



Signal Coordination Analysis Between Intersection: Case Study

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Abstract

The increase number of vehicles every year has caused a declining road function and performance, which then causes a high volume of vehicles in Intersection I of Endro Suratmin street – Pulau Tegal street / Pulau Legundi street, Intersection II of Urip Sumoharjo street – Soekarno-Hatta street, and Intersection III of Urip Sumoharjo street – Arif Rahman Hakim street. The distance between intersection I to II is 460 m, and Intersection II to III is 700 m. The distance between these intersections become a factor that lead to unsatisfactory level of comfort for road users, which in turn causes problems. The problem occurs because of the absence of signal coordination between the three intersections which causes traffic jams during peak hours. Therefore, this research will provide alternative solutions to overcome these problems. This research uses data from field surveys including traffic volume, intersection geometry, and traffic signal data. VISSIM software is used to analyze queue lengths and delays in existing conditions and signal coordination planning. In addition, reference methods such as the calculation of the Indonesian Road Capacity Manual, the Webster Method, and the Transportation Research Board in Highway Capacity Manual are also used. As the result of the analysis, it was found that the performance of the three intersections had not been coordinated. In the existing condition, the service level value in each arm reached E service level, only a few arms at the three intersections have C service level with a delay time of 29.58 seconds/vehicle. Therefore, three planning solutions were conducted to coordinate signals between the three intersections using a plan with a new cycle time acquired from the Webster method. Plan I coordinates the signals of the three intersections by using the new cycle time of intersection I at each intersection, Plan II coordinates the signals of the three intersections by using a new cycle time of intersection II at each intersection, and Plan III coordinates the signals of the three intersections in each arms using the new cycle time. Out of the three plans, the first plan is obtained as the best solution for giving a significant reduction in delays with an average service level of B.

Introduction

Intersections are critical components of urban road networks, functioning as nodes where traffic streams converge, diverge, and interact. Their operational performance strongly influences overall traffic efficiency, safety, fuel consumption, and environmental sustainability in urban areas. As urbanization accelerates and motorization rates continue to increase in developing cities, intersections increasingly become bottlenecks that constrain network capacity and degrade level of service (He & Zeng, 2024; Luitel et al., 2025; Mainali

et al., 2024; Markony & Siena, 2025; Pojani & Stead, 2015; Lieberthal et al., 2024). Inefficient intersection control is widely recognized as a major contributor to traffic congestion, excessive delays, and long vehicle queues, particularly in arterial corridors with closely spaced intersections.

Traffic signal control remains one of the most widely applied strategies for managing traffic flows at signalized intersections (Qadri et al., 2020; Majstorović et al., 2023; Fajardo et al., 2011; Wei et al., 2019; Li et al., 2024). However, isolated signal operation often fails to accommodate the dynamic nature of traffic demand, especially along urban arterials where vehicles encounter multiple intersections within short distances. Previous studies emphasize that uncoordinated signals can significantly increase stops, delays, and fuel consumption, even when individual intersections operate within acceptable capacity limits (Alshayeb et al., 2022; Ma et al., 2025; Wang et al., 2023; Shahbazi & Nowaczyk, 2023). Consequently, signal coordination has become a fundamental approach in urban traffic management to improve progression, reduce travel time variability, and enhance corridor-level performance.

Signal coordination refers to the synchronization of traffic signals along a corridor such that vehicles traveling at a predetermined speed can pass through consecutive intersections with minimal stopping. When properly implemented, coordinated traffic signals allow platoons of vehicles released from an upstream intersection to arrive at downstream intersections during the green phase, thereby reducing unnecessary stopping and delay (Jiang et al., 2022; Liu et al., 2022; Deng et al., 2023). This approach is particularly effective on arterial roads with relatively uniform spacing between intersections and dominant directional traffic flows during peak periods. Despite its proven benefits, effective coordination requires careful consideration of traffic volumes, intersection geometry, signal timing parameters, and spacing between intersections.

