Jurnal Inovasi Teknologi dan Rekayasa
Vol. 10, No. 2, July-December 2025, pp. 516-522
ISSN: 2581-1274

Traffic Congestion Reduction Strategy Through Total Waiting Time Optimization with Compatible Graph Application (Case Study: Air Putih Intersection, Samarinda City)

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ARTICLE INFO

Article history:
Published
December 31, 2025

Keywords:
Compatible Graph
Four-way Intersection
Traffic
Waiting Time Optimization

ABSTRACT

The imbalance between vehicle growth and road capacity increases traffic density at intersections, leading to congestion. This issue can be addressed through various strategies, including infrastructure development, traffic flow management, and traffic signal control. This study aims to optimize traffic signal timing by minimizing the total vehicle waiting time as a strategy to alleviate congestion. The congestion reduction strategy is implemented by grouping compatible traffic flows into the same signal phase and calculating their optimal durations. The research was conducted at the Air Putih Intersection in Samarinda City on Monday, May 5, 2025, during peak traffic hours. Graph theory particularly the concept of compatible graphs is applied by identifying traffic flows that can proceed simultaneously without conflict. These compatible flows are then modeled into a compatible graph structure to determine the optimal vehicle waiting time durations. These groupings were modeled using compatible graphs to determine the optimal vehicle waiting durations. The results show that total vehicle waiting time can be reduced from 522 seconds to 120 seconds during the morning peak, from 507 seconds to 120 seconds at midday, and from 552 seconds to 120 seconds in the evening. This approach has proven effective in designing a more efficient and adaptive traffic signal control system that responds to actual traffic conditions.

I. Introduction

Traffic congestion at intersections is one of the most common problems faced in urban transportation systems. As vehicle volumes increase while road capacity remains relatively constant, intersections become critical points where delays accumulate. This condition is clearly observed at the Air Putih Four-Way Intersection in Samarinda City, where high vehicle density during peak hours leads to long queues and excessive waiting times. Several approaches are commonly used to reduce congestion, such as road widening, traffic diversion, and improvement of traffic signal control systems [6]. Among these, optimizing traffic light timing is the most practical and cost-effective solution because it does not require major infrastructure changes.

Traffic lights at intersections serve several purposes, including preventing accidents and congestion caused by disparities in traffic flow, and facilitating the safe crossing of pedestrians. The purpose of traffic lights is crucial, so it is important to pay close attention to traffic light control in order to avoid traffic jams and accidents [12].

Mathematics is divided into two, namely pure mathematics and applied mathematics. Applied mathematics can be used outside the field of mathematics [8]. Mathematics is a very important tool in modeling various phenomena and problems in the real world. In many fields, mathematics is used to find optimal solutions in decision-making processes, one of which is graph theory. According to [2], graph theory is a branch of discrete mathematics that studies structures consisting of points and edges

DOI: 10.31572/inotera.Vol10.Iss2.2025.ID576 http://inotera.poltas.ac.id | inotera@poltas.ac.id

that connect them. The application of graph theory has proven to be effective in various fields, such as computers, transportation systems, and traffic light control.

Graph theory provides a mathematical approach to model the movement of vehicles at intersections. In particular, compatible graph theory plays a significant role in identifying traffic movements that can proceed simultaneously without conflict. By grouping compatible flows into the same signal phase, traffic performance can be improved and unnecessary delays can be minimized. Therefore, compatible graphs have strong potential for reducing congestion in intersections with complex flow interactions [3].

This study focuses on the application of compatible graph theory at the Air Putih intersection in Samarinda City, with the aim of constructing a compatible graph that represents the Air Putih intersection, determining the optimal total waiting time based on traffic flow data, and identifying effective congestion reduction strategies using compatible flow grouping. Through this approach, mathematical optimization serves as a tool to improve decision-making in real-world traffic engineering applications. Several studies conducted by [3], [4], [5], [7] and [10] use Compatible Graphs to solve traffic flow management problems and determine the optimal total waiting time at various intersections.

II. Method

This study was conducted at the Air Putih intersection in Samarinda City on May 5, 2025. The study period covered three peak hours, namely morning (06:45–07:45), noon (12:00–13:00), and afternoon (16:00–17:00). The data obtained included the layout of the intersection, traffic flow through the intersection, and daily traffic light duration data. Observations were made directly in the field and data was collected from the Samarinda Transportation Agency. The stages of data processing with the application of compatible graphs are as follows:

A. Intersection Modeling

The first step was mapping the Air Putih intersection into a mathematical model. Each vehicle movement direction straight, right-turn, and left-turn was represented as a traffic flow. All flows were coded and analyzed based on their physical interactions and potential conflict points [11]. There are various types of traffic light control, where the selection of this method is highly dependent on the situation and conditions of the intersection, such as traffic light duration, intersection geometry, and other factors [9].

