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https://doi.org/10.5109/7326992

出版情報：Evergreen. 11 (4), pp.3595-3605, 2024-12. Interdisciplinary Graduate School of Engineering Sciences, Kyushu University, Japan
バージョン：

Traffic Congestion Management in South Tangerang City as an Effort to Conserve Energy in the Transportation Sector

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(Received May 13, 2024; Revised July 19, 2024; Accepted November 26, 2024).

Abstract: Traffic congestion management is crucial in urban areas due to its impact on air quality and energy consumption. This research aims to demonstrate that traffic engineering interventions can reduce congestion, lower fuel consumption, and decrease emissions, using empirical evidence from case study in Puspiptek Serpong (central hub in South Tangerang). Traffic modeling results showed that reducing traffic conflict points decreases average delays by 3.1% (from 516.65 to 599.72 seconds/vehicle), increases speed by 9.2% (from 26.01 to 28.41 km/h), and decreases fuel consumption by 2.69% (from 143.73 to 139.87 liters/1000km) Lower vehicle speeds contribute to the higher fuel consumption and emissions.

Keywords: congestion; fuel consumption; traffic engineering; delay; speed

1. Introduction

Indonesia, which is known for its richness in natural resources, faces a significant challenge in its excessive consumption of fossil energy. Among the various contributing sectors, transportation stands out as a significant problem, leading to both energy wastage and Greenhouse Gas (GHG) emission[1]. Data indicates that the greatest volume of greenhouse gas emissions originates not only from industrial activities but also from the transportation sector and residential households[2]. Inefficiency in energy consumption primarily comes from the prevalent use of fossil fuels in the transportation sector, accelerated by increasing dependence on private cars. This surge in private vehicle usage, coupled with inadequate public transportation options, has resulted in widespread traffic congestion across Indonesian cities and it harms many aspects. The aspects that can be negatively impacted are economic aspects, environmental aspects, etc. From an economic standpoint, traffic congestion causes delays in the production processes and the distribution of goods, affecting the local economy. This is particularly significant in Indonesia, where land transportation dominates the distribution of goods and logistics[3]. Furthermore, congestion results from time losses due to prolonged commutes, translating into increased vehicle operational costs[4]. Whereas from the environmental aspect, it contributes to increased carbon emissions[5], reduced air quality and noise[2,6–11]. The previous study also conveyed, that traffic congestion also increased fuel consumption and emissions raising[12]. Vehicle honking appears to be the most common cause of noise in towns[13]. The release of pollutants from transportation, such as Greenhouse Gases (GHG) and particulate matter, adds to both air pollution and the issue of climate change. Both noise and air pollution can lead to environmental degradation and have economic impacts[14].

The increased usage of fossil fuel vehicles leads to higher levels of air and noise pollution. A strategy for diversifying energy sources is required to decrease dependence on fossil fuels[15]. One potential solution for reducing air and noise pollution is the adoption of environmentally friendly vehicles, particularly electric vehicles. Electric vehicles that do not use combustion engines are a solution to air pollution[16]. Several manufacturers have introduced electric motorized private vehicles, and by 2022, there were 332 charging stations established in Indonesia[17]. The use of private vehicles, both powered by fossil fuel and electricity-based, will increase. With the increasing use of private cars, congestion will continue to increase if not handled properly. Energy wastage occurs because energy consumption in the form of fossil fuel, electricity, and other renewable energy will be higher, roads are more crowded and vehicle engines do not operate optimally at low speeds.

The correlation among traffic volume, speed, and density, as outlined in Greenshield's traffic flow model, suggests that speed gradually decreases as traffic volume increases[18]. When traffic flow approaches the capacity of a road, the decrease in speed is greater. When the capacity is reached, the maximum flow is obtained and if the condition is forced to get a flow exceeding capacity (forced flow), a smaller flow with a lower speed will be formed[19]. When the maximum density (hour density) occurs, the speed of the vehicle is equal to 0. This condition occurs during total congestion where the vehicle cannot move at all for a certain time interval. In such circumstances, there will be increased energy consumption and higher vehicle operating costs (VOC). Vehicle operating costs are composed of two elements: fixed and non-fixed costs. Fixed costs are expenses that remain constant and do not fluctuate (remain despite changes in the volume of service production to a certain level), while non-fixed costs fluctuate in response to alterations in the volume of service production[20]. Energy consumption in the form of fuel and other renewable energy as one of the components in the calculation of vehicle operating costs (VOC), will increase. This indicates that the energy wastage resulting from increased energy consumption in vehicles due to congestion will directly impact vehicle operating costs (VOC)[21,22].