In many urban contexts, particularly in medium-sized cities in developing countries, signal coordination is often implemented without rigorous analytical evaluation or updated field data. Signal timing plans may remain unchanged for long periods, even as traffic demand and road conditions evolve (Ardalan et al., 2024; Uribe-Chavert et al., 2025; Tan et al., 2024; Russo et al., 2024). This mismatch frequently leads to inefficient signal operation, manifested in long queues, excessive delays, and spillback that disrupts upstream intersections (Xiong et al., 2025). These challenges highlight the need for systematic evaluation and redesign of signal coordination based on empirical data and robust analytical methods.

The corridor formed by Urip Sumoharjo Street and Endro Suratmin Street in Bandar Lampung City exemplifies these challenges. Along this corridor, three signalized intersections are located in close proximity, creating interdependent traffic operations. The first intersection connects Endro Suratmin Street with Pulau Tegal Street and Pulau Legundi Street, the second lies at the junction of Urip Sumoharjo Street and Soekarno–Hatta Street, and the third connects Urip Sumoharjo Street with Arif Rahman Hakim Street. The distances between these intersections approximately 460 meters between the first and second intersections and 700 meters between the second and third fall within the range where signal coordination is theoretically effective (FHWA, 2015). However, preliminary observations indicate that these intersections currently operate without optimal coordination.

Field surveys conducted at the study location reveal several operational deficiencies. At the first and second intersections, relatively long signal cycle times contribute to substantial delays and extended vehicle queues during peak hours (An et al., 2024; Tan et al., 2024; Shafik & Rakha, 2024; Zhu et al., 2024). At the third intersection, geometric constraints, including limited roadway width and approach capacity, exacerbate congestion, particularly when combined with long signal timings. These conditions result in recurrent queuing and delays that propagate along the corridor, reducing overall traffic efficiency and user comfort.

Such problems underscore the importance of evaluating coordinated signal timing as a corridor-level solution rather than addressing intersections in isolation (Cesme et al., 2023; Patel & Maltare, 2025; Pudasaini, 2025).

Previous research has demonstrated that analytical methods such as the Indonesian Highway Capacity Manual (Najid & Marlianny, 2022) provide a standardized framework for evaluating intersection performance under existing conditions. MKJI-based analysis enables the calculation of critical performance indicators, including degree of saturation, delay, queue length, and level of service, which are essential for diagnosing operational problems. However, while analytical methods are effective for assessing static conditions, they may be limited in capturing complex vehicle interactions, platoon dispersion, and dynamic signal coordination effects (Nandhini & Rabik, 2024; Wang et al., 2025; Haque, 2025).

To overcome these limitations, microscopic traffic simulation tools such as VISSIM have been increasingly adopted in traffic engineering research and practice. VISSIM allows for detailed modeling of individual vehicle behavior, signal control logic, and network interactions under varying traffic conditions. Numerous studies have shown that combining analytical methods with microscopic simulation provides a more comprehensive understanding of traffic performance and enables the testing of alternative signal coordination scenarios before implementation (Yue et al., 2022; Dasgupta et al., 2024; Das et al., 2023). This integrated approach is particularly valuable for evaluating coordinated signal systems along arterial corridors with heterogeneous traffic and geometric constraints.

Despite the growing body of literature on signal coordination and traffic simulation, there remains a research gap in the context of medium-sized Indonesian cities, where traffic characteristics, driver behavior, and infrastructure conditions differ from those in developed countries. Many existing studies focus on large metropolitan areas or rely solely on either analytical or simulation-based approaches. Limited research has systematically compared existing intersection performance using MKJI with planned coordination scenarios evaluated through microscopic simulation for closely spaced intersections in Indonesian urban corridors. Addressing this gap is essential to support evidence-based traffic management and policy decisions at the local level.