B. Compatible Graph Construction

A compatibility graph is created with each node representing a traffic flow, and the edges connecting two nodes representing compatibility relationships between flows that can move simultaneously without conflict [1].

C. Assumptions

- The first assumption used in this study is that all traffic flows follow traffic light rules, including left turns.
- The second assumption used in this study is that all traffic flows follow traffic light rules, except for left turns.

D. Analysis Steps

- Determining Complete Subgraphs
  From the compatible graph, complete subgraphs (cliques) are identified.
  Each complete subgraph represents one phase of the traffic flow, in which all flows within the subgraph can move together [3]. A subgraph in which every two vertices are adjacent to each other is called a clique. In other words, a clique is a complete subgraph [8]. Assuming one cycle lasts 60 seconds, the complete subgraphs can be visualized using a clock diagram.

- Waiting Time Calculation
  The total waiting time for all vehicles is calculated by multiplying the duration of each flow by the number of nodes in the entire complete subgraph [3]. The main goal is to find the combination of red light durations that results in the lowest total waiting time.

III. Results and Discussion

The analysis in this study uses two assumptions. The first assumption is that all traffic flows follow traffic light rules. The second assumption is that left-turning traffic does not follow traffic light rules. The analysis for each assumption includes flow compatibility, compatible graphs, complete subgraphs, visualization with clock diagrams, and total waiting time calculations. Finally, the discussion compares the actual waiting time with the optimized results using the application of compatible graphs.

A. Assumption 1: All Traffic Follows Traffic Light Rules

The first step in constructing the optimization model is identifying all traffic flows at the Air Putih Four-Way Intersection. The traffic flow diagram at the Air Putih intersection can be seen in the following image.

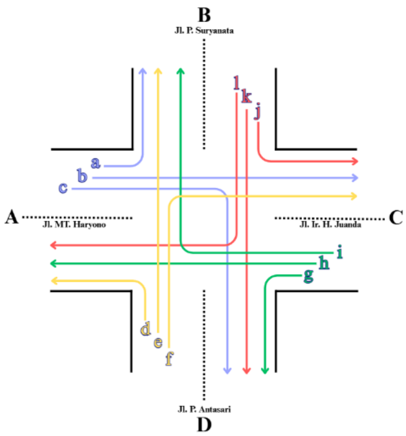

Fig. 1. Traffic Flow Assumption 1

Based on the traffic flow diagram in Figure 1, it is shown that all traffic can move through intersections and any conflict points that may arise. Traffic flows compatibility is as follows:

1. Flows a is compatible with all flows
2. Flows b is compatible with flows a, c, d, f, g, h, j
3. Flows c is compatible with flows a, b, d, g, j, k
4. Flows d is compatible with all flows
5. Flows e is compatible with flows a, d, f, g, i, j, k
6. Flows f is compatible with flows a, b, d, e, g, j
7. Flows g is compatible with all flows
8. Flows h is compatible with flows a, b, d, g, i, j, l
9. Flows i is compatible with flows a, d, e, g, h, j
10. Flows j is compatible with all flows
11. Flows k is compatible with flows a, c, d, e, g, j, l
12. Flows l is compatible with flows a, d, g, h, j, k

Based on the traffic flow in Figure 1, a compatible graph was obtained that shows the flow pattern in accordance with traffic light rules as follows.

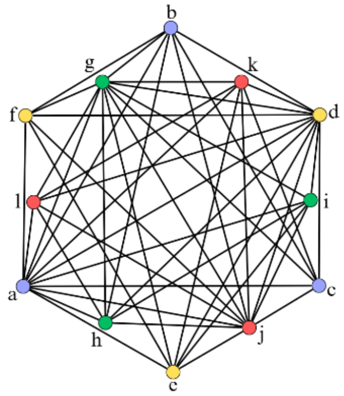

Fig. 2. Compatible Graph Assumption 1

Based on Figure 2, four complete subgraphs containing three points, namely $abc, def, ghi,$ and jkl, were obtained. These main complete subgraphs were selected based on the compatible flows in each phase of the road at the intersection. The first assumption complete subgraph can be seen in Figure 3.