The Puspiptek Serpong as one of the centers of activity in South Tangerang City is an area that has a diversity of land use functions with a fairly high population density. The Puspiptek Serpong area has residential, office, school, commercial, industrial, and tourist areas. Therefore, trip generation and attraction that occur in this area are very high. People leaving and heading to Puspiptek have a variety of travel purposes. This causes the emergence of many critical points of congestion with a long duration of congestion. For this reason, in-depth research is needed to identify the causes of congestion and alternative solutions to provide a better transportation system that is acceptable to users/travelers.

The spread of traffic congestion in a road network is influenced by several factors, including the network's topology, traffic distribution, and driver behavior[23]. Congestion can be caused by an imbalance between the high volume of vehicles and insufficient road capacity. This condition is typically observed in urban areas, especially during peak hours[24]. Another contributing factor is the disorderly behavior of travelers, the ineffective implementation of transportation control and regulation policies with low public acceptance[25], the low utilization of mass public transport by citizens[26], and also the potential mismatch between public transport system services and traveler preferences[27].

Congestion management solutions can be categorized into short, medium, and long-term solutions. Traffic management is included in short-term solutions. One example of a short-term solution is the optimization of traffic signal timing. Stevanovic et al. (2009) researched how optimizing traffic signal timing affects traffic performance and fuel consumption[28]. Medium-term solutions include travel demand management. One example of a medium-term solution is the implementation of daily predictive tolls, as done by Vosough et al. (2020). The application of daily predictive tolls for various vehicle classes can have an impact on reducing air pollution. With the implementation of these tools, people are more likely to switch to public transportation, thus reducing the use of private vehicles[29]. One of the long-term solutions is the provision of public transport facilities and infrastructure. Improvements in public transport development can positively affect the increase in public transport usage. People will be more inclined to switch to using public transportation, resulting in a decrease in vehicle emissions caused by the use of private vehicles in urban areas[30].

This research will focus on short-term solutions by giving traffic management recommendations. Traffic management involves controlling the supply and demand of the current road infrastructure to achieve specific objectives without the need for new infrastructure. One of the methods for implementing traffic management involves conducting traffic engineering, which includes altering the traffic flow formation, changing it from two-way to one-way, or vice versa. Determining the appropriate traffic management for a road network can be achieved by initially identifying the traffic conflict points within the existing network. The identification of traffic conflicts can be utilized to analyze road improvement projects, such as enhancements in intersection design and improvements in traffic management at intersections[31].

The objective of this research is to address and mitigate the negative impacts of traffic congestion in urban areas. Traffic congestion not only leads to time wastage but also increases vehicle operating costs due to energy wastage. This research aims to provide traffic engineering recommendations to alleviate the congestion, thereby improving traffic flow and reducing associated costs and environmental impacts. Traffic congestion is a pervasive issue in urban environments, leading to various negative impacts that affect both individuals and the community as a whole. Traffic congestion causes significant delays, resulting in considerable time wastage for commuters. By implementing the proposed traffic engineering solutions, the research seeks to reduce these delays, allowing for more efficient movement of vehicles and shorter travel times for commuters. Congestion increases vehicle operating costs due to prolonged idling and frequent stop-and-go driving, which leads to higher fuel consumption and more wear and tear on vehicles. Alleviating congestion can lower these operating costs by reducing fuel consumption and the need for frequent vehicle maintenance, ultimately leading to cost savings for drivers. Congested traffic contributes to higher emissions of pollutants and greenhouse gases, worsening air quality and contributing to climate change. By improving traffic flow and reducing congestion, the research aims to lower vehicular emissions, contributing to better air quality and a reduction in the urban area's overall environmental footprint.

The research methods include assessing the performance of the current traffic conditions, identifying key congestion points, and proposing engineering solutions such as optimizing traffic signal phase, implementing one-way traffic systems, and reducing traffic conflict points at intersections. By conducting thorough traffic modeling and simulations, the study will evaluate the effectiveness of these proposed measures in improving traffic efficiency and reducing fuel consumption and emissions. Ultimately, this research aims to contribute to the broader goals of sustainable urban mobility and energy conservation in the transportation sector.

In this research, the first step involved assessing the performance of the network in the study area where one-way system had been implemented during morning peak hours in the Puspiptek area. Next, the traffic microsimulation model of the scenario without one-way system was created to illustrate the impact of the one-way system on traffic performance within the study area. Then, the do-something condition was modeled by adjusting traffic flow directions to reduce remaining conflict points from the previously implemented one-way system. The implementation process for reducing traffic conflict points includes analyzing current traffic patterns and identifying high-conflict intersections, redesigning intersections to reduce the number of conflict points, using traffic engineering software (PTV Vissim) to simulate the changes, and gradually implementing the redesigned traffic pattern in the intersection. The expected outcome of this research is to provide recommendation for alleviating congestion and enhancing the transport system's performance in the Puspiptek Serpong area. Implementing these traffic management strategies is anticipated to improve road network performance and reduce fuel consumption. The reduction in fuel consumption indicates fuel savings, which serves as a parameter for energy conservation in the transportation sector.

