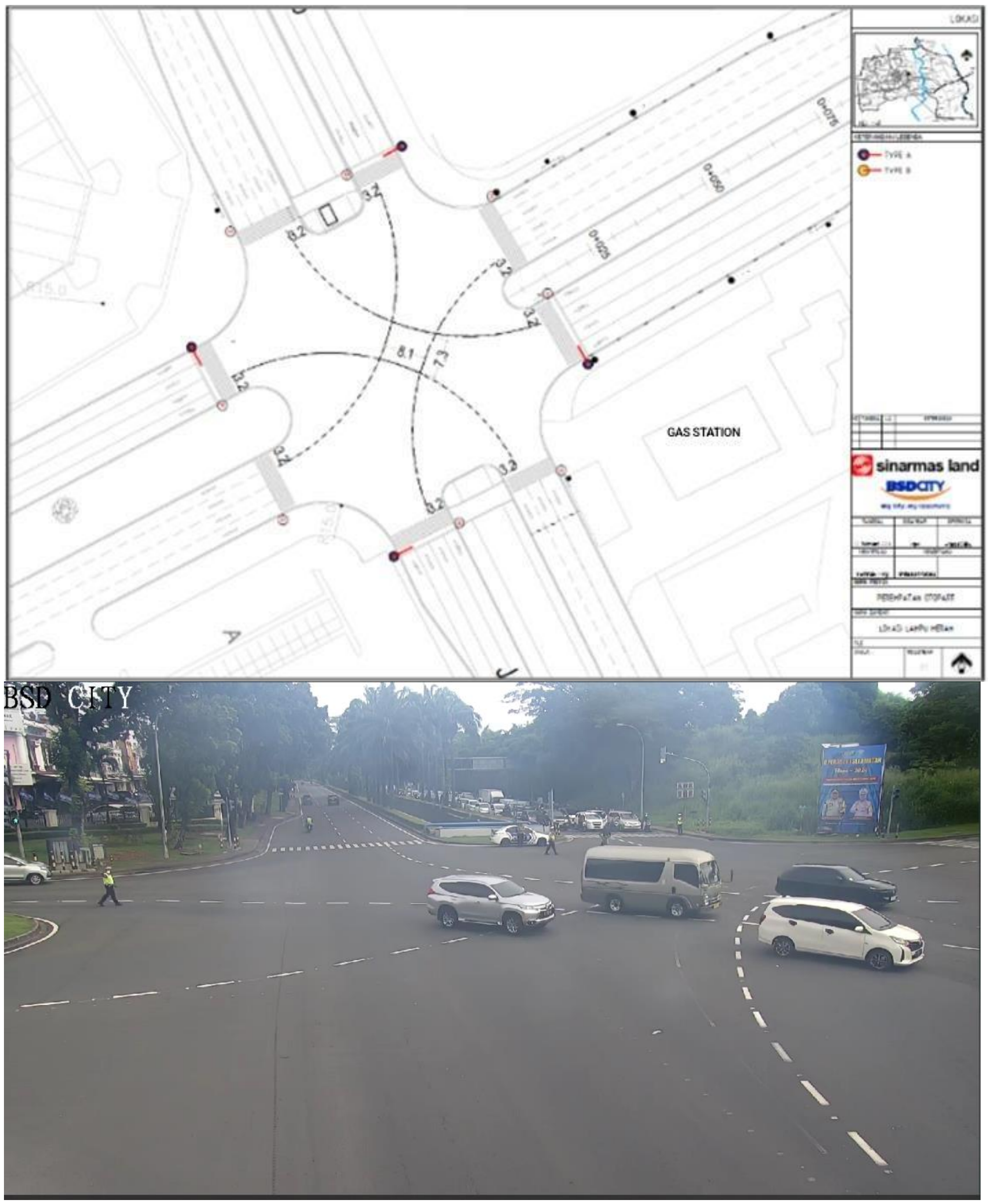

Figure 2 Sketch of Auxiliary Markings (PT. Bumi Serpong Damai Tbk, 2024)

Finally, the results of the analysis are compiled to determine the effectiveness of the auxiliary markings in improving intersection safety and service levels. The findings are used to provide recommendations for further enhancements in traffic management and safety measures at the intersection, contributing to a broader strategy for reducing traffic accidents and improving road safety in urban areas.