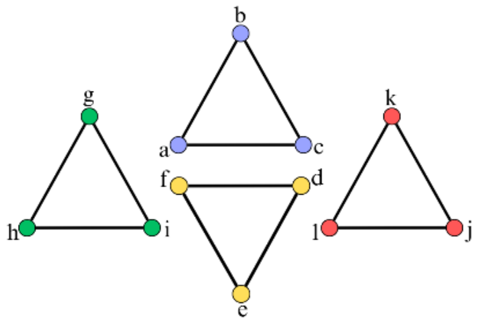

Fig. 3. Complete Subgraph Assumption 1

Assuming that one traffic light cycle lasts 60 seconds, the solution used is to divide 60 seconds into 4 complete subgraphs, so that each flow can run for 15 seconds per cycle. The division of the duration is then visualized in the form of a cycle diagram as shown in Figure 4.

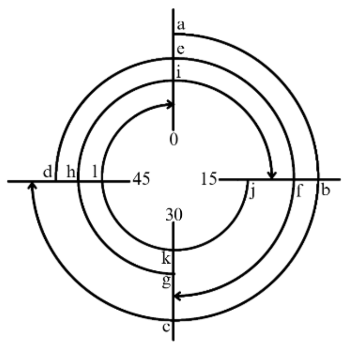

Fig. 4. Cycle Diagram Assumption 1

Since each complete subgraph consists of 3 points, the flow from each path runs for 3×15 seconds $= 45$ seconds. Since there are 12 points in the entire subgraph, the total waiting time is 12×15 seconds $= 180$ seconds.

B. Assumption that Left Turns Do Not Follow Traffic Light Rules

The assumption that all left-turning traffic does not follow traffic light rules means that all left-turning traffic can proceed at any time without regard to the traffic light signal status. The diagram for the assumption that all left-turning traffic does not follow traffic light rules can be seen in Figure 5.

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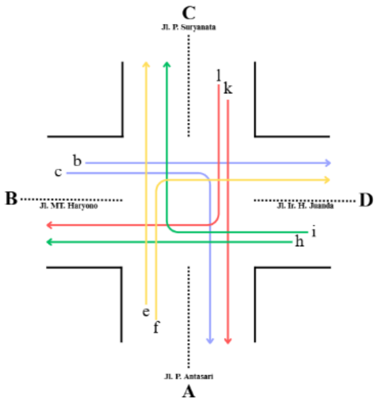

Fig. 5. Traffic Flow Assumption 2

Based on the traffic flow diagram in Figure 5, it can be seen that the traffic pattern at the intersection eliminates the pattern of left-turn traffic. Thus, a graph compatible with the assumption that left turns do not follow traffic light rules is obtained as follows.

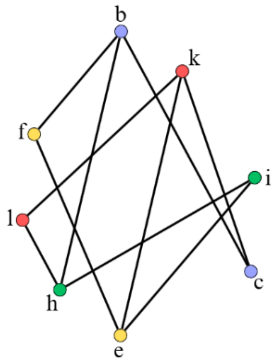

Fig. 6. Compatible Graph Assumption 2

By eliminating currents that do not affect the duration of movement, a complete subgraph is obtained that shows the corresponding relationships between currents as follows.

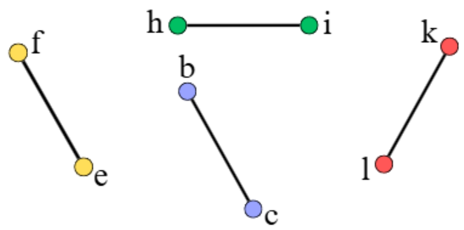

Fig. 7. Complete Subgraph Assumption 2

From Figure 7, four complete subgraphs containing two points, namely $bc, ef, hi,$ and kl, are obtained. These main complete subgraphs are selected based on the compatible flows in each phase of the road at the intersection. Assuming that one traffic light cycle lasts 60 seconds, the solution used is to divide 60 seconds into 4 complete subgraphs, so that each flow can run for 15 seconds per cycle. The division of the duration is then visualized in the form of a clock diagram as shown in Figure 8.

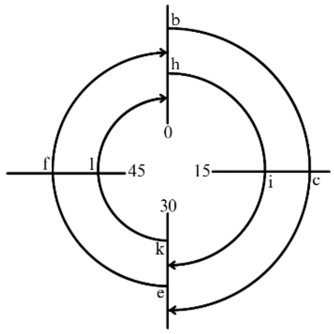

Fig. 8. Cycle Diagram Assumption 2

Since each complete subgraph consists of 2 points, the flow of each lane runs for 2 × 15 seconds = 30 seconds. Since there are 8 points in the entire subgraph, the total waiting time is 8 × 15 seconds = 120 seconds. The second assumption, with left-turn traffic not following traffic light rules, yields an optimal total waiting time of 120 seconds. A comparison of the duration of the red light and the total waiting time in the field with the duration of the red light and the total waiting time using a compatible graph can be seen in Table 1.