2. Method

The initial phase of this research involves identifying problems or issues within the scope of the research area. A preliminary survey will be conducted to assess the current conditions, encompassing traffic conditions, observation points, and geometry of the road network. This process aims to pinpoint suitable observation locations that will facilitate effective data collection[32]. In the following phase, data collection will be conducted using traffic surveys, floating car speed surveys, cycle times, and geometric surveys. Subsequent analysis involves utilizing Vissim software to model the existing traffic conditions at the intersection and develop a new simulation model aimed at enhancing the performance of the Puspiptek Serpong area. The methodology of the study is depicted in Fig. 1.

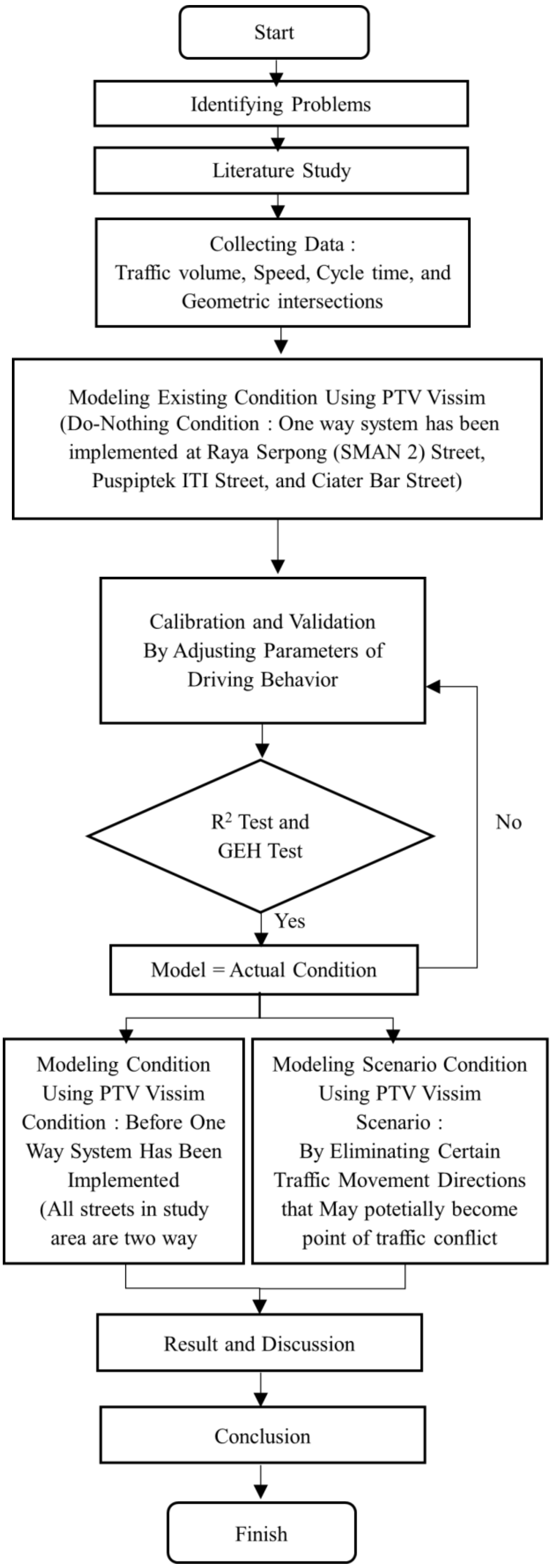

Fig. 1: Research flow diagram.

During the preparation stage (problem identification and literature review), a review of existing literature will be conducted. Various traffic management approaches explored in transportation issue studies will be examined to determine the most suitable and appropriate traffic management for implementation in this study. After completing the preparation stage, the next step is to collect data. The data needed to develop a simulation model in Vissim include geometric road data, traffic volume data, and speed.

Road geometric data, such as the width of the approach lanes, are measured using a length gauge, and the number of lanes in each approach is recorded to determine the type of intersection. Road geometric measurements are conducted using laser distance measurement tool. Data collection for road geometric is carried out on all road sections within scope of this study.

Traffic volume was gathered by conducting a traffic volume survey (traffic counting) in the study area. To describe traffic conditions at peak hours, the survey was carried out during peak hours, which was taken per 5 minutes[33]. Traffic volume data is conducted by counting the number of vehicles passing through each road section according to the direction of traffic flow. The classification of vehicles in this traffic counting survey is divided into 9 categories: passenger cars, motorcycles, small-sized freight vehicle, medium-sized freight vehicles, large-sized freight vehicles, extra large-sized freight vehicles, small-sized buses, large-sized buses, and non-motorized vehicles.

