

Reducing Congestion via Coordination of Signalized Intersection on Corridor KH. Abdul Halim Majalengka District

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Abstract. KH Abdul Halim Street have three intersections where the conditions are uncoordinated, resulting in vehicles that have just passed Mambo Market Intersection having to stop and wait for the green phase again at Abok Intersection, and a similar situation occurs at Tugu Kecap Intersection. Consequently, long queues, delays, and numerous stops, especially during peak hours, are unavoidable. Therefore, a thorough coordination analysis among the intersections is necessary to reduce traffic congestion at these three intersections. The purpose of this study is to analyze the signal coordination among the three intersections using Transyt 14.1 software. The research was conducted by analyzing primary and secondary data with Indonesian Highway Capacity Manual to obtain values for Capacity, Queue Length, Delay, Degree of Saturation, and Level of Service in the existing conditions, followed by analyzing the existing signal settings at these intersections using the Time-Distance Method diagram. The signal coordination analysis was carried out using Transyt 14.1, and the results from the software were compared with the existing conditions. The study results show that the delay has increased from the existing conditions at Pasar Mambo, Abok, and Tugu Kecap Intersections. The Degree of Saturation has decreased, and the Queue Length has also decreased. The novelty of this research lies in its practical application of signal optimization software to an understudied area, offering actionable recommendations for local governments to improve urban traffic flow and reduce congestion on busy corridors.

1 Introduction

Signalized intersections are directed at supporting smooth urban traffic and road safety, which has an important function as transportation infrastructure in the development of urban road networks [1]. Previous research on traffic signal coordination has predominantly

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focused on intersections with high traffic volumes in large cities [2]. However, little attention has been given to corridor roads in smaller towns like Majalengka, where uncoordinated traffic signals at several intersections cause significant local congestion. Therefore, this study aims to address this gap by developing more effective signal coordination strategies using Transyt software, which can be applied to traffic conditions on corridor roads like KH Abdul Halim. For this reason, it is important to create an urban fixed-time signalized intersection scenario to explore the distribution characteristics of spatial groups in the intersection entry route [3]. Signalized intersections are one of the causes of obstruction of the traffic network in various urban areas which has an impact on traffic jams and increased traffic emissions [4]. Majalengka regency located between the cities of Cirebon and Bandung. This regency serves as a transit route for vehicles traveling from Cirebon to Bandung and vice versa, making the traffic on Majalengka regency's roads busy. The volume of vehicles passing through Majalengka regency increases every year. Due to the growing number of vehicles, especially at the intersections along the route passing through the Central Business District (CBD), there are frequent traffic jams and long queues of vehicles [5]. This situation can be influenced by the relatively slow speed of vehicles, often caused by passing freight vehicles [6]. Additionally, it can also be affected by the suboptimal phase settings of the traffic lights [7].

The highlights the importance of signalized intersections in managing urban traffic flow, particularly in busy regions like Majalengka Regency. However, a key gap in the current analysis is the focus on conventional fixed-time signalized intersections, which often fail to adapt to the complex and dynamic conditions of urban traffic, such as varying vehicle types, peak-time congestion, and the close spacing of intersections. This results in long delays, inefficient signal timing, and increased emissions, especially in high-traffic areas like CBD of Majalengka. The current model does not adequately address the impact of freight vehicles and non-uniform signal cycle times, leading to frequent traffic jams, reduced travel efficiency, and underperformance at intersections. Furthermore, existing studies often overlook the potential of newer, more adaptive traffic management technologies, such as automated dedicated lanes or advanced traffic signal coordination, which could significantly improve intersection performance. By focusing on improving the performance of traffic lights through coordinated cycles, seeks to mitigate inefficiencies inherent in fixed-time signal systems and enhance the overall flow and safety of urban traffic.

The central activity area in the CBD is dominated by a mix of activities, including trade and services, especially along KH. Abdul Halim Street. CBD is a location for businesses and communities to compete for space due to its socio-economic and political factors so that it is able to attract many users and has a regulatory planning focus as a behavioral control [8], as a core area of urban planning and management decisions where cartography and its representation play an important role in urban development [9]. There are also healthcare facilities, educational institutions, sports facilities, and offices around the CBD. The CBD area of Majalengka Regency attracts visitors due to its supporting facilities, such as sports facilities, places of worship, and others that have been modified from one-way streets. The presence of these facilities has impacted the traffic characteristics within the CBD. Additionally, there are educational facilities ranging from early childhood education, elementary schools, junior high schools, senior high schools, to higher education institutions. These educational facilities are essentially available in every sub-district. Several healthcare facilities, including community health centers located in each district, clinics, and hospitals are spread across various locations [10]. Some of the hospitals include RSIA Livasya, RSUD Cideres, RS Khusus Bedah Budi Kasih, and other hospitals.