Therefore, this study aims to evaluate and optimize the coordination of three closely spaced signalized intersections along the Urip Sumoharjo–Endro Suratmin corridor in Bandar Lampung City. The study integrates analytical evaluation using MKJI (1997) with microscopic simulation using VISSIM to assess existing conditions and develop alternative coordinated signal timing plans. The novelty of this research lies in its corridor-based approach that combines nationally recognized analytical methods with advanced simulation to identify the most effective coordination strategy under local traffic and geometric conditions. The scope of the study is limited to peak-hour traffic operations, focusing on delay, queue length, and overall intersection performance, with the ultimate goal of improving traffic efficiency and user comfort along the study corridor.

Methods

Primary data were collected through comprehensive field surveys conducted directly at the study location. The surveys focused on traffic volume, geometric characteristics of the road, and operational conditions at the intersection. Data collection was carried out during peak traffic periods in the morning, afternoon, and evening to capture variations in traffic demand. Observations were conducted over three representative days—Monday, Thursday, and Saturday selected to reflect typical weekday peak conditions and weekend traffic patterns, under the assumption that these days represent the highest traffic demand levels.

In addition to primary data, secondary data were utilized to support and contextualize the analysis. These included a detailed map of the research location and demographic data on the population of Bandar Lampung City obtained from the Central Statistics Agency (BPS, 2020). The secondary data were used to understand the broader urban context, support assumptions related to traffic demand, and ensure that the analysis aligned with existing spatial and demographic conditions.

The collected data were analyzed using a combination of the Indonesian Highway Capacity Manual (MKJI, 1997) and microscopic traffic simulation software, VISSIM. The MKJI method was applied to evaluate existing traffic performance analytically, including key indicators such as capacity, degree of saturation, delay, and level of service. This approach provided a standardized baseline assessment of the current operational conditions based on nationally recognized guidelines.

Subsequently, the same field data were input into the VISSIM software to simulate traffic operations under both existing and proposed conditions. VISSIM was used to model vehicle interactions and signal control in greater detail, allowing for a more dynamic representation of traffic flow. Based on the simulation results, the performance of the three signalized intersections was evaluated, focusing on queue length, delay, and overall efficiency. Following this evaluation, coordination between the three intersections was designed by applying a new effective signal cycle time under three alternative coordination plans.

Finally, a comparative analysis was conducted to assess differences in intersection performance between existing conditions and planned scenarios. Performance under existing conditions was evaluated using the MKJI (1997) method, while planned coordination scenarios were assessed using VISSIM simulation outputs. This comparison enabled the identification of the most effective coordination plan in terms of improving traffic performance, reducing delays, and enhancing operational efficiency across the three intersections.

Results and Discussion

To find out the condition of traffic in the field, researchers assisted surveyors to conduct traffic counting taken partly using direct observation in the field and some of it was taken using video with tools from mobile phone cameras at peak hours both in the morning, afternoon, and evening.

Table 1. Third Traffic Volume Data for Monday's Period

		Volume (Kend/Jam)			
Time		Intersection I	Intersection II	Intersection III	Total
Morning	06.30-07.30	3569	4675	2744	10988
Morning	06.45-07.45	4463	6198	3734	14395
Morning	07.00-08.00	4437	6145	3782	14364
Morning	07.15-08.15	4131	5955	3553	13639
Morning	07.30-08.30	3672	5440	3319	12431
noon	11.00-12.00	3521	3921	3166	10608
noon	11.15-12.15	3641	4050	3280	10971
noon	11.30-12.30	3693	4206	3311	11210
noon	11.45-12.45	3689	4243	3279	11211
noon	12.00-13.00	3851	4340	3247	11438
Afternoon	16.00-17.00	4559	5552	3493	13604
Afternoon	16.15-17.15	4817	5669	3900	14386
Afternoon	16.30-17.30	4638	5550	4105	14293

Afternoon	16.45-17.45	4469	5396	4049	13914
Afternoon	17.00-18.00	4378	5142	4082	13602