Vehicle speed survey was undertaken to ascertain the average speed of vehicles passing through the road section. Vehicle speed data can be used to calculate fuel consumption. In this study, two approaches were used to determine the vehicle's speed. The first method involves recording the speed of several random vehicles using a speed gun, while the second method entails the surveyor recording the vehicle's speed by driving it at a speed following the average speed of other vehicles in the flow. The classification of vehicles in this vehicle speed survey is divided into 4 categories: passenger cars, motorcycles, freight vehicles, buses, and non-motorized vehicles. During the data processing and simulation stage for existing condition, an analysis of the current conditions (do-nothing condition) is conducted by establishing a road network, inputting data, and executing simulations in PTV Vissim. VISSIM is microscopic flow traffic simulation software that supports multiple modes of transportation. VISSIM developed by PTV (Planning Transportation Verkehr AG) in Karlsruhe, Germany. Users of this software can model all kinds of geometric configurations or road user behavior that occurs in the transportation system. System modeling is an approach to describe the relationship between transportation infrastructure and traffic flow in the current condition[34].

After the simulation existing condition has been done, the next stage is calibration and validation model. The process of calibration and validation needs to be carried out to ensure the confidence level of the model's validity and how closely the model outputs represent the actual conditions. In this study, the calibration process involves adjusting the parameters of driving behavior to achieve the same condition between the model and the actual condition.

The validation process in this research uses two methods, including the R^2 test (determination test method) and the GEH (Geoffrey E. Havers) method. The validation process using the R^2 test is carried out based on speed data. When the determination coefficient is close to 1, the model achieves the same conditions as the actual conditions. Meanwhile, the validation process using the GEH (Geoffrey E. Havers) method is conducted based on traffic volume data. GEH (Geoffrey E. Havers) method is employed to calculate the distribution similarity between observation data and the model conditions[35]. A GEH (Geoffrey E. Havers) value less than 5.0 indicates that the model condition is capable of representing the actual conditions in the field. GEH (Geoffrey E. Havers) method formula is as follows. The symbol used in the formula are explained in the Nomenclature section.

$$\mathrm{GEH} = \sqrt{\frac{(Q_{simulated} - Q_{observed})^2}{0{,}5x(Q_{simulated} + Q_{observed})}} \qquad (1)$$

After the calibration and validation processes are completed, the performance of the road network under existing conditions can be assessed. In the current existing condition (do-nothing condition), a one-way system has been implemented during the morning peak hours. The traffic movement in the current existing condition is illustrated in Fig. 2.

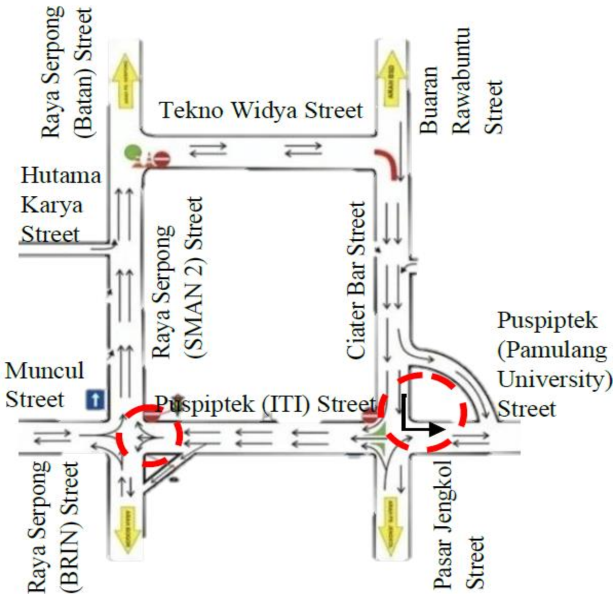

Fig. 2: Traffic movement in current existing or do nothing condition.

In next step, modelling is conducted for the traffic condition before implementing one way system in the study area, in comparison with the existing condition where one way system has been implemented. The traffic movement in the condition before implementing one way system is illustrated in Fig. 3.

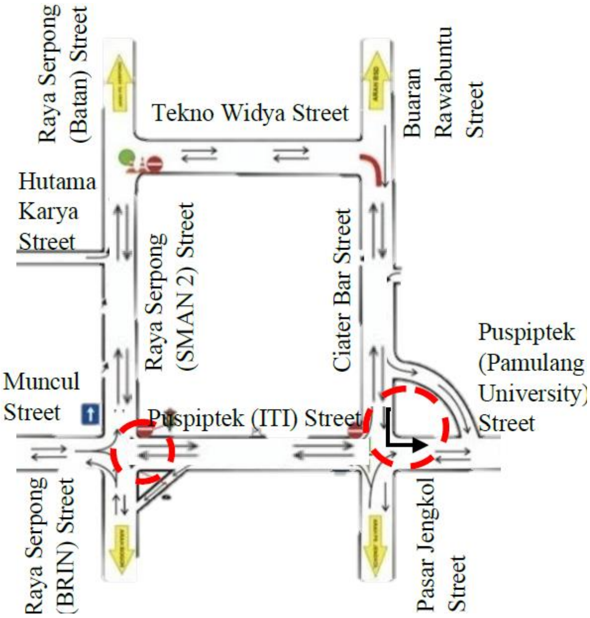

Fig. 3: Traffic movement in condition before implementing one way system.