RESULTS AND DISCUSSION

The conflicts reviewed involved a combination of vehicles, including cars and Motorcyclecyclecycles. Two types of conflicts were examined during the survey and data processing, as illustrated in Figures 3 and 4.

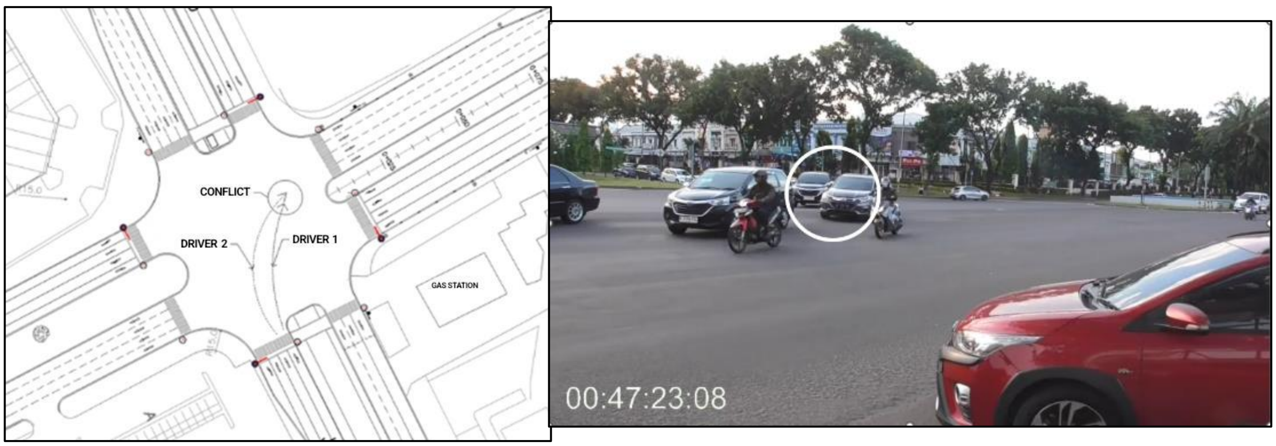

Figure 3 Conflict Type 1 Sketch

Figure 4 Conflict Type 2 Sketch

The first type of conflict involved a driver in the rightmost lane swerving to avoid a driver in the middle lane who was cutting into their lane and moving too far to the right. The second type involved a driver in the middle lane swerving to avoid a driver in the right lane cutting into their lane or veering left. These avoidance actions included braking or slowing down.

Table 1 Vehicle Volume Before Auxiliary Markings at the Study Intersection

Time	East BSD Boulevard Street			Letnan Sutopo Street Southbound			Promoter Street			Letnan Sutopo Street Northbound		
	HV	LV	MC	HV	LV	MC	HV	LV	MC	HV	LV	MC
16.00 - 16.15	0	288	141	9	987	564	0	63	78	5	750	306
16.15 - 16.30	2	319	157	12	1087	622	2	71	87	8	827	338
16.30 - 16.45	0	260	129	9	890	510	0	71	73	5	676	279
16.45 - 17.00	2	347	171	13	1186	678	2	77	96	8	904	370
17.00 - 17.15	0	279	124	7	718	526	0	61	82	3	705	302
17.15 - 17.30	1	313	129	7	637	589	2	59	70	3	600	284
17.30 - 17.45	0	312	149	7	518	508	1	65	71	0	613	311
17.45 - 18.00	1	251	122	8	601	569	0	67	74	2	544	268
18.00 - 18.15	1	275	143	10	520	584	0	81	81	4	527	315
18.15 - 18.30	0	295	145	6	531	568	0	79	71	3	529	269
18.30 - 18.45	1	301	120	7	579	575	2	59	65	2	534	296
18.45 - 19.00	0	260	150	5	546	549	2	70	80	2	509	292

Based on the survey conducted before the installation of auxiliary markings, the vehicle volume over a three-hour observation period was 13,080 cars, 20,841 Motorcyclecyclecycles, and 164 large vehicles. Below are the results of the conflict observation based on the survey conducted before the auxiliary markings were installed.