The sports facilities in Majalengka regency are integrated into one block or area located in the Gelanggang Generasi Muda (GGM) Majalengka, which is currently under construction. These sports facilities include the GGM running track and a multi-purpose

arena that, once completed, will accommodate sports like futsal, basketball, badminton, and more. Additionally, there are religious facilities in Majalengka Regency, such as mosques built in every sub-district, reflecting the predominantly Muslim population of the area. Besides mosques, there are also other places of worship, including churches and temples in various districts. Majalengka regency has extensive green spaces, including green open spaces, rice fields, community plantations, and vacant land. Land use in Majalengka Regency also includes transportation hubs such as terminals and the new airport, west java international airport (BIJB) Kertajati, located in Kertajati District. The regency has six type C terminals included Kadipaten Terminal, Bantarujeg Terminal, Cigasong Terminal, Rajagaluh Terminal, Maja Terminal, and Cikijing Terminal, all serving passengers for boarding and alighting.

The balance of the transportation network is usually influenced by demand [11]. Comprehensive transportation systems develop by means of lifeline engineering that offers intercity transportation services that impact economic and social development [12]. Therefore, to enhance the capacity and reach of the existing transportation system, Majalengka regency has adopted a predominant grid pattern for its road network. This pattern ensures that community activities are evenly distributed and easily accessible from all areas [13]. According to data from the central bureau of statistics of Majalengka regency in 2023, the total length of roads in the regency reaches 918,726 kilometers, with widths varying between 2,50 and 11 meters. These roads include national, provincial, regency, and village roads. Most of the roads are paved, although some still use rigid (concrete) pavement. Of the total, 654,396 kilometers of roads are in good condition, 158,042 kilometers are in fair condition, 87,688 kilometers are in poor condition, and 18,6 kilometers are in severely damaged condition. The development of a capacity model to address the impact of automated dedicated lanes on the capacity of signalized intersections can be carried out using car-following modes in mixed traffic flows analyzed, and the influence of automated dedicated lane arrangements on average headway discussed, or a new capacity model with automated dedicated lanes derived based on classic capacity model [14]. The problem with intersections controlled by traffic lights is the close proximity of the intersections and the uncoordinated or unequal cycle times, resulting in long vehicle delays and frequent red signals that reduce travel efficiency. The closely spaced intersections include Mambo market intersection, Abok Intersection, and Tugu Kecap Intersection. Mambo market intersection has a delay time of 26,96 seconds per vehicle with a level of service (LOS) of "D". Abok intersection has a delay time of 17,61 seconds per vehicle with a LOS of "C", and Tugu Kecap intersection has a delay time of 26,15 seconds per vehicle with a LOS of "D". Based on these conditions, an analysis of the signal timing and total cycle time of the intersections will be conducted to improve their performance.

The aim of the study is to analyze signal coordination between the three intersections using Transyt 14.1 software. This objective directly addresses the gap identified in previous studies, namely the lack of effective coordination between signal cycles at adjacent intersections in the Majalengka CBD area. This study seeks to improve the performance of intersections that have often experienced vehicle delays and travel inefficiencies due to misalignment of traffic signal timing. By using a coordinated signal analysis approach, this study is expected to reduce delays, improve traffic efficiency, and mitigate negative impacts on travel in this densely populated area. This is in line with the need to optimize traffic infrastructure in urban areas that continue to grow and experience increasing vehicle volumes [15].

2 Method

This research was conducted in Majalengka Regency, focusing on the three intersections along KH. Abdul Halim Street consist of Mambo market intersection, Abok intersection, and Tugu Kecap intersection. Data collection activities were carried out from February to June 2024 for data processing, data analysis, and report writing of the research results. In this research, two sources of data are required: secondary data and primary data from the intersections, namely: Secondary data are data sourced from government agencies that are relevant to the technical implementation of this research. The government agencies that serve as data sources in this study include Department of Transportation of Majalengka Regency, Department of Public Works and Spatial Planning of Majalengka Regency. Primary data is data obtained directly from field surveys or with the assistance of available technology shown in Table 1. The primary data used in this research process include geometric intersection data, traffic volume data, cycle time data, speed data, queue and delay data.

Table 1. Data Collection (primary data collection)

Number	Data	Survey
1	Geometric intersection	Intersection inventory survey
2	Traffic volume	Classified Turning Movement Counting (CTMC) survey
3	Cycle time	Cycle time survey
4	Speed	Travel speed survey using Moving Car Observer method
5	Queue and Delay	Queue and Delay survey

After collecting secondary and primary data, the data analysis technique in this research follows the guidelines of Indonesian road capacity guidelines and utilizes Transyt software. Intersection performance is measured based on several aspects including saturation degree, queue length, delay, and network performance such as delay cost and fuel consumption. Starting with the first step, which is the analysis of the intersection's performance based on the Indonesian Road Capacity Guidelines 2023. Intersection capacity is calculated for each approach.