Table 2. Intersection Third Traffic Volume Data For Thursday Period

Volume (Kend/Jam)					
Time		Intersection I	Intersection II	Intersection III	Total
Morning	06.30-07.30	2904	4170	2463	9537
Morning	06.45-07.45	3604	4838	3392	11834
Morning	07.00-08.00	4187	5320	3880	13387
Morning	07.15-08.15	4451	5508	3898	13857
Morning	07.30-08.30	4397	5656	3958	14011
noon	11.00-12.00	3449	3296	3127	9872
noon	11.15-12.15	3489	3464	3296	10249
noon	11.30-12.30	3472	3678	3328	10478
noon	11.45-12.45	3446	3820	3260	10526
noon	12.00-13.00	3589	4031	3274	10894
Afternoon	16.00-17.00	4255	5373	3469	13097
Afternoon	16.15-17.15	4563	5734	3832	14129
Afternoon	16.30-17.30	4330	5416	4026	13772
Afternoon	16.45-17.45	4354	5102	3927	13383
Afternoon	17.00-18.00	4115	4727	3906	12748

Table 3. Third Intersection Traffic Volume Data For Saturday Period

Volume (Kend/Jam)					
Time		Intersection I	Intersection II	Intersection III	Total
Morning	06.30-07.30	2265	4086	2498	8849
Morning	06.45-07.45	2747	4767	2967	10481
Morning	07.00-08.00	3237	5072	3420	11729
Morning	07.15-08.15	3521	5256	3276	12053
Morning	07.30-08.30	3996	4922	3547	12465
noon	11.00-12.00	3580	4240	3103	10923

noon	11.15-12.15	3511	4192	3171	10874
noon	11.30-12.30	3595	4285	3192	11072
noon	11.45-12.45	3649	4277	3328	11254
noon	12.00-13.00	3986	4534	3474	11994
Afternoon	16.00-17.00	3510	5195	4120	12825
Afternoon	16.15-17.15	3729	5209	4329	13267
Afternoon	16.30-17.30	3673	5045	4392	13110
Afternoon	16.45-17.45	3733	4768	4318	12819
Afternoon	17.00-18.00	3840	4442	4550	12832

From the three periods of data collection above, it has been obtained results that show that for peak hours occurred on Monday, June 21, 2021 at 06.45 - 07.45 WIB with a volume of 14,395 vehicles / hour.

Table 4. Intersection Peak Hour On Monday Morning Per 15 minutes

Monda y Afternoon	Intersection I smp/15 minutes			Intersection II smp/15 minutes			Intersection III smp/15 minutes		
	LV	HV	MC	LV	HV	MC	LV	HV	MC
06.45-07.00	192	7	537	299	51	599	160	10	397
07.00-07.15	279	13	753	353	166	839	231	5	610
07.15-07.30	269	18	1000	449	169	1174	214	7	772
07.30-07.45	278	24	1093	496	177	1426	297	8	1023
Total	1018	62	3383	1597	563	4038	902	30	2802
	4463			6198			3734		

The following table describes the table of peak hours obtained on Monday morning June 21, 2021 at 06.45-07.45 per 15 minutes with separation into three groups namely light vehicles (LV), heavy vehicles (HV), and motorcycles (MC). With the aim to make it easier to calculate the flow of vehicles that will be multiplied by the equivalent of the passenger car (emp) of each vehicle.

Traffic Flow

LV = number of vehicles x emp sheltered/ fought
= 126 vehicle/hour x 1,0
= 126 smp/hour.

