STUM
Sustainable Transportation and Urban Mobility
STUM 2(1): 30–47
ISSN 3063-1416

Institute for Advanced Science,
Social and Sustainable Future
MORALITY BEFORE KNOWLEDGE

Sustainable urban mobility through traffic engineering and public transport integration: A microsimulation approach using Planung Transport Verkehr (PTV) Vissim

Michael Ferdinand Ramlan[1,*], **Irene Tintan Aprilian**[1], **Naufal Ariq Pratama**[1]
[1] *Department of Civil Engineering, Faculty of Engineering and Industrial Education, Universitas Pendidikan Indonesia, Bandung, West Java 40154, Indonesia.*
*Correspondence: michaelfer22@upi.edu

Received Date: December 21, 2024 Revised Date: February 1, 2025 Accepted Date: February 20, 2025

ABSTRACT

Background: Traffic congestion is a major problem faced by the city of Bandung, particularly at the Soekarno-Hatta – Buah Batu intersection, which often experiences saturated conditions where traffic volume exceeds the basic capacity of the arterial road. This study aims to analyze the existing condition of the intersection and evaluate the effectiveness of integrating traffic engineering and public transportation as a sustainable solution. **Method:** This study employs a microscopic traffic simulation approach using Planung Transport Verkehr (PTV) VISSIM 9 software, based on traffic volume data obtained from ATCS CCTV observations, classified by vehicle type and movement direction. Two scenarios were analyzed: the existing condition with a 360 second signal cycle and the engineered condition with a 150 second cycle combined with high-capacity bus services. **Finding:** The simulation results show that under existing conditions, the average queue length reaches 267.74 meters with a traffic flow of about 2,600 pcu/hour/lane, far exceeding the basic capacity of 1,700 pcu/hour/lane. After applying traffic engineering and public transport integration, the average queue length decreased significantly to 22.9 meters, with a potential reduction of up to 1,920 private vehicles per day. **Conclusion:** The combination of signal cycle optimization and high-capacity public transport can improve intersection performance efficiency while supporting sustainable urban mobility in Bandung. **Novelty/Originality of this article:** This study introduces an integrated framework combining signal timing optimization and high-capacity public transport, evaluated through microscopic traffic simulation using ATCS CCTV data. It provides quantitative evidence of congestion reduction and private vehicle demand shifts at a saturated urban intersection in a developing city context.

KEYWORDS : public transport; PTV Vissim; sustainable mobility; traffic engineering; urban mobility.

1. Introduction

In recent decades, urban mobility has become a critical challenge for cities worldwide, particularly in rapidly urbanizing countries. The growth of urban populations, economic activities, and spatial expansion has significantly increased travel demand, placing immense pressure on existing transportation systems. Without adequate planning and management, this rapid motorization often leads to congestion, inefficiencies, environmental degradation, and reduced quality of life. Urban transportation systems are therefore no longer viewed merely as supporting infrastructure, but as a strategic component of sustainable city

Cite This Article:
Ramlan, M. H., Aprilian, I. T., Pratama. N. A. (2025). Sustainable urban mobility through traffic engineering and public transport integration: A microsimulation approach using PTV Vissim. *Sustainable Transportation and Urban Mobility, 2*(1), 30-47. https://doi.org/10.61511/stum.v2i1.2025.2398

development that directly influences economic productivity, social equity, and environmental resilience. In developing cities such as those in Indonesia, the dominance of private vehicles remains a central issue in urban mobility management. Limited road capacity expansion, coupled with inadequate public transportation services, exacerbates traffic congestion, especially at critical nodes such as intersections. As a result, intersections have become focal points for traffic conflicts, delays, and safety risks, underscoring the necessity for efficient traffic control and travel demand management measures.

The movement of people is unavoidable in daily life. Over time, the need to travel from one place to another continues to increase significantly. However, transportation systems operate within a complex environment. The growing number of vehicles has become an important factor that must be considered as society continues to develop and industrialization accelerates. Therefore, reliable transportation is required to support these mobility needs. Transportation plays an important role in fulfilling the demands and objectives of modern society, as it represents an integrated system consisting of facilities and infrastructure. Efficient traffic flow is not only essential in major cities but also in suburban and rural areas. In Bandung, rapid urban development has led to significant road construction, which consequently increases the level of mobility and traffic flow throughout the city. If this condition is not supported by appropriate traffic policies or the implementation of an effective traffic management system, it may lead to traffic congestion on the roads and even increase the risk of traffic accidents (Erika, 2019). Intersection are critical points where two or more roads meet. Due to the convergence of traffic streams from different directions, conflict points are created, which may increase the potential for traffic disturbances or accidents. Therefore, proper traffic control and management aims to reduce conflicts, reduce delays, and improve the overall capacity and efficiency of the intersection.