Through the analysis of the road network's performance under existing conditions, recommendations for implementing do-something scenarios are formulated to enhance the road network's performance. The implemented scenario in this research will focus on formulating recommendations for traffic management to reduce conflict points occurring at each intersection. In the do-something scenario, traffic engineering will be implemented by eliminating certain traffic movement directions that may potentially become points of traffic conflict. The do-something scenario is depicted in Fig. 4. The eliminated movement directions are as follows:

1. The movement direction from Puspiptek (ITI) Street turning left towards Raya Serpong (BRIN) street.
2. The movement direction from Puspiptek (ITI) Street turning straight towards Muncul street.
3. The movement direction from Ciater Bar Street turning left towards Puspiptek (Pamulang University) street.
4. The movement direction from Ciater Bar Street turns straight towards Pasar Jengkol Street.

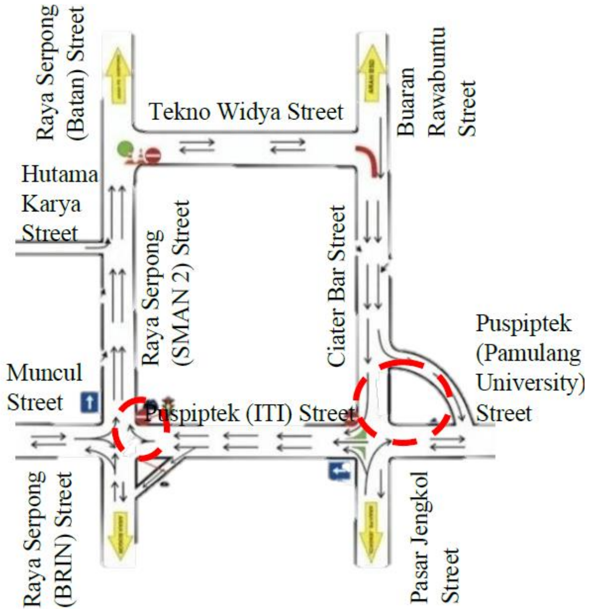

Fig. 4: Traffic movement in do something condition.

After simulating all conditions, the network/s performance is assessed. Network performance parameters, including average delay, stopped delay, average speed, and fuel consumption, are calculated. The results of the simulation from the PTV Vissim traffic model provide the average delay, stopped delay, and average speed parameter. Fuel consumption is determined using the formula developed by LAPI-ITB (Research and Industry Affiliation Agency, Bandung Institute of Technology)[36]. Fuel consumption is determined by considering correction factors, including road gradient, traffic and road surface condition, and vehicle speed which are differentiated based on the type of vehicle category. The calculation of fuel consumption on toll-road differs from non-toll road because there are differences in road surface types, traffic conditions, and road gradient between toll and non-toll roads. In this research, fuel consumption is calculated based on traffic condition on non-toll road and speed of class I or equivalent to passenger car. The formula for calculating fuel consumption of vehicle class I on non-toll road is shown below. The symbol explanations for the formula used can be seen in the Nomenclature section.

$$Y = 0.05693V^2 - 6{,}42593V + 269{,}18567 \tag{2}$$

The calculation of vehicle fuel consumption serves as an approach to estimate the emission released due to transportation sector activities. Emission estimation can be approached as a result of fuel combustion, considering the fuel type used in transportation sector activities[37]. Increasing fuel consumption corresponds to a higher level of emissions generated.

3. Result and Discussion

3.1 Simulation Do Nothing Condition (Existing Condition/Implemented One-Way System)

The scope of this research is the Puspiptek Serpong area, characterized by complex traffic and predominantly consists of unsignalized intersections. In this study, an analysis of the existing conditions is conducted on the road network, consisting of the Muncul Signalized Intersection, Viktor Unsignalized Intersection, Buaran Ciater Unsignalized Intersection, and the Batan Tekno Roundabout. The traffic flow in unsignalized intersection is relatively irregular and causes many traffic conflict point. The number of traffic conflict point can affect the traffic performance and cause traffic congestion within a road network[38].

Previously, under normal traffic conditions, the average road network in the Puspiptek Serpong area had not been subject to one-way traffic flow regulation, and in the current existing condition, one-way traffic regulation is implemented during the morning peak hours. This current existing condition will serve as the basis for the Do-Nothing simulation in this research.