Table 1. Comparison of Red Light Duration and Total Waiting Time

Time	Comparison of Red Light Duration and Total Waiting Time				
	Phase	**Red Light at the Intersection (seconds)**	**Waiting Time at the Intersection (seconds)**	**Red Light with Compatible Graph (seconds)**	**Waiting Time with Compatible Graph (seconds)**
06.45-07.45 WITA	A	123	522	28	120
	B	128		29	
	C	148		34	
	D	123		28	
12.00-13.00 WITA	A	123	507	29	120
	B	123		29	
	C	143		34	
	D	118		28	
16.00-17.00 WITA	A	133	552	29	120
	B	133		29	
	C	153		33	
	D	133		29	

IV. Conclusion

The conclusion of this study based on two different assumptions is that the first assumption, where left turns follow traffic light rules, results in a total waiting time of 180 seconds, while the second assumption, where left turns do not follow traffic light rules, results in 120 seconds. Both assumptions show that the compatible graph approach can significantly reduce waiting time compared to field data with left turns not following traffic light rules, which is 552, 522, and 507 seconds. With the same assumptions as those used in the field, the optimal total waiting time is 120 seconds. Overall, the compatible graph approach provides a mathematically sound and operationally effective strategy for improving traffic light performance. The findings confirm that applying this technique at congested intersections can substantially reduce delays and support better traffic management decisions.

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Acknowledgment

The author thanks the supervisors, examiners, and the Samarinda Transportation Agency for their support and data access. The author also expresses gratitude to family and peers for their unwavering support and motivation during the completion of this study.

References

[1] Buhaerah, dkk. (2022). Teori Graf dan Aplikasinya. Makassar: LSQ Makassar

[2] Deo, Narsingh, Graph Theory with Applications to Engineering and Computer Science. New York : Dover Publications, 2016.

[3] Farida, dkk, "Pemodelan Arus Lalu Lintas dan Waktu Tunggu Total Optimal di Persimpangan Jl. Jemur Andayani Ahmad Yani Sebagai Upaya Mengurangi Kemacetan". *Barekeng* : *Jurnal Ilmu Matematika dan Terapan*, vol. 14, pp. 387–396, 2020.

[4] Mentari, dkk, "Pemodelan matematika arus lalu lintas dan solusi waktu tunggu optimal di persimpangan jl. Padayungan, Kota Tasikmalaya". *Humantech : Jurnal Ilmiah Multidisiplin Indonesia*. vol. 4, pp. 1–8, 2024.

[5] Monalisa, dkk, "Penerapan Graf Kompatible Pada Durasi Lampu Lalu Lintas di Simpang Empat Andalas Kota Padang". *IJESPG Journal*. vol. 1, 2023.

[6] Natalia N.E, M. Saleh Soeaidy, Heru Ribawanto, "Kajian Dampak Pengembangan Pembangunan Kota Malang Terhadap Kemacetan Lalu Lintas (Studi pada Dinas Perhubungan Kota Malang)". *Jurnal Administrasi Publik (JAP*), vol. 2, pp. 129-133, 2015.

[7] Nisa, Ayuk K., dan Lilik Muzdalifah, "Optimasi Waktu Tunggu Lalu Lintas dengan Menggunakan Graf Kompatibel sebagai Upaya Mengurangi Kemacetan." *Mathvision*, vol. 3, pp. 1-5, 2021.

[8] Rahadi, Andi P, "Penjadwalan Mata Kuliah Menggunakan Pewarnaan Graf Algoritma Largest First". *Jurnal Padegogik*, vol. 2, pp. 3-4, 2019.

[9] Rosi, dkk, "Application of Integer Linear Programming in the Optimization of Profit Production of Processed Glutinous Rice in the Household Industry of Long Pejeng Village". *Jurnal Inovasi Teknologi dan Rekayasa*, vol. 10, pp. 212-221, 2025.

[10] Sarbaini, S, "Perbandingan penerapan graf kompatibel dengan realita dilapangan dalam pengaturan lampu lalu lintas persimpangan bandara pekanbaru". *MAp (Mathematics and Applications) Journal*, vol. 4, pp. 85–93, 2022.

[11] Wijayanti, H. & Virgantari, F, "Model Waktu Tunggu Kendaraan Di Persimpangan Lalu Lintas Menggunakan Distribusi Compound Poisson Arrivals". *Interval J*, vol. 1, pp. 18–30. 2021.

[12] Yaqin, dkk, "Penerapan Teori Graf pada Pengaturan Lampu Lalu Lintas di Perempatan Alun Alun Kota Bojonegoro". *Buana Matematika: Jurnal Ilmiah Matematika dan Pendidikan Matematika*, vol.13, 2023.