After conducting the analysis of the existing intersection conditions, the coordination analysis of intersection traffic signals using Transyt software will be performed. This optimization phase involves striving for optimal cycle time coordination or traffic light synchronization among the three intersections consist of Tugu Kecap, Abok, and Mambo market, and taking into account the proposed intersection design from the research. Transyt is software used to optimize signal timing at intersections [16], software developed by the Transport Road Research Laboratory (TRRL). This program application can coordinate traffic lights for various purposes, such as reducing queue lengths, minimizing vehicle waiting times, decreasing the number of vehicle stops, prioritizing public transport, or reducing vehicle operating costs [17]. Transyt generates optimized signal timing to advance platoons through the network. Platoon advancement is influenced by various factors including inter-section spacing, lateral friction such as roadside parking facilities, and road width [18]. In optimizing signal coordination between intersections, especially between uncontrolled ones, the Performance Index (PI) is utilized. This index combines intersection signal values with priority settings and factors such as delay, queue length, and stopped vehicles proportionally [19]. This software can be used in scenarios where intersections are prone to congestion, providing performance index information that helps calculate travel costs, thereby illustrating the losses caused by delays at intersections [20]. After conducting

a series of intersection coordination analyses, the next step involves comparing the performance between the intersection's existing condition and the intersection optimized through coordination. The parameters to be compared include saturation degree, queue length in meters and delay time.

The three intersections selected for this study include Mambo market, Abok and Tugu Kecap on Jalan KH. Abdul Halim, selected based on several considerations including the three intersections are located in the central business district (CBD) which has heavy traffic due to a mixture of trade, service and public facilities, so that congestion often occurs. These intersections are quite close to each other, causing signal coordination problems that contribute to long queues and vehicle delays. The combination of private vehicles, public transportation, and heavy vehicles (freight) that often pass through this route plays a role in adding to the complexity of traffic movements. These intersections have also been identified as areas with suboptimal signal phase problems, making them ideal candidates for signal optimization applications. By combining intersection selection based on critical traffic criteria and using validated data through a systematic process, this study can ensure that the analysis carried out is relevant and in-depth, and the proposed signal optimization results can be effectively applied at the research location.

3 Result and discussion

The performance of existing intersections is a critical aspect in traffic planning and management. Transyt Analysis (Traffic Network Study Tool) is one of the methods used to evaluate intersection performance. The importance of analyzing the performance of existing intersections using Transyt includes identifying traffic problems where the analysis helps identify locations that often experience traffic jams and their causes and by understanding traffic patterns accident-prone points can be identified. Additionally, it helps optimize traffic signal settings to reduce waiting times and improve traffic flow efficiency and reduce congestion contributing to reduced vehicle emissions. By analyzing the performance of existing intersections using Transyt, traffic planners can make more informed and effective decisions, which will ultimately increase efficiency, safety and comfort in the transportation system. From the initial analysis, the performance of the existing intersection based on Transyt is summarized as follows. The results of the existing intersection performance based on Transyt analysis shown in Table 2.

Table 2. Existing Intersection Performance based on Transyt

Morning Peak Hours			
Intersection Name	Saturation Degree	Queue Length (meters)	Delay (seconds/pcu)
Mambo Market	0.67	61.32	24.67
Abok	0.56	44.71	21.82
Tugu Kecap	0.71	77.15	23.46
Afternoon Peak Hours			
Intersection Name	Saturation Degree	Queue Length (meters)	Delay (seconds/pcu)
Mambo Market	0.49	36.59	19.27
Abok	0.48	30.68	19.44

Morning Peak Hours			
Intersection Name	Saturation Degree	Queue Length (meters)	Delay (seconds/pcu)
Tugu Kecip	0.55	50.81	18.82
Evening Peak Hours			
Intersection Name	Saturation Degree	Queue Length (meters)	Delay (seconds/pcu)
Mambo Market	0.60	47.92	21.30
Abok	0.51	36.21	19.93
Tugu Kecip	0.62	60.37	20.28

From the performance Table 3, ascertain the existing performance of the intersections studied using Transyt software, which includes performance parameters such as saturation degree, queue length, and delay time during the busy morning, afternoon, and evening hours. After obtaining the existing intersection performance and using Transyt, the next step is to validate the model or align the model results with actual field conditions. Validation is conducted to determine the feasibility of using the Transyt software model by comparing the performance of the existing intersection with the performance predicted by Transyt.

Table 3. Chi-square test

I.	Hypothesis		
	H ₀ :	Model Consistent with Survey	
	H ₁ :	Model Not Consistent with Survey	
II.	Confidence Level $\alpha = 95\%$	0.05	
III.	Degrees of Freedom (V) = (K-1) = (11-1)	10	
IV.	Chi-Square Table Value (X2 Table)	18.307	
V.	Chi-Square Calculated		0.00662
VI.	Decision Rule: H ₀ is Accepted If X2 Calculated <		18.307
	H ₁ is Accepted If X2 Calculated >		18.307
VII.	Decision	: H ₀ Accepted	

The importance of assessing the performance of existing intersections using Transyt software lies in the software's ability to provide a more in-depth and accurate picture of traffic performance at intersections, especially during morning, afternoon and evening rush hours. Performance parameters such as saturation level, queue length, and delay time are important indicators in evaluating whether an intersection is functioning optimally or causing congestion and inefficiency. With Transyt, conduct signal optimization simulations aimed at improving traffic light cycle times and coordinating signals at several adjacent intersections. After the intersection performance analysis is carried out, the next critical step is to validate

the model. This validation aims to align the simulation results from the software with real conditions in the field. It is important to ensure that the model used in the simulation can accurately represent the actual traffic situation. This validation process is carried out by comparing the intersection performance predicted by Transyt such as saturation level, queue length, and delay time with actual performance data obtained from field observations. Performance indicators of the intersection used as the subject of the chi-Square test is saturation degree, which is an output from the Transyt 14.1 application and serves as an indicator of intersection service level performance. After model creation, the modeled performance data results were used for validation. Below is the table of saturation degree validation results.