Figure 5 Total Conflicts Before Auxiliary Markings

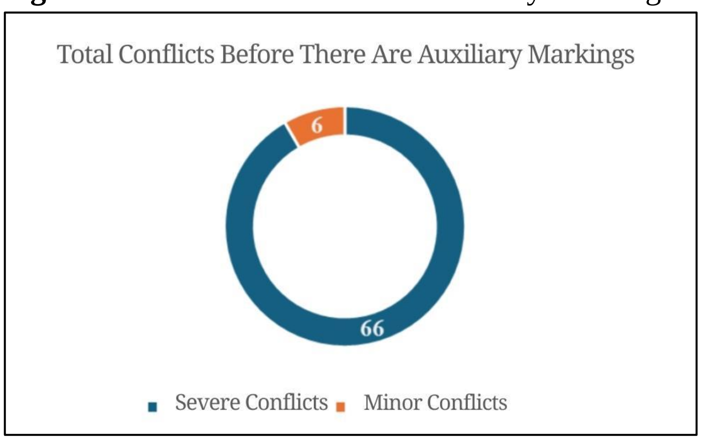

Table 2 Conflict Data Before Auxiliary Markings

No.	Driver 1	Driver 2	Conflict Speed (Kmph)	Inter-vehicle Distance (Meter)	Time-to-Accident (TA)	Severity
1	Vehicle	Motorcyclecycle	24.372	2	0.295	Severe
2	Motorcyclecycle	Vehicle	18	1	0.200	Severe
3	Motorcyclecycle	Motorcyclecycle	21.6	1	0.167	Severe
4	Vehicle	Vehicle	25.2	3	0.429	Severe
5	Vehicle	Motorcyclecycle	21.6	3	0.500	Severe
6	Motorcyclecycle	Vehicle	12.6	2	0.571	Severe
7	Motorcyclecycle	Motorcyclecycle	16.2	3.5	0.778	Severe
8	Vehicle	Motorcyclecycle	19.8	2	0.364	Severe
9	Motorcyclecycle	Vehicle	29.7	2.5	0.303	Severe

No.	Driver 1	Driver 2	Conflict Speed (Kmph)	Inter-vehicle Distance (Meter)	Time-to-Accident (TA)	Severity
10	Vehicle	Motorcyclecycle	14.4	2	0.500	Severe
11	Vehicle	Vehicle	32.4	4	0.444	Severe
12	Motorcyclecycle	Vehicle	16.2	2.5	0.556	Severe
13	Vehicle	Motorcyclecycle	18	2.5	0.500	Severe
14	Vehicle	Motorcyclecycle	21.6	6	1.000	Severe
15	Vehicle	Motorcyclecycle	14.4	1.5	0.375	Severe
16	Vehicle	Motorcyclecycle	12.6	1	0.286	Severe
17	Vehicle	Motorcyclecycle	16.2	2.5	0.556	Severe
18	Vehicle	Vehicle	31.2	2	0.231	Severe
19	Motorcyclecycle	Motorcyclecycle	16.8	4.5	0.964	Severe
20	Vehicle	Vehicle	16.2	4	0.889	Severe
21	Motorcyclecycle	Motorcyclecycle	29.7	1.5	0.182	Severe
22	Vehicle	Motorcyclecycle	22.32	3	0.484	Severe
23	Vehicle	Motorcyclecycle	18	2	0.400	Severe
24	Vehicle	Motorcyclecycle	14.4	3.5	0.875	Severe
25	Motorcyclecycle	Motorcyclecycle	16.2	2.2	0.489	Severe
26	Vehicle	Motorcyclecycle	28.8	4	0.500	Severe
27	Vehicle	Vehicle	16.8	3.5	0.750	Severe
28	Motorcyclecycle	Motorcyclecycle	21.6	2.5	0.417	Severe
29	Motorcyclecycle	Motorcyclecycle	32.4	4	0.444	Severe
30	Motorcyclecycle	Motorcyclecycle	14.4	2	0.500	Severe
31	Motorcyclecycle	Vehicle	17.28	3.5	0.729	Severe
32	Vehicle	Motorcyclecycle	18.36	5.5	1.078	Severe
33	Motorcyclecycle	Motorcyclecycle	14.4	5	1.250	Severe
34	Vehicle	Motorcyclecycle	18	4	0.800	Severe
35	Vehicle	Vehicle	12	4.5	1.350	Severe
36	Motorcyclecycle	Motorcyclecycle	16.2	2	0.444	Severe
37	Motorcyclecycle	Motorcyclecycle	27	2.5	0.333	Severe
38	Motorcyclecycle	Motorcyclecycle	14.4	1.5	0.375	Severe
39	Motorcyclecycle	Motorcyclecycle	19.8	2	0.364	Severe
40	Vehicle	Motorcyclecycle	14.4	1	0.250	Severe
41	Vehicle	Motorcyclecycle	13.8	2	0.522	Severe
42	Vehicle	Motorcyclecycle	18	3.5	0.700	Severe
43	Motorcyclecycle	Vehicle	27	3	0.400	Severe
44	Vehicle	Vehicle	33.12	2	0.217	Severe
45	Motorcyclecycle	Vehicle	10.8	3	1.000	Severe
46	Motorcyclecycle	Vehicle	39.6	3	0.273	Severe
47	Vehicle	Motorcyclecycle	23.4	3	0.462	Severe
48	Vehicle	Motorcyclecycle	18	2	0.400	Severe
49	Vehicle	Motorcyclecycle	36	2.5	0.250	Severe
50	Vehicle	Vehicle	20.4	3	0.529	Severe
51	Vehicle	Motorcyclecycle	14.4	2	0.500	Severe
52	Motorcyclecycle	Vehicle	20.16	3.1	0.554	Severe
53	Vehicle	Motorcyclecycle	36	2.5	0.250	Severe
54	Motorcyclecycle	Motorcyclecycle	13.32	2.8	0.757	Severe
55	Motorcyclecycle	Vehicle	21.6	2	0.333	Severe
56	Vehicle	Motorcyclecycle	11.52	3	0.938	Severe
57	Vehicle	Motorcyclecycle	21.6	2	0.333	Severe
58	Motorcyclecycle	Motorcyclecycle	14.4	3	0.750	Severe
59	Vehicle	Vehicle	30.6	2	0.235	Severe
60	Vehicle	Motorcyclecycle	18	2.5	0.500	Severe
61	Vehicle	Motorcyclecycle	19.8	4	0.727	Severe
62	Vehicle	Motorcyclecycle	34.2	2.5	0.263	Severe