HV = number of vehicles x emp sheltered/ fought
= 7 vehicle/hour x 1,3

$$= 9,1 \approx 10 \text{ smp/hour.}$$

MC = number of vehicles x emp sheltered

$$= 498 \text{ vehicle/hour} \times 0,2$$

$$= 99,6 \approx 100 \text{ smp/hour.}$$

Capacity and Degree Of Saturation

- Capacity (C) = S x g/c

$$= 1853,3 \times 35 \text{ sec}$$

$$127 \text{ sec}$$

$$= 510,74 \text{ smp/hour} - DS = Q/C$$

$$= 327/476,95$$

$$= 0,69$$

Long Queue and Delay

$$20 - QL = NQMAX \times W \text{ entry}$$

LV = number of vehicles x emp sheltered/ fought

$$= 17,20 \times 20$$

$$2,46$$

$$= 139,80 - D = DT + DG$$

$$= 43,20 + 4,80$$

$$= 47,99 \text{ sec/smp}$$

Table 6. Level Of Service in existing conditions

Intersection I			Intersection II			Intersection III		
short	delay(sec/smp)	Index	short	delay(sec/smp)	index	short	Delay(sec/smp)	index
North	32,98	C	North	50,55	D	North	61,57	E
West	34,94	C	West	56,13	E	West	65,04	E
South	36,19	D	South	42,68	D	South	49,67	D
East	29,58	C	East	71,6	E	East	47,99	D

Table 7. Cycle Adjustment Intersection III

Number of Phases	Yellow Time (s)	All-Red Time (s)	Intergreen Period (s)	Initial Lost Time (s)	Final Lost Time (s)	Total Lost Time (s)	Flow Ratio (y)	Critical Flow Ratio (y _{crit})	Intersection Flow Ratio (Y)	Optimal Cycle Time (C _o)	Adopted Cycle Time (s)	Effective Green Time (s)	Effective Green per Phase (s)	Actual Green Time (s)
4	3	3	4	1	1	12	0.20	0.20	0.62	60.865	91	79	25.024	25
4	3	3	4	1	1	12	0.16	0.16	0.62	60.865	91	79	20.016	20
4	3	3	4	1	1	12	0.09	0.09	0.62	60.865	91	79	17.966	18
4	3	3	4	1	1	12	0.17	0.17	0.62	60.865	91	79	22.165	22

Design of Signal Coordination Between Simpang Using VISSIM on intersection I Endro Suratmin street – P. Tegal street / P. Legundi street, intersection II Urip Sumoharjo street – Soekarno-Hatta street, and intersection III Urip Sumoharjo street – Arif Rahman Hakim street.



Figure 1. Intersection I Endro Suratmin street – P. Tegal street/ P. Legundi street



Figure 2. Intersection II Urip Sumoharjo street – Soekarno-Hatta street



Figure 3. Intersection III Urip Sumoharjo street – Arif Rahman Hakim street

The average existing speed used in the direction of intersection I to intersection II is 28.5 km/h and then at intersection II to intersection III by 40 km / h.

Time travel intersection I to intersection II

$$\begin{aligned}
 t &= \frac{\text{distance (S)}}{\text{speed (v)}} \\
 &= \frac{0,46 \text{ km}}{28,5 \text{ km/hour}} \\
 &= 0,01614035 \text{ hour} \\
 &= 58 \text{ sec}
 \end{aligned}$$

Time travel intersection II to intersection III

$$\begin{aligned}
 T &= \frac{\text{distance (S)}}{\text{speed (v)}} \\
 &= \frac{0,70 \text{ km}}{40 \text{ km/hour}} \\
 &= 0,0175 \text{ hour} \\
 &= 63 \text{ sec}
 \end{aligned}$$

Alternative Planning I

The first planning alternative to signal coordination between intersections is to use a coordination diagram with the same cycle time, which uses the cycle time on Intersection I of 71 seconds.