Table 4. Results of chi-square test

No.	Intersection Name	Approach	Road Name	Degree of Saturation		Chi-square Test	Result
				Existing	Model		
1	Mambo Market	N	Jl. Pertanian	0.54	0.53	0.00026	Ho Accepted
		S	Jl. Babakan	0.54	0.52	0.00063	Ho Accepted
		E	Jl. KH Abdul Halim	0.78	0.77	0.00028	Ho Accepted
		W	Jl. KH Abdul Halim	0.89	0.87	0.00031	Ho Accepted
2	Abok	N	Jl. Kesehatan	0.49	0.46	0.00150	Ho Accepted
		S	Jl. Jatisampay	0.42	0.40	0.00120	Ho Accepted
		E	Jl. KH Abdul Halim	0.87	0.85	0.00033	Ho Accepted
		W	Jl. KH Abdul Halim	0.54	0.53	0.00014	Ho Accepted
3	Tugu Kecap	N	Jl. Raya Laswi	0.57	0.55	0.00067	Ho Accepted
		E	Jl. KH Abdul Halim	0.86	0.84	0.00069	Ho Accepted
		W	Jl. KH Abdul Halim	0.76	0.74	0.00061	Ho Accepted
Total						0.00662	Ho Accepted

It is known that the saturation degree between field conditions and modeling is appropriate shown Table 4. Based on the calculation results, it can be seen that H_0 is accepted, which means the model is consistent with the field conditions and can be used for intersection modeling because $X^2 < 18,307$, indicating that the model created can be applied and is suitable for field use. Next, after validating the existing model, and confirming its validity or suitability for use, the next step is to coordinate the intersection traffic signal timings. Below is the data from the intersection coordination using Transyt software, where the coordination was done by synchronizing the cycle times of intersections to create a green wave between them. In this coordination, experiments were conducted by aligning the cycle times of each intersection using optimized times during each peak hour. Here is the offset diagram during the busy morning hours after achieving the best signal capabilities for vehicle throughput.