No.	Driver 1	Driver 2	Conflict Speed (Kmph)	Inter-vehicle Distance (Meter)	Time-to-Accident (TA)	Severity
63	Motorcyclecycle	Motorcyclecycle	16.2	2	0.444	Severe
64	Motorcyclecycle	Motorcyclecycle	17.64	3	0.612	Severe
65	Motorcyclecycle	Vehicle	10.8	1	0.333	Severe
66	Motorcyclecycle	Vehicle	25.2	2	0.286	Severe
67	Vehicle	Motorcyclecycle	28.8	5	0.625	Severe
68	Vehicle	Vehicle	21.6	3	0.500	Severe
69	Vehicle	Vehicle	25.2	3	0.429	Severe
70	Motorcyclecycle	Vehicle	22.32	2	0.323	Severe
71	Vehicle	Motorcyclecycle	14.4	2.5	0.625	Severe
72	Vehicle	Motorcyclecycle	27	2.5	0.333	Severe

The measurement of near-miss distances was done by scaling the distances on video with the approach distances previously measured in the field, allowing the scaled distances for each conflict in the video to be determined. The severity was influenced by the distance between vehicles and their speed, with a severity score above 25 classified as serious, as shown in Figure 7. Before the installation of the markings, there were a total of 72 conflicts, with 66 considered serious and 6 not serious. This indicates that most vehicle conflicts had serious implications based on the Collision Diagram TCT, with an average severity score of 27. The data from Figure 12 and Table 6 underscore the need for further attention and measures to prevent more severe accidents.

Table 3 Vehicle Volume After Auxiliary Markings at the Study Intersection

Waktu	East BSD Boulevard Street			Letnan Sutopo Street Southbound			Promoter Street			Letnan Sutopo Street Northbound		
	HV	LV	MC	HV	LV	MC	HV	LV	MC	HV	LV	MC
16.00 - 16.15	0	165	183	12	309	684	0	24	90	6	267	357
16.15 - 16.30	2	183	203	17	341	753	2	28	100	11	297	394
16.30 - 16.45	0	150	166	12	280	617	1	28	83	7	241	324
16.45 - 17.00	3	199	221	19	372	822	2	30	109	11	327	430
17.00 - 17.15	0	107	204	11	280	662	0	25	76	10	258	350
17.15 - 17.30	0	132	168	5	350	658	0	23	71	9	284	350
17.30 - 17.45	1	122	166	11	346	657	1	24	89	7	299	352
17.45 - 18.00	0	142	174	11	307	654	0	24	83	10	292	335
18.00 - 18.15	0	101	161	12	308	670	0	24	95	7	259	324
18.15 - 18.30	0	122	204	7	332	625	0	21	77	5	284	335
18.30 - 18.45	2	132	189	8	300	626	2	25	73	10	300	356
18.45 - 19.00	0	150	206	10	313	656	0	22	75	7	252	353