Traffic congestion is a major problem in large cities across Indonesia. Bandung serves as a concrete example, with the number of motorized vehicles exceeding 2.2 million units almost equal to its population. This increase in vehicle ownership is not matched by an improvement in road capacity or the efficiency of public transportation, making it one of the main causes of congestion at several critical points in the city. The rapid development of Bandung City, along with the continuous growth of its population, has led to an increasingly complex road transportation system. This rapid growth has resulted in a higher volume of motorized vehicle movements passing through the streets of Baandung, especially during peak hours in the morning when people commute to work and in the late afternoon to evening when they return home (Alfaridz, 2020). The continuous movement of vehicles in high volumes further exacerbates this condition. Congestion typically occurs on a regular basis and affects resource utilization and nearby activities, influencing the overall quality of social, economic, and cultural activities in an area (Ruswanda, 2018).

Intersections, particularly in urban areas, tend to experience higher levels of congestion compared to other parts of the road network. This occurs because traffic volumes from each approach converge at the intersection, which often leads to vehicle queues and travel delays. Thus, most traffic congestion occurs at intersections (Muchlisin et al., 2018), especially at unsignalized intersections. These conditions can cause discomfort and stress for drivers, making it difficult for them to feel comfortable while driving (Nyame-Baafi et al., 2018). Traffic management refers to a series of activities that include the planning, provision, installation, regulation, and maintenance of road facilities and equipment aimed at supporting and maintaining road security, safety, and smooth traffic flow (Makino et al., 2018). Traffic management addresses several issues in order to maintain system performance. Tamin states that urban traffic performance can be assessed using traffic parameters, namely for roads, which can be in the form of V/C ratio, speed and traffic density (Tamin, 2008). As for the intersection, it can be in the form of delay time and queue length. If available, traffic accident data can also be considered in evaluating the effectiveness of the urban traffic system (Sandhyavitri et al., 2021).

From a policy and planning perspective, traffic congestion has increasingly drawn the attention of urban authorities due to its far reaching impacts on economic efficiency, fuel consumption, air quality, and public health. National and local governments are encouraged to implement integrated traffic management strategies that not only focus on physical infrastructure improvements but also emphasize operational efficiency and system optimization. Traffic signal control, intersection management, and public transportation enhancement are among the most widely adopted short and medium term measures due to their relatively low cost and high effectiveness.

Thus, this study attempts to approach intersection evaluation to reduce congestion through traffic light engineering. The approach used in this study is to develop a microscopic simulation to evaluate the performance under existing conditions (intersections without traffic lights) and intersections with traffic lights, using parameters including delay, queue length, and capacity with the PTV VISSIM microsimulation tool (Muchlisin & Widodo, 2019). This study demonstrates the systematic development of microscopic traffic simulations in the Bandung area to support appropriate strategic decision making in urban transportation management (Maheswary et al., 2018).

Traffic congestion remains a major issue in Bandung City, which is currently ranked as the most congested city in Indonesia according to the latest survey by the Asian Development Bank. Traffic jams often occur at intersections where road segments meet or cross, resulting in conflicts between traffic flows (Hutahaean & Susilo, 2021). The number of motorized vehicles in Indonesia increases by approximately 5–7% each year. The phenomenon of traffic congestion is not only a burden for road users but also has a significant impact on both the economy and the environment (Andriyanto, 2025). The Soekarno Hatta – Buah Batu intersection has now become one of the most critical and frequently highlighted junctions. Based on observations from ATCS CCTV, traffic flow during peak hours can reach approximately 2,600 pcu/hour/lane, far exceeding the basic capacity of an arterial road, which is 1,700 pcu/hour/lane. This condition triggers long queues, inter cycle delays, and results in an oversaturated intersection. Therefore, a more strategic and sustainable approach is required to address congestion not only through traffic engineering but also by reducing the number of personal vehicles through the optimization of public transportation within a smart city framework.

One of the efforts that can be carried out to improve intersection performance is by evaluating and adjusting the signal cycle plan that has been implemented at the intersection (Wulandari & Muchlisin, 2021). Adjusting the signal cycle plan is expected to reduce queue lengths and delays on each approach (Aryadewi, 2024). Previous studies have largely emphasized the importance of traffic signal cycle regulation in improving intersection performance (Ulfah & Purwanti, 2019). In addition, other research has focused on the development of public transportation as a long term strategy to reduce private vehicle volume (Isyafani et al., 2025). However, most of these studies discuss both approaches separately. To date, there has been very limited research that integrates traffic engineering through signal control with the optimization of public transportation.