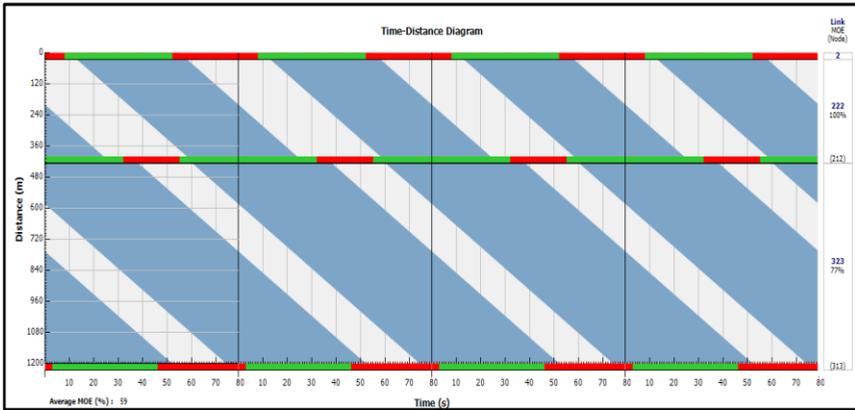


Fig. 1. Offset diagram during busy morning hours from west to east

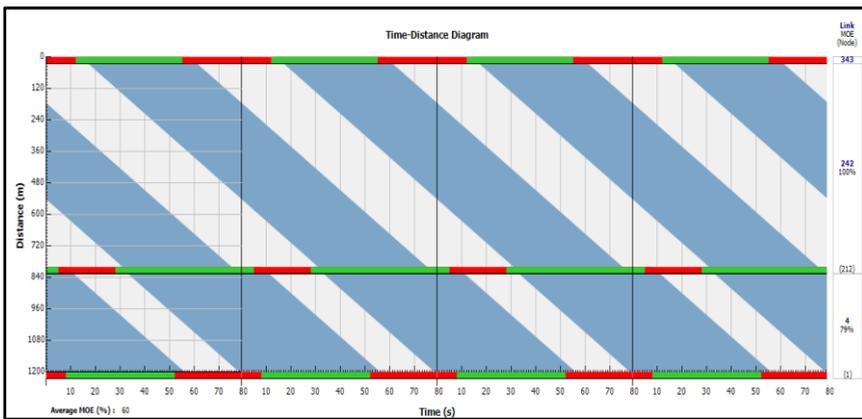


Fig. 2. Offset diagram during busy morning hours from east to west

Based on Figure 1 and Figure 2, it shows the coordination during the busy morning hours sequentially among the three intersections with the order of 1 (Mambo market intersection), 2 (Abok Intersection), and 3 (Tugu Kecap Intersection). For example, if vehicles from Pasar Mambo Intersection get a green light, then vehicles will also receive green lights at the second and third intersections in the same sequence. This situation is also known as a Green Wave [21]. The percentage in the flow diagram indicates the measure of effectiveness of the coordination implemented among intersections. With a coordination percentage of 100% between the first and second intersections, followed by 77% between the second and third intersections during the busy morning hours from west to east direction, this percentage signifies that all vehicles (100%) will receive a green signal from the first to the second intersection. Subsequently, 77% of vehicles will receive a green signal from the second to the third intersection, while the remaining 23% will encounter a red signal. After conducting the analysis of cycle time coordination at the intersections, the next step involves a comparison. The comparison is made between the performance of the existing intersections and the performance of the intersections after coordination during each busy morning, afternoon, and evening period.

This study plays an important role in improving traffic efficiency through optimizing traffic light signals at adjacent intersections. By highlighting signal coordination at three intersections including the Mambo Market intersection, the Abok intersection, and the Tugu Kecap intersection, this study aims to reduce vehicle delay time, queue length, and saturation levels on busy highways, especially during peak hours. The important role of this study lies

in the application of signal coordination between intersections, for example by coordinating the green light signal, this study ensures that vehicles that get a green light at the Mambo Market intersection will continue to get a green light at the next intersection, so that traffic movement becomes smoother. The percentage of coordination effectiveness, such as 100% between the first and second intersections, and 77% between the second and third intersections, illustrates the success rate of vehicles passing through the intersection without stopping. This shows how well the coordination is able to reduce vehicle stopping time, which is important for reducing congestion and saving drivers' time. In addition, this study provides an in-depth understanding of how changes in signal coordination can affect the overall performance of an intersection. After analyzing the coordinated time cycle, this study compares the performance of the intersection before and after coordination. By making comparisons at each peak period (morning, afternoon, and evening), this study ensures that the optimization results can be applied to various daily traffic conditions, ultimately reducing traffic load significantly in the studied area.

Table 5. Comparison of Existing and Transyt Performance during Morning Peak Hours

Morning Peak Hours							
Intersection Name	Road Name	Degree of Saturation		Queue Length (m)		Delay (sec/pcu)	
		Exist	Coord	Exist	Coord	Exist	Coord
Mambo Market	Pertanian	0.53	0.64	39.25	40.05	23.14	27.58
	Babakan	0.52	0.64	41.55	42.30	22.91	27.14
	KH. Abdul Halim 7	0.77	0.69	70.72	53.24	23.15	15.34
	KH. Abdul Halim 6	0.87	0.78	93.76	70.24	29.48	18.2
Mean		0.67	0.69	61.32	51.46	24.67	22.07
Abok	Kesehatan	0.46	0.65	20.60	22.75	30.89	35.86
	Jatisampay	0.40	0.56	21.20	22.55	29.09	30.83
	KH. Abdul Halim 8	0.85	0.78	96.16	70.16	18.38	10.03
	KH. Abdul Halim 7	0.53	0.48	40.88	22.84	8.91	4.33
Mean		0.56	0.62	44.71	34.58	21.82	20.26
Intersec-tion Name	Road Name	Degree of Saturation		Queue Length (m)		Delay (sec/pcu)	
		Exist	Coord	Exist	Coord	Exist	Coord
Tugu Kecip	Tonjong	0.55	0.67	59.00	62.07	22.05	27.44
	KH. Abdul Halim 9	0.84	0.75	98.88	63.70	26.47	16.99
	KH. Abdul Halim 8	0.74	0.66	73.56	49.16	21.85	10.62
Mean		0.71	0.69	77.15	62.56	23.46	18.35

During the morning peak hours, the coordination of intersections using Transyt software aimed to synchronize signal cycles, creating a green wave between intersections shown in Table 5. The data reveals the before and after conditions of this coordination effort included at Mambo market intersection, along Pertanian road, the degree of saturation improved slightly from 0.53 to 0.64 after coordination, while queue lengths increased marginally from 39.25 meters to 40.05 meters. However, delays per passenger car unit (pcu) rose from 23.14 seconds to 27.58 seconds. Similarly, at Abok intersection, on Kesehatan Road, the degree of saturation increased from 0.46 to 0.65 post-coordination. Queue lengths also grew from 20.60 meters to 22.75 meters, and delays per pcu rose from 30.89 seconds to 35,86 seconds. At Tugu Kecap intersection, Tonjong Road saw a degree of saturation rise from 0.55 to 0.67 following coordination. Queue lengths increased slightly from 59.00 meters to 62.07 meters, and delays per pcu rose from 22.05 seconds to 27.44 seconds. The coordination resulted in varying impacts on intersection performance, with improvements in saturation observed but accompanied by increased queue lengths and delays in some cases.