Based on the survey conducted after the installation of auxiliary markings, the vehicle volume over a three-hour observation period was 9,201 cars, 15,610 Motorcyclecyclecycles, and 251 large vehicles, totaling 25,026 vehicles.

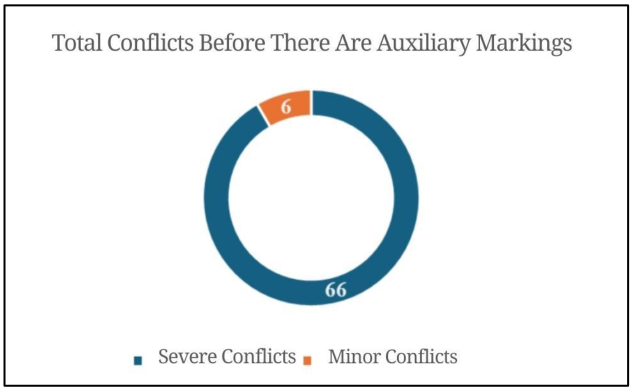

Figure 6 Total Conflicts After Auxiliary Markings

Table 4 Conflict Data After Auxiliary Markings

No.	Driver 1	Driver 2	Conflict Speed (Kmph)	Inter-vehicle Distance (Meter)	Time-to-Accident (TA)	Severity	No.
1	Motorcycle	Motorcycle	27	2.5	Konflik 1	0.333	Serius
2	Motorcycle	Motorcycle	25.2	4	Konflik 2	0.571	Serius
3	Motorcycle	Motorcycle	21.6	2	Konflik 2	0.333	Serius
4	Motorcycle	Vehicle	16.2	3	Konflik 1	0.667	Serius
5	Motorcycle	Motorcycle	21.6	3	Konflik 2	0.500	Serius
6	Motorcycle	Motorcycle	21.6	3	Konflik 2	0.500	Serius
7	Vehicle	Vehicle	23.4	2.25	Konflik 1	0.346	Serius
8	Vehicle	Vehicle	18	3.75	Konflik 2	0.750	Serius
9	Motorcycle	Motorcycle	18	3	Konflik 1	0.600	Serius
10	Vehicle	Vehicle	23.4	2.5	Konflik 1	0.385	Serius
11	Vehicle	Motorcycle	18	2.5	Konflik 1	0.500	Serius
12	Motorcycle	Vehicle	25.2	3	Konflik 2	0.429	Serius
13	Motorcycle	Motorcycle	23.4	3.5	Konflik 2	0.538	Serius
14	Motorcycle	Motorcycle	16.2	4.5	Konflik 2	1.000	Serius
15	Motorcycle	Motorcycle	28.8	2	Konflik 1	0.250	Serius
16	Motorcycle	Motorcycle	30.6	2.5	Konflik 2	0.294	Serius
17	Motorcycle	Motorcycle	21.6	2.5	Konflik 1	0.417	Serius
18	Vehicle	Vehicle	22.8	3	Konflik 1	0.474	Serius
19	Vehicle	Motorcycle	19.8	3	Konflik 1	0.545	Serius
20	Vehicle	Vehicle	16.2	4	Konflik 1	0.889	Serius
21	Vehicle	Vehicle	21.6	3.5	Konflik 1	0.583	Serius
22	Motorcycle	Motorcycle	18	2.5	Konflik 1	0.500	Serius
23	Motorcycle	Vehicle	18	2	Konflik 1	0.400	Serius
24	Motorcycle	Motorcycle	23.4	2.5	Konflik 2	0.385	Severe
25	Vehicle	Motorcycle	34.2	2.75	Konflik 1	0.289	Serius
26	Motorcycle	Motorcycle	19.8	2.5	Konflik 2	0.455	Serius
27	Vehicle	Motorcycle	19.8	3	Konflik 1	0.545	Serius
28	Motorcycle	Motorcycle	19.8	3.5	Konflik 2	0.636	Serius
29	Motorcycle	Motorcycle	14.4	2	Konflik 2	0.500	Serius
30	Vehicle	Vehicle	27	4	Konflik 2	0.533	Serius