To align the model condition with the current existing condition, calibration has been performed on the technical improvements of the initially run model and the driving behavior parameters within PTV Vissim. In this research, driver behavior settings are based on the Wiedemann 74 traffic flow model, which corresponds to the movement characteristics of urban traffic. Parameters adjusted in the driving behavior model in PTV Vissim for this research include desired position at free flow, overtaking on the same lane, distance standing in meters, and distance driving in meters. Additionally, adjustments have been made to the Wiedemann 74 model parameters, namely average standstill distance, additive part of safety distance, and multiplicative part of safety distance[39]. The adjustments of driving behavior are shown in Table 1.

Table 1. Trial and error (calibration process).

Trial	Parameter Adjustion	Value	
		Before	After
0	First running without any parameter adjusting	-	-
1	Vehicle Input Point and Start-End Point of Route Position	Starting line position of vehicle input and route is not at the end of the link	Adjustment of the vehicle input and route starting line position
2	continue from the 1st trial		
	Desired position at free flow	Middle of lane	any
	Overtake on same lane: on left & right	Off	on
3	continue from the 1st trial		
	Distance standing (at 0 km/h) (m)	1	0.2
	Distance driving (at 50 km/h) (m)	1	0.4
4	continue from the 2nd trial		
	Average standstill distance	2	0.6
	Additive part of safety distance	2	0.6
	Multiplicative part of safety distance	3	1

Following calibration, the model undergoes validation through the calculation of the determination test or by calculating R^2 and GEH (Geoffrey E. Havers) test. The validation process using R^2 test is carried out based on speed data. The validation process using the GEH (Geoffrey E. Havers) method is conducted based on traffic volume data. After conducting trial and error as outlined in Table 1, the final results indicate an R2 value of 0.91 (approaching 1) for the speed parameter (as shown in Fig. 5), and no GEH (Geoffrey E. Havers) values for the traffic volume parameter exceed 5 (as shown in Table 2). This indicates that the model condition is capable of representing the actual conditions in the field.

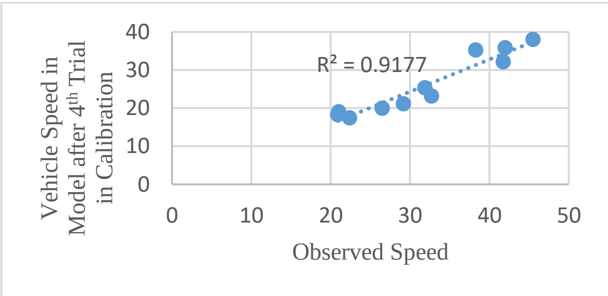

Fig. 5: Determination test (R^2) for speed parameter.

Table 2. GEH test for traffic volume parameter.

Street Name	Observed Traffic Volume (Vehicle/hour)	Traffic Volume in Model After 4th Trial Calibration Process (Vehicle/hour)	GEH Test
Buaran Rawabuntu	4911	4610	4.37
Tekno Widya	6526	6782	3.13
Ciater Bar	3249	3512	4.53
Puspiptek (Pamulang University)	2294	2093	4.30
Pasar Jengkol	2841	2808	0.62
Puspiptek (ITI)	9488	9019	4.88
Raya Serpong (BRIN)	8602	9022	4.47
Muncul	1108	996	3.45
Raya Serpong (Batan Indah)	661	651	0.39

Street Name	Observed Traffic Volume (Vehicle/hour)	Traffic Volume in Model After 4th Trial Calibration Process (Vehicle/hour)	GEH Test
Raya Serpong (SMAN 2)	15899	15350	4.39
Hutama Karya	1689	1680	0.22

After the calibration and validation processes have been completed, the next step involves analyzing network performance and fuel consumption under current traffic conditions. The traffic density visualization map for the current existing condition is presented in Fig. 6.

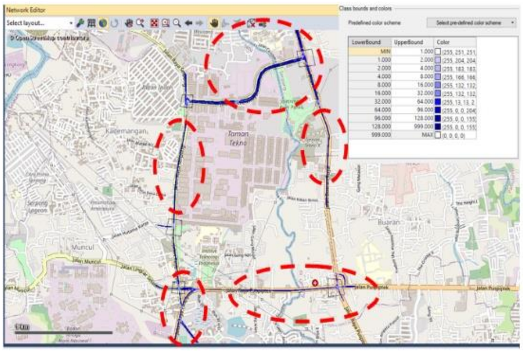

Fig. 6: Traffic density visualization for current traffic condition modeling.