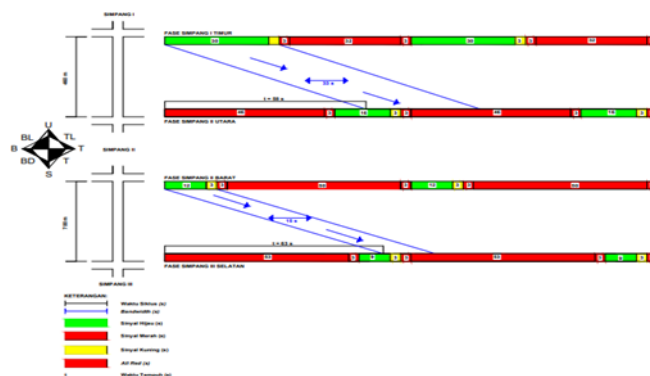


Figure 4. Signal Diagram After Coordinated Alternative Conditions of Planning I

Alternative Planning II

The second planning alternative for signal coordination between intersections is to use a coordination diagram with the same cycle time that uses the cycle time in Intersection II of 85 seconds. Here is a cycle time data and a traffic signal coordination diagram.

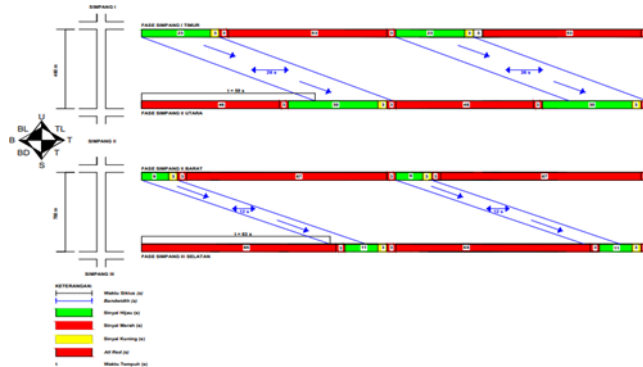


Figure 5. Signal Diagram After Coordinated Alternative Planning Conditions II

Alternative Planning III

The third planning alternative to signal coordination between intersections is to create a coordination diagram with the same cycle time that uses the cycle time in Intersection III of 91 seconds. Here is a cycle time data and a traffic signal coordination diagram.

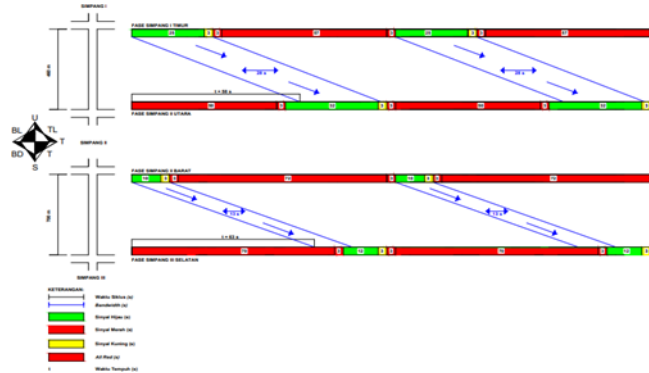


Figure 6. Signal Diagram After Coordinated Alternative Conditions of Planning III

Results and Analysis Using MKJI, 1997 and Using VISSIM Software

Table 8. Results of Analysis and Discussion

Intersection	Approach	MKJI 1997 Existing Delay (s/pcu)	LOS	VISSIM Existing Delay (s/pcu)	LOS	Plan I Delay (s/pcu)	LOS	Plan II Delay (s/pcu)	LOS	Plan III Delay (s/pcu)	LOS
I	T	29.58	C	13.01	B	5.160	A	16.728	B	23.235	C
I	B	34.94	C	33.91	B	31.622	C	67.424	E	77.820	E
I	U	32.63	C	21.56	C	27.553	C	23.094	C	36.810	D
I	S	36.19	D	18.79	C	16.529	B	27.625	C	26.705	C
I	S	42.68	D	27.19	C	19.548	B	18.908	B	21.764	C