No.	Driver 1	Driver 2	Conflict Speed (Kmph)	Inter-vehicle Distance (Meter)	Time-to-Accident (TA)	Severity	No.
31	Motorcycle	Motorcycle	32.4	1	Konflik 2	0.111	Serius
32	Motorcycle	Motorcycle	16.2	5.5	Konflik 2	1.222	Severe

After the installation of the markings, 32 vehicle conflicts were recorded, with 30 considered serious and 2 not serious, based on Figure 8 and Table 4. This shows that the installation of road markings helped reduce the overall number of vehicle conflicts, although most of the remaining conflicts tended to be serious.

Before the post-marking survey, the installation of auxiliary markings was communicated digitally via videos and images through social media platforms such as WhatsApp, Instagram, and Facebook. This was done to raise awareness among drivers about the new auxiliary markings, influencing their behavior.

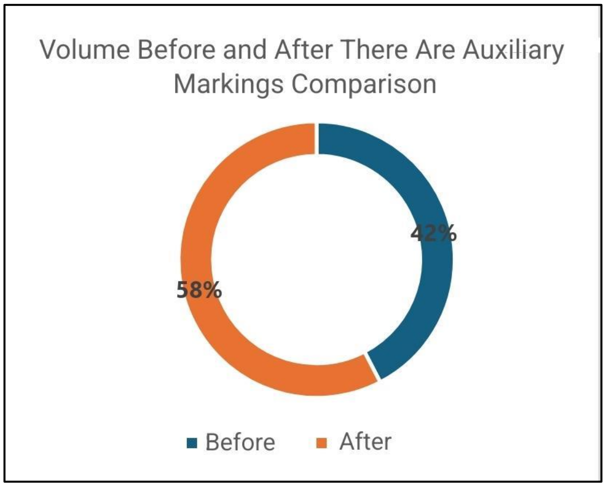

Figure 7 Comparison of Vehicle Volume at the Study Location

Based on the survey conducted before the installation of auxiliary markings, as shown in Figure 10, there was no significant difference in vehicle volume. This justifies that vehicle volume was not the main factor influencing the changes observed after the installation of auxiliary markings using the TCT method based on the number of conflicts.

Conflict comparison analysis was conducted to determine the effectiveness of the auxiliary markings at the intersection of Jl. Letnan Sutopo - Jl. Promoter - Jl. Boulevard BSD Timur.

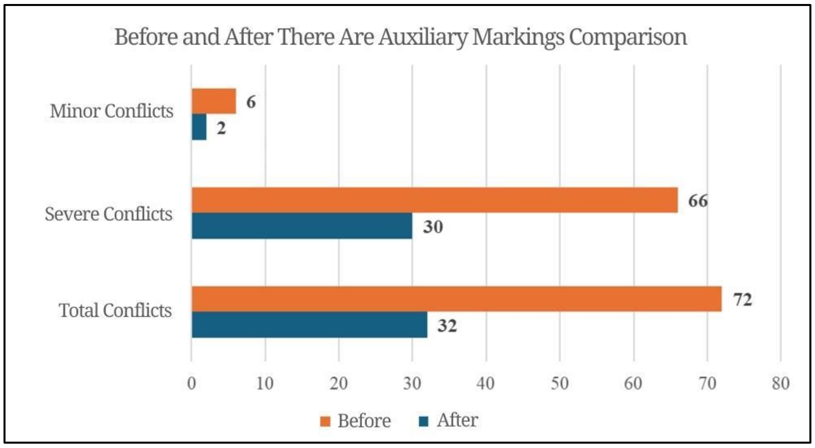

Figure 8 Comparison of Total Conflicts at the Study Location Before and After Auxiliary Markings

According to Figure 15, the installation of road markings successfully reduced the total number of vehicle conflicts from 72 to 32, a 55.56% decrease. Furthermore, the percentage of serious conflicts in the total conflicts only showed a slight reduction from 91.67% to 93.75%, while the percentage of non-serious conflicts significantly decreased from 8.33% to 6.25%. This indicates that the installation of road markings effectively reduced the total number of vehicle conflicts and helped decrease the percentage of non-serious conflicts, suggesting improved traffic safety after the markings were installed.