Figure 6 shows five locations high traffic density, indicated by the deep blue color on the traffic density visualization map. The total conflict points occurring in the current condition are 6 points, all situated at road intersections within the study area. The traffic movement map, which shows potential conflict points in the existing condition, is illustratedin Fig. 2. These conflict points primarily involve vehicular turning movements at both unsignalized and signalized intersections, contributing to significant delays and potential safety hazards. At signalized intersections, several conflict points arise from vehicles the major road attempting to move straight but being interrupted by vehicles on minor roads making left or right turns. At signalized intersection, some traffic flight phases are designed to have overlapping green times due to the low traffic volume. However, this overlap creates conflict points between the arms of intersection that share the same green phase. The results indicate an average delay of 516.65 seconds, a stopped delay of 183.95 seconds, an average speed of 26.01 km/hour, and fuel consumption of 143.73 liters per 1000 km

3.2 Simulation Condition Before One-Way System Has Been Implemented

After completing the analysis process of the existing condition, the next step involves creating a simulation model for traffic conditions before implementing the one-way system in the study area. By obtaining the simulation results of the road network conditions before reducing traffic conflict points through the implementation of one way system, it can determined whether this one way system will have a beneficial effect on congestion reduction and fuel consumption. In this simulation, the traffic flow in all road segments within the study is currently in a two-way system. These traffic conditions have more potential traffic conflict compared to the condition of one-way road implementation, as previously modeled in the simulation of the existing conditions. The total conflict points occurring in this traffic condition are 20 points, situated at road intersections within the study area. The number of traffic conflicts tends to be higher before the implementation of a one-way system due to less efficient traffic patterns. The traffic movement map that has the potential as conflict points in this traffic condition is shown in Fig. 3.

The simulation model for traffic conditions before implementing the one-way system is developed to obtain network performance from traffic conditions with a higher potential for conflict points than the current existing conditions. Thus, this research facilitates a comparison between the existing one-way system implementation and the conditions before implementing the one-way system. Subsequently, simulations are conducted for the implementation of other traffic engineering scenarios. The results indicate an average delay of 920.96 seconds, a stopped delay of 621.76 seconds, an average speed of 21.95 km/hour, and fuel consumption of 158.83 liters per 1000 km. The traffic density visualization map for this traffic condition is presented in Fig. 7. Figure 7 shows six locations characterized by high traffic density, as indicated by the deep blue color on the traffic density visualization map. The simulation results confirm the presence of significant congestion an inefficiencies in the traffic simulation conditions before the implementation of the one way system.

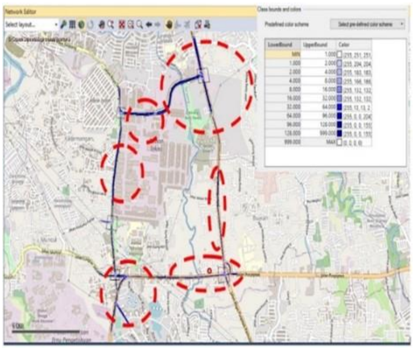

Fig. 7: Traffic density visualization for traffic modeling of condition before one way system has been implemented.

3.3 Simulation Do-Something Condition (Eliminating Traffic Conflict Point)

In this scenario, the implementation of a one way system and changes in the traffic movement patterns at several intersections are carried out. The scenario applied in the do-something condition aims to provide suggestions for traffic management to reduce conflict points at intersections. In the implemented traffic engineering scenario, specific traffic movements that could potentially lead to conflicts will be eliminated. Figure 4 illustrates the details of the implemented scenario. The traffic density visualization map for the do-something condition is presented in Fig. 8.

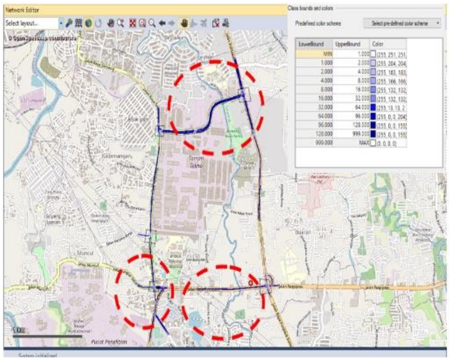

Fig. 8: Traffic density visualization for do something condition modelling.

Figure 8 shows three locations characterized by high traffic density, as indicated by the deep blue color on the traffic density visualization map. The total conflict points occurring in the current condition are 4 points, situated at road intersections within the study area. The number of conflict points that occur is fewer compared to the previous simulation scenario conditions because, in this scenario, there is a change in the traffic movement patterns that direct traffic to more efficient routes and more effective traffic priority management on the major traffic flow. The traffic movement map that has the potential as conflict points in the do-something condition is shown in Fig. 4. The results indicate an average delay of 500.72 seconds, a stopped delay of 140.67 seconds, an average speed of 28.41 km/hour, and fuel consumption of 139.87 liters per 1000 km.

3.4 Comparison of Simulation Results from 3 Model Conditions

Based on the analysis results, indicate that the implemented traffic management, which involves reducing conflict points at intersections in the Puspiptek Serpong Area, to mitigate congestion can have a positive impact on traffic performance. The impact assessment involves calculating network performance and fuel consumption under three conditions: the current condition with the implementation of a one-way system, the condition before the one-way system was implemented, and the condition with the implementation of the recommended traffic engineering scenario (eliminating traffic conflict points). The analysis results can be seen in Table 3.

Table 3. Network performance analysis.