Table 6. Comparison of Existing and Transyt Performance during Afternoon Peak Hours

Afternoon Peak Hours							
Intersection Name	Road Name	Degree of Saturation		Queue Length (m)		Delay (sec/pcu)	
		Exist	Coord	Exist	Coord	Exist	Coord
Mambo Market	Pertanian	0.40	0.52	27.40	25.60	20.89	23.43
	Babakan	0.39	0.51	29.45	27.40	20.63	22.95
	KH. Abdul Halim 7	0.50	0.44	35.52	24.12	16.13	9.7
	KH. Abdul Halim 6	0.66	0.58	54.00	36.72	19.41	11.62
Mean		0.49	0.51	36.59	28.46	19.27	16.93
Abok	Kesehatan	0.32	0.40	13.10	11.95	28.23	28.5
	Jatisampay	0.51	0.64	28.15	26.65	31.09	33.6
	KH. Abdul Halim 8	0.59	0.57	45.52	24.00	10.01	7.03
	KH. Abdul Halim 7	0.49	0.47	35.96	24.36	8.44	3.53
Mean		0.48	0.52	30.68	21.74	19.44	18.17
Tugu Kecap	Tonjong	0.49	0.66	48.87	49.27	20.95	26.93
	KH. Abdul Halim 9	0.54	0.47	48.12	32.80	16.9	9.72
	KH. Abdul Halim 8	0.63	0.54	55.44	26.84	18.61	7.99
Mean		0.55	0.56	50.81	36.30	18.82	14.88

During the afternoon peak hours shown in Table 6, the coordination of intersections using Transyt software aimed to synchronize signal cycles continued to show varying impacts on intersection performance: at Mambo market intersection, along Pertanian Road, the degree of saturation improved marginally from 0.40 to 0.52 after coordination. Queue lengths

decreased slightly from 27.40 meters to 25.60 meters, while delays per passenger car unit (pcu) increased from 20.89 seconds to 23.43 seconds. Abok intersection and on Kesehatan Road, the degree of saturation increased from 0.32 to 0.40 post-coordination. Queue lengths decreased from 13.10 meters to 11.95 meters, yet delays per pcu remained relatively stable, changing from 28.23 seconds to 28.5 seconds. Tugu Kecap intersection and Tonjong Road saw a degree of saturation rise from 0.49 to 0.66 following coordination. Queue lengths increased slightly from 48.87 meters to 49.27 meters, and delays per pcu rose from 20.95 seconds to 26.93 seconds. The afternoon coordination efforts generally resulted in improved saturation levels at intersections, with varied impacts on queue lengths and delays, highlighting the complex adjustments needed to optimize traffic flow during peak hours.

Detailed analysis of the impact of signal coordination on the performance of three major intersections during the afternoon peak hour using Transyt software. Variations in performance results after the implementation of coordination highlight that despite some performance improvements, such as reduced queue lengths at some locations, increased levels of saturation and delays still occur, especially at the Tugu Kecap intersection. Signal coordination does not always produce uniform improvements at each location depending on different traffic characteristics and intersection conditions, for example at the Mambo market intersection, despite the reduced queue lengths there is an increase in delay time per pcu, indicating that signal coordination needs further adjustment to mitigate negative impacts such as increased delay times. Furthermore, the results from the Abok intersection, which show stability in delay times despite reduced queue lengths and increased levels of saturation at Tugu Kecap, underscore the complexity of traffic management in areas with adjacent intersections. Traffic signal synchronization can have varying results based on the specific situation at each intersection, which is important to consider when designing more efficient traffic management strategies [22]. This analysis plays an important role in highlighting the challenges of signal coordination and the need for further evaluation to maximize traffic efficiency during peak periods.

Table 7. Comparison of Existing and Transyt Performance during Evening Peak Hours

Evening Peak Hours							
Intersection Name	Road Name	Degree of Saturation		Queue Length (m)		Delay (sec/pcu)	
		Exist	Coord	Exist	Exist	Coord	Exist
Simpang Pasar Mambo	Pertanian	0.55	0.59	41.35	36.60	23.63	22.48
	Babakan	0.58	0.62	48.80	43.35	24.17	23.08
	KH. Abdul Halim 7	0.65	0.64	51.16	42.00	19.19	15.84
	KH. Abdul Halim 6	0.61	0.60	50.36	41.16	18.21	14.98
Mean		0.60	0.61	47.92	40.78	21.30	19.10
Simpang Abok	Kesehatan	0.41	0.54	17.80	17.70	29.82	34.33
	Jatisampay	0.37	0.50	19.30	19.15	28.65	31.86
	KH. Abdul Halim 8	0.56	0.52	41.16	32.84	9.39	6.69
	KH. Abdul Halim 7	0.70	0.65	66.56	47.20	11.85	6.20

Evening Peak Hours							
Intersection Name	Road Name	Degree of Saturation		Queue Length (m)		Delay (sec/pcu)	
		Exist	Coord	Exist	Exist	Coord	Exist
Mean		0.51	0.55	36.21	29.22	19.93	19.77
Simpang Tugu Kecap	Tonjong	0.59	0.67	61.80	60.07	22.83	25.43
	KH. Abdul Halim 9	0.60	0.56	55.44	43.80	18.01	13.3
	KH. Abdul Halim 8	0.68	0.63	63.88	36.24	20	11.60
Mean		0.62	0.62	60.37	46.70	20.28	16.78