The cycle time is the period required for a full round of traffic light operations at an intersection or crossing. This cycle time includes all the traffic light phases at the intersection, including green, yellow, and red times for each traffic direction. Below is the existing cycle time at the study location.

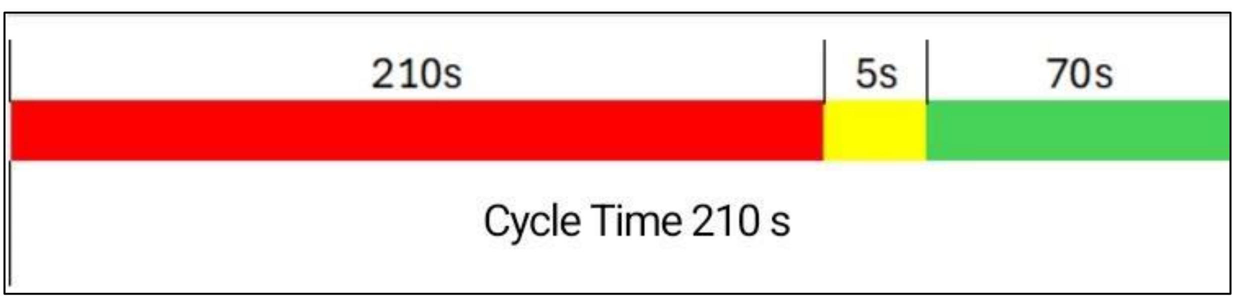

Figure 9 Existing APILL Cycle Time

The evaluation of the existing intersection performance with a 4-phase cycle time of 285 seconds resulted in a Level of Service (LOS) rating of F, as indicated by the high delay values for each approach or intersection leg. This can be attributed to parameters such as the number of vehicles stopped by red lights or those that cannot pass in one phase but require two phases.

Table 5. Intersection Performance Before Auxiliary Markings

Intersection Leg	C (smp/jam)	DS	NQ Total (smp)	NS (Stop/smp)	Dj	D	Level of Service (LOS)
East BSD Boulevard Street	3106.89	0.43	21.20	0.18	94.40	154.58	F
Letnan Sutopo Street Southbound	1722.87	2.72	85.40	0.21	260.61		
Promoter Street	1756.52	1.59	92.80	0.31	155.24		
Letnan Sutopo Street Northbound	2147.44	0.19	101.20	3.37	108.08		

Table 6 Intersection Performance After Auxiliary Markings

Intersection Leg	C (smp/jam)	DS	NQ Total (smp)	NS (Stop/smp)	Dj	D	Level of Service (LOS)
East BSD Boulevard Street	3479.83	0.25	21.20	0.28	89.68	108.65	F
Letnan Sutopo Street Southbound	1861.28	1.05	85.40	0.50	124.97		
Promoter Street	1795.30	0.60	92.80	0.72	114.47		
Letnan Sutopo Street Northbound	2452.94	0.10	101.20	6.12	105.47		

After the installation of auxiliary markings at the study location, the intersection's LOS remained at F. However, there was a significant reduction in delay from 154.8 seconds to 105.47 seconds, a 29.81% decrease. This improvement was due to the auxiliary markings guiding drivers to avoid conflicts, resulting in smoother traffic flow. Despite the reduction in delay, the intersection still had a poor LOS of F, prompting a proposal for an adjustment to the traffic signal cycle times.

Despite the reduction in delay due to the auxiliary markings, the intersection still had a poor LOS of F, prompting a proposal for an adjustment to the traffic signal cycle times. Below is the proposed APILL cycle time for the study location.