II	T	71.60	E	43.73	D	16.31 4	B	28.40 5	C	25.29 9	C
II	U	50.55	E	34.19	D	14.76 4	B	10.91 1	B	15.39 3	B
II	B	56.13	E	27.19	D	19.54 8	B	18.90 8	B	21.76 4	C
II	S	49.67	E	69.14	D	22.96 5	C	52.64 9	D	64.92 0	E
III	B	65.04	E	46.82	D	15.31 1	B	17.18 4	B	24.41 3	C
III	U	61.67	E	34.94	D	14.77 1	B	20.04 3	C	23.13 3	C
III	T	47.99	D	69.14	C	22.96 5	C	52.64 9	D	64.92 0	E

Based on the results of the above analysis and discussion for coordinated signals between intersections used planning using each of the time cycles and equalized to the time cycle at each intersection. In the planning that has been done to get a better level of service, the planning chosen is planning I.

which can be seen in the table above. Because in planning I seen a very significant delay change in each short compared to existing using MKJI, 1997 and compared to existing using vissim. In addition, in the research conducted it can also be concluded that planning I is better than planning II and planning III because the longer the cycle time on the three intersections that have been coordinated, the higher the value of vehicle delays in the short at each intersection. In planning I done using a cycle time of 71 seconds can improve the performance of the three intersections and coordinated the three intersections.

Table 9. Planning Recapitulation Using Vissim and Using MKJI, 1997

Intersection	Approach	VISSIM Delay (s)	VISSIM Queue Length (m)	MKJI (1997) Delay (s)	MKJI (1997) Queue Length (m)
I	T	5.16	8.44	29.58	96.49
I	B	31.62	222.17	34.94	52.69
I	U	27.53	13.13	32.98	143.54
I	S	16.53	13.48	36.19	88.08
II	S	19.55	13.69	42.68	88.08
II	T	16.31	3.52	71.60	96.49
II	U	14.76	9.33	50.55	143.54
II	B	19.55	5.93	56.13	52.69
III	S	22.96	3.98	49.67	89.51
III	B	15.31	9.29	65.04	141.61
III	U	14.77	11.29	61.67	143.94
III	T	22.96	120.80	47.99	139.80

Based on the results of the analysis that has been done in table 4.44 obtained the results of comparison using vissim application with new cycle time effective, and has been coordinated for intersection Endro Suratmin street - P. Tegal street/ P. Legundi street, Urip Sumharjo street - Soekarno- Hatta street, and Urip Sumoharjo street - Arif Rahman Hakim street and by using MKJI, 1997 at a time when existing conditions are quite noticeable due to the average delay and length of queues are experiencing a lot of A pretty big drop.

Conclusion

From the results of research analysis and discussions that have been done can be summarized several things, among others:

Results from the analysis of synergistic intersection performance at intersection I Endro Suratmin street – P. Tegal street/ P. Legundi street, Intersection II Urip Sumoharjo street – Soekarno-Hatta street, and Intersection III Urip Sumoharjo street –Arif Rahman Hakim street based on synergistic intersection performance parameters using MKJI, 1997. For the three intersections at the time of existing conditions with reference to the average delay of each intersection in each intersection short, there is less good performance at the intersection shorts, especially on the shorts in intersection II and the shorts at intersection III, then on each intersection II and intersection III, and based on the Transportation Research Board. Highway Capacity Manual, 2010, at intersection I of South there is still a fairly bad service level with level of service D and E.

From the analysis that has been done, obtained vehicle delays at the three intersections have high value and a poor level of service. For this reason, the analysis that has been done based on planning I using an effective cycle time of 71 seconds can improve the performance of the three intersections and coordinate the three intersections well in serving traffic at peak hours, as well as for the service level of the three intersections to be better based on the Transportation Research Board. Highway Capacity Manual, 2010.

Suggestion

From the research that has been done, it is obtained some advice that aims to help the development if the next research will be done. These suggestions include:

The value of calibration parameters used in research that has been done can not necessarily be used if implemented at other intersections, but the value of calibration parameters will not be much different from what has been done in the research that has been done.

Expand the planning alternatives that can be done at the three intersections

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