During the evening peak hours, the coordination of intersections using Transyt software aimed to synchronize signal cycles continued to show varied impacts on intersection performance included at Mambo market intersection, along Pertanian Road, the degree of saturation increased from 0.55 to 0.59 after coordination shown in Table 7. Queue lengths decreased from 41.35 meters to 36.60 meters. while delays per passenger car unit (pcu) decreased from 23.63 seconds to 22.48 seconds. Abok intersection. on Kesehatan Road. the degree of saturation increased from 0.41 to 0.54 post-coordination. Queue lengths remained nearly unchanged. decreasing slightly from 17.80 meters to 17.70 meters. Delays per pcu increased slightly from 29.82 seconds to 34.33 seconds. Tugu Kecap intersection. Tonjong Road saw a degree of saturation rise from 0.59 to 0.67 following coordination. Queue lengths increased slightly from 61.80 meters to 60.07 meters and delays per pcu rose from 22.83 seconds to 25.43 seconds. The evening coordination efforts generally resulted in improved saturation levels at intersections. with varied impacts on queue lengths and delays. reflecting the dynamic nature of traffic management during peak hours.

The importance of this study lies in its attempt to analyze signal coordination at three major intersections using Transyt 14.1 software. which aims to improve traffic efficiency during peak hours. especially in the afternoon. This study is relevant to the research objectives because it focuses on optimizing traffic signals to align signal cycles between three intersections (Pasar Mambo Intersection, Abok Intersection, and Tugu Kecap Intersection). which are critical nodes in the busy road network in Majalengka. This coordination plays an important role in reducing vehicle queues and delays often experienced by drivers, which is the main purpose of using Transyt. However, the results of the study indicate that although there are improvements in several intersection performance parameters such as decreasing queue lengths and delays at some intersections (such as Mambo market intersection), there are also challenges, such as increasing levels of saturation at other intersections. The variation in impacts seen after implementing signal coordination during the afternoon peak hour reflects the complexity of traffic management, where not all intersections experience significant improvements uniformly. For example, the Mambo Market intersection shows a decrease in saturation and delay, while the Abok and Tugu Kecap intersections experience an increase in saturation and delay, although the queue length is slightly reduced. This shows that signal cycle synchronization has a positive impact, but the results can vary from intersection to intersection depending on unique traffic conditions. This study is important because it provides an in-depth understanding of how signal coordination can be optimized with Transyt software, but also highlights the need for more adaptive and specific strategies for each intersection to achieve maximum results. Thus, the results of this study not only support the main objective of signal coordination analysis but also provide a basis for more

informed decision-making in traffic management in areas with adjacent intersections, especially during critical peak hours.

4 Conclusion

Based on results of the study to analyze traffic signal coordination at three intersections in Majalengka Regency using Transyt 14.1 software where after signal coordination was carried out at the Mambo, Abok, and Tugu Kecap market intersections. There was an increase in performance in several aspects although not evenly distributed at all intersections. The decrease in queue length at the Mambo and Abok market intersections shows that signal coordination has succeeded in reducing the volume of vehicles waiting at several points, especially during the morning and evening rush hours. This proves that signal coordination can help facilitate smoother traffic flow, especially in high traffic conditions. The degree of saturation which is an indicator of traffic load on road capacity was able to increase at several intersections after signal coordination. For example, at Tugu Kecap, the degree of saturation increased from 0.49 to 0.66, indicating that even though the signal cycle has been optimized, the intersection still experiences significant traffic pressure. This highlights that signal coordination alone is not enough to overcome traffic problems at intersections that are already saturated without further intervention, such as increasing road capacity or other traffic engineering. However, the decrease in delay time at several intersections shows significant optimization potential to reduce vehicle waiting time at intersections. Transyt 14.1 software proved effective in synchronizing signal cycles at the three intersections studied. The success rate of coordination between the first and second intersections reached 100%, while between the second and third intersections it reached 77%. This shows that signal coordination produced by Transyt is able to improve overall traffic flow despite differences in the level of effectiveness at each intersection. Transyt provides a signal cycle optimization solution that reduces queues and delays, although challenges remain related to the increasing degree of saturation at some locations. The impact of signal coordination varies from intersection to intersection, depending on the specific traffic conditions at each location. The reduction in queue lengths and delays at the Mambo and Abok market intersections indicates that signal coordination can be effective in reducing congestion at certain intersections. However, the increase in the degree of saturation and delay at Tugu Kecap indicates that the performance improvement is not uniform, and a more comprehensive approach is needed to optimize traffic flow at all intersections.

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References

1. Q. Yang and X. Fu. An extended queueing model for vehicles at signalized intersections considering the platoon correlated arrivals. *Phys. A Stat. Mech. its Appl.* **635** (129483). (2024). doi: 10.1016/j.physa.2023.129483.
2. A. Maulana, S. Sarjana, and T. R. Prastya. Traffic Performance Analysis in The Traditional Market Area. in *E3S Web of Conferences*. **576** (05003). (2024). doi: 10.1051/e3sconf/202457605003.
3. J. Zhang, H. Li, Y. Ma, C. Zhang, L. Qin, and N. Chen. Modeling and optimization of platooning behaviors in fixed-time signalized intersection entrance areas. *Simul. Model. Pract. Theory*. **132** (102900). (2024). doi: 10.1016/j.simpat.2024.102900.