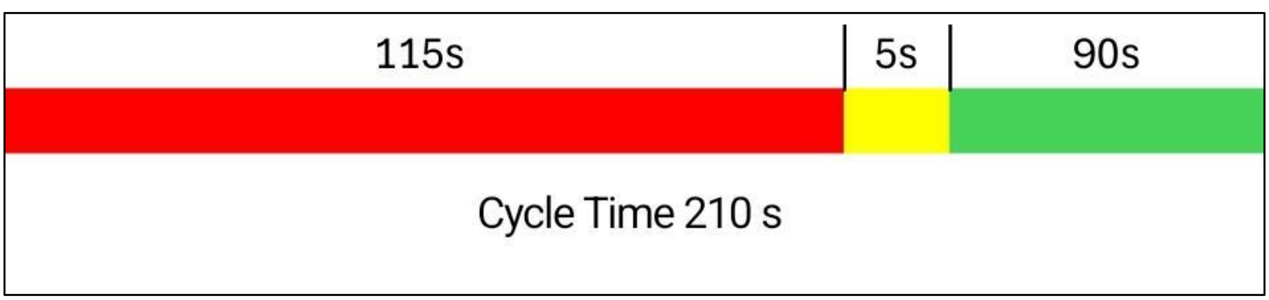

Figure 10 Proposed APILL Cycle Time

Table 7 Intersection Performance After Auxiliary Markings and Cycle Time Adjustment

Intersection Leg	C (smp/jam)	DS	NQ Total (smp)	NS (Stop/smp)	Dj	D	Level of Service (LOS)
East BSD Boulevard Street	5397.29	0.16	21.20	0.38	45.26	56.41	E
Letnan Sutopo Street Southbound	2886.88	0.68	85.40	0.67	64.67		
Promoter Street	2784.54	0.38	92.80	0.98	60.01		
Letnan Sutopo Street Northbound	3804.56	0.07	101.20	8.31	55.69		

After the adjustment to the APILL cycle time and the installation of auxiliary markings at the study location, there was a significant reduction in delay to 56.41 seconds, resulting in an LOS of E. This marked a 63.56% improvement from the initial conditions and a 48.08% improvement from the post-marking, pre-adjustment conditions, demonstrating significant enhancement in intersection performance and traffic safety.

CONCLUSION

Based on observations and the analysis using the TCT method of the auxiliary markings installed at the intersection of Jl. Letnan Sutopo, Jl. Promoter, and Jl. Boulevard BSD Timur, it is evident that there has been a significant decrease in the total number of conflicts compared to when there were no auxiliary markings. This is demonstrated by the reduction in total vehicle conflicts from 72 to just 32, a decrease of 55.56%. However, the percentage of severe conflicts has not decreased with the auxiliary markings, as shown by the change in the percentage of serious conflicts out of the total conflicts. Before the auxiliary markings, there were 66 serious conflicts out of 72 total conflicts, which means 91.67% of the total conflicts were serious. After the installation of the auxiliary markings, 30 out of 32 conflicts were serious, or 93.75%, indicating an increase in this regard.

The 55.56% reduction in near-miss incidents based on the TCT method analysis suggests that the probability of accidents from potential vehicle conflicts is reduced due to the auxiliary markings. Additionally, the performance of the intersection at the study location, in terms of the existing cycle time before the markings, had a Level of Service (LOS) F with a delay of 154.58 seconds. After the installation of the auxiliary markings, the LOS remained at F, but there was a significant 29.81% reduction in delay. Following the proposed cycle time adjustment, the LOS improved to E, with a 63.56% reduction from the conditions before the markings and the proposed cycle time adjustment, and a 48.08% reduction from the conditions after the markings and cycle time adjustment.

A limitation of this study is the use of a handy cam positioned at a height of 1.5 meters, which may have restricted the field of view and the accuracy of conflict observations. Future research could benefit from utilizing more advanced and higher-placed cameras to capture a broader perspective. Additionally, exploring other supplementary measures, such as traffic signal optimization and driver education programs, could further enhance the safety and efficiency of intersections.

REFERENCES

Chrysnanda, D. (2017). Ideal traffic conditions reflect safe, orderly, and smooth traffic flow, which allows people to live, grow, and thrive productively, making traffic the lifeblood of society. *Journal of Transportation Engineering and Management, 3(1), 45-58.*

Mahardianto. (2015). Traffic safety is a crucial aspect of traffic engineering to achieve the goals of safe, comfortable, and economical traffic management. *International Journal of Traffic Engineering, 5(2), 112-125*.

Marsaid, A. R., et al. (2013). Typically, the primary factors contributing to high traffic accident rates are human factors (such as high speed, inattention, fatigue) and the low discipline of drivers. *International Journal of Transportation Science and Technology, 2(2), 78-92.*

PT. Bumi Serpong Damai Tbk. (2024). Detail Engineering Design of Auxiliary Markings.

World Health Organization. (2022). Global Status Report on Road Safety.