Parameter	**Network Performance**		
	Do Nothing	**Condition Before Implemented One Way System**	**Do Something**
Total Traffic Conflict Points	6	20	4
Delay Average (second)	516.65	920,96	500,72
Delay stopped (average) (second)	183.95	621,76	140,67
Speed Average (km/hour)	26,015	21,95	28,41
Fuel Consumption (liter/1000 km)	**143,73**	**158,83**	**139,87**

The implementation of traffic engineering aimed at reducing conflict points, as demonstrated in the do-nothing and do-something conditions, has a positive impact on network performance and fuel consumption. Conversely, in the condition without the implementation of the one-way system, a high occurrence of traffic conflict points is noted, resulting in a negative impact on network performance and fuel consumption. The changes in traffic movement patterns, directing traffic to more efficients routes, can reduce potential vehicle encounters that may cause conflicts. Reducing the potential conflict has an impact on increasing average speed. The fuel consumption and emissions from vehicles are greater when they are traveling at low speeds compared to higher speeds. The lower the speed of those vehicles, resulting in higher fuel consumption and emissions. The improvement in traffic performance, characterized by a decrease in vehicle delays and stops, as well as an increase in average travel speed on the road network, can have a positive effect on fuel consumption.

Based on the analysis results, several limitations of this research should be considered for future studies or potential follow-up research:

1. This research's focus on specific area (Puspiptek Serpong) and a particular time frame (morning peak hours) may limit the generalizability of the findings. Different areas or times of day might exbihit different traffic patterns and challenges.
2. External factors such as weather conditions, special events, or road construction activities can significantly influence traffic flow and were not accounted in this research. These factors could alter the effectiveness of the proposed traffic engineering measures.
3. This research assumes that drivers will adapt to the new traffic management measures as expected. However, actual driver behavior can be unpredictable, and resistance or non-compliance

with the new measures could diminish their effectiveness.

4. Conclusion

This research demonstrates that micro-level interventions, such as traffic engineering to eliminate traffic conflict points, can significantly reduce fuel consumption by 2.69% compared to the existing condition. Conversely, the absence of such interventions results in an 11% increase in fuel consumptions. This indicates the positive impact of addressing small-scale issues on fuel consumption reduction and overall traffic efficiency. Another example of micro-level intervention, such as optimizing traffic signal timings, also shows a positive impact on fuel consumption reduction. Stevanovic et al (2009) conducted research on fuel consumption savings achievable through optimizing traffic signal timings, revealing a 1.5% decrease in fuel consumption compared to the existing condition[28].

By conducting traffic engineering, which involves reducing conflict points at intersections, the potential for congestion can be decreased, leading to smoother traffic flow within the network. Based on the analysis results, it can be concluded that the greater the number of vehicles experiencing stop-and-delay phases, as observed in congested conditions or when vehicle speed approaches 0 km/hour, the higher the fuel consumption. As fuel consumption rises, so do the emissions released by vehicles. Consequently, the implementation of traffic management to mitigate congestion results in a reduction of vehicles in stop-and-delay phases, leading to decreased fuel consumption and a corresponding decrease in the emissions released by vehicles.

These findings highlight the importance of addressing small-scale issues to improve traffic flow, reduce congestion risk, minimize delays, and increase vehicle speed. Implementing targeted traffic engineering measures not only addresses immediate congestion issues but also contributes to long-term sustainability goals. Improved traffic low reduces the overall time vehicles spend idling and in stop-and-go conditions, directly lowering fuel consumption and emissions. This aligns with urban planning objectives that aim to create more efficient, livable, and environmentally friendly cities. Moreover, the reduction in fuel consumption and emissions support global efforts to combat climate change by decreasing the transportation sector's carbon footprint. Urban planners and policymakers can use these insight to develop integrated transportation strategies that prioritize both traffic efficiency and environmental sustainability. By incorporating micro-scale interventions, such as optimizing traffic signals and reducing conflict points, alongside larger-scale initiatives like promoting public transportation and developing infrastructure for electric vehicles, cities can achieve more holistic approach to energy conservation.

In conclusion, this research highlight the critical role of traffic engineering in enhancing urban transport systems. The demonstrated benefits of reduced congestion, lower fuel consumption, and decreased emissions provide a compelling case for the adoption of similar measures in other urban areas. As cities continue to grow an evolve, integrating these findings into urban planning practices will be essential for fostering sustainable, energy-efficient transportation networks that contribute to overall environmental well-being.

Acknowledgments

This research is conducted as part of the research activities within the New Energy Program from Energy and Manufacturing Organizations, National Research and Innovation Agency (BRIN).

Nomenclature

GEH	Geoffrey E. Haveres Statistic
$Q_{observed}$	Observed Traffic Volume (vehicle/hour)
$Q_{simulated}$	Simulated Traffic Volume (vehicle/hour)
V	Vehicle Speed (km/hour)

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