4. Y. Wang, C. Lin, B. Zhao, B. Gong, and H. Liu. Trajectory-based vehicle emission evaluation for signalized intersection using roadside LiDAR data. *J. Clean. Prod.*, **440** (140971). (2024). doi: 10.1016/j.jclepro.2024.140971.
5. R. I. Salas and S. Sarjana. Peningkatan Kinerja Jaringan Jalan Alternatif Melalui Efektivitas Jalan Lingkar. *J. Transp. Multimoda*, **21** (2). (2024). doi: 10.25104/mtm.v21i2.2277.
6. S. Sarjana, M. A. A. Najib, and J. Hanun. Digitalization of supply chain technology to encourage green supply chain. in *E3S Web of Conferences*, **577** (03005). (2024). doi: 10.1051/e3sconf/202457703005.
7. S. Sarjana. Smart City in Supporting Sustainable Cities. in *10th International Conference on Information Technology, Computer, and Electrical Engineering*. (2023). doi: 10.1109/ICITACEE58587.2023.10277619.
8. M. Amoah, A. B. Marful, S. A. Takyi, O. Amponsah, and M. Poku-Boansi. Space use in Central Business District of emerging economies: Regulation or rationale?. *Urban Gov.*, **3** (4). (2023). doi: 10.1016/j.ugj.2023.08.002.
9. W. Yu, T. Ai, and S. Shao. The analysis and delimitation of Central Business District using network kernel density estimation. *J. Transp. Geogr.*, **45**. (2015). doi: 10.1016/j.jtrangeo.2015.04.008.
10. H. Fachri and S. Sarjana. Performance evaluation through the effectiveness of resources and reputation: A case study of hospitals in Indonesia. *Probl. Perspect. Manag.*, **20** (3). (2022). doi: 10.21511/ppm.20(3).2022.06.
11. S. Sarjana. Analisis Bibliometrik Transit-Oriented Development. *War. Penelit. Perhub.*, **34** (2). (2022). doi: 10.25104/warlit.v34i2.1816.
12. L. Wang, S. Zhang, G. Szűcs, and Y. Wang. Identifying the critical nodes in multi-modal transportation network with a traffic demand-based computational method. *Reliab. Eng. Syst. Saf.*, **244** (109956). (2024). doi: 10.1016/j.res.2024.109956.
13. F. Tampubolon, W. Seno, and S. Sarjana. Analysis of lashing gear in ship loading spaces to meet safety transportation. *E3S Web Conf.*, **519**. (2024). doi: 10.1051/e3sconf/202451903024.
14. Y. Jiang, Y. Ma, G. Xiao, Y. Wu, B. Ran, and Z. Yao. A capacity model of signalized intersection with dedicated lanes for automated vehicles Author. *Transp. Lett.*, **2236852**. (2024). doi: 10.1080/19427867.2023.2236852.
15. S. Sarjana. Green transportation : Development opportunities in support of sustainable transportation. in *E3S Web of Conferences*. (2023). **429** (03003). doi: 10.1051/e3sconf/202342903003.
16. N. T. Ratrout and I. Reza. Comparison of optimal signal plans by synchro & TRANSYT-7F using PARAMICS-A case study. *Procedia Comput. Sci.*, **32**. (2014). doi: 10.1016/j.procs.2014.05.437.
17. D. C. Indrashwara and P. A. Yasa. Koordinasi Sinyal antar Simpang untuk Mengurangi Kemacetan di Jalan P.B. Sudirman Denpasar dengan Menggunakan Software TRANSYT 15. *J. Manaj. Teknol. Tek. Sipil*, **5** (2). (2022). doi: 10.30737/jurmateks.v5i2.3577.
18. E. Odhiambo. Evaluation of Signal Optimization Software. **19492**. *KTH Transport and Geoinformation Technology*. (2019).
19. H. Ceylan and Y. S. Murat. Performance Comparison of TRANSYT and SIDRA with Genetic Algorithm and Fuzzy Logic in Signalized Intersections. *J. Res.*. (2019).
20. I. W. Suteja and N. M. Y. Cahyani. Aplikasi Program Transyt Pada Simpang Di Bawah

- Jenuh Studi Kasus: Simpang Airlangga dan Simpang Udayana. *Dimens. Tek. SIPIL.* **4** (1). (2002).
21. A. Widodo, W. P. Maryunani, and D. S. A. Yuwana. Evaluasi dan Pengaturan Simpang Bersinyal Terkoordinasi Dengan Metode MKJI 1997 Dan Transyt 14.1 di Jalan Brigjen Katamso Kota Parakan. *Word Civ. Environ. Eng.* **01**. (2018).
 22. E. P. Raharjo, S. Sarjana, and M. Safitri. Transportation infrastructure planning in supporting disaster mitigation: Case study in Mount Gamalama. *Jamba J. Disaster Risk Stud.* **14** (1). (2022). doi: 10.4102/jamba.v14i1.1123.