Transportation refers to the process of moving people, animals, or goods from one location to another using various modes of transport. it can also be defined as the transfer of passengers or goods through vehicles operated either by human power or by machines. Transportation plays a crucial role in supporting human activities, as many daily activities depend on mobility. The availability of transportation systems enables people to travel more easily and facilitates the movement of goods to specific destinations. The identification and measurement of traffic congestion are essential for decision makers to implement mitigation strategies that enhance the sustainability of the overall transportation system (Afrin & Yodo, 2020).

An intersection is defined as the meeting point of two road segments, either at the same level or at different levels. According to PP number 43 of 1993, intersections are locations where accidents frequently occur due to conflicting movements of vehicles from different directions. Conflicts commonly arise at unsignalized intersections, particularly in the form of queues caused by the system of "giving in to each other" among drivers. This situation often leads to irregular driving behaviour at both signalized and unsignalized adjacent intersections, resulting in delays and traffic queues. In general, there are four basic types of vehicle movements at intersections: diverging, merging, crossing, and weaving

Traffic management refers to the process of regulating and optimizing the use of the existing road network to meet specific transportation objectives without requiring additional infrastructure or the construction of new facilities (Hasibuan & Muttaqin, 2021). Traffic management measures are primarily implemented to address short-term traffic problems prior to the development of new infrastructure, as well as to anticipate potential traffic issues, such as congestion during construction phases or other temporary disruptions.

The implementation of these simulations typically represents the main behavioral characteristics of a specific physical or abstract system. To evaluate intersection performance and conduct traffic engineering, VISSIM software is used. PTV VISSIM is a type of software used for microscopic traffic modeling. The PTV VISSIM program facilitates comprehensive traffic analysis as it can provide a visual representation of field conditions through 2D and 3D simulations (Wicaksono, 2023). VISSIM is also a microscopic simulation application, which means it treats each vehicle as an individual unit that moves independently while also considering detailed parameters such as driving behavior (Pakpahan & Susilo, 2021).

Although numerous studies have examined traffic congestion mitigation through signal timing optimization or intersection performance evaluation, most of them primarily focus on traffic engineering solutions in isolation. Other studies emphasize the development of the public transportation system as a long term strategy to reduce private vehicle dependency. However, limited research has explicitly integrated both approaches within a single analytical framework, particularly using microscopic simulation to evaluate their combined impacts on intersection performance. Furthermore, studies that apply such integrated approaches at highly saturated urban intersections in Indonesian cities remain scarce. This limitation highlights the need for a comprehensive evaluation that combines traffic signal engineering with public transportation optimization to achieve sustainable congestion mitigation. Addressing this research gap is essential to support urban transportation planning that is not only technically effective but also aligned with long term mobility and sustainability goals.

Based on the conditions described earlier, this study seeks to analyze the performance of the Soekarno Hatta – Buah Batu intersection, design the traffic signal cycle, and evaluate as well as provide recommendations regarding the implementation of an appropriate public transportation system, in this case, high capacity buses. A microscopic simulation using PTV VISSIM software is employed to compare the existing conditions with the integration scenario. The results of this study are expected to contribute meaningfully to sustainable traffic management strategies and support the development of effective and efficient urban mobility in the city of Bandung. This article can serve as a reference for the Bandung local government, the Department of Transportation, and engineering students in performing systematic traffic flow simulation in the Soekarno Hatta – Buah Batu area using PTV Vissim.

2. Methods

2.1 Research design

This study employs a quantitative approach using microscopic simulation analysis with PTV VISSIM 9 software. The research design consists of evaluating the existing intersection performance and comparing it with an engineering and public transport integration scenario. The simulation-based comparative approach allows systematic assessment of traffic performance improvements under different operational conditions.

The research method consists of three main stages. First, an analysis of the existing conditions was conducted to determine the intersection's performance using parameters such as traffic volume, queue length, and degree of saturation. Second, a traffic engineering scheme was implemented by adjusting the signal cycle time from 360 seconds to only 150 seconds, with green phases for each intersection leg set as follows: north 27 seconds, east 38 seconds, south 39 seconds, and west 22 seconds. Third, the integration of high capacity bus based public transportation was introduced as a congestion mitigation solution. Each bus is estimated to accommodate the equivalent of 20 to 40 vehicles, thereby reducing traffic volume by approximately 4–5% per cycle. The proposed route covers the Soekarno Hatta – Terusan Buah Batu corridor, integrated with the Trans Metro Pasundan network.

2.2 Study location

The study was conducted at the Soekarno Hatta–Buah Batu intersection in Bandung, Indonesia. The analysis of the Soekarno Hatta–Buah Batu intersection was conducted using ATCS CCTV data and evaluated based on the PKJI 2023 and MKJI 1997 methodologies. These approaches were used to assess traffic performance indicators such as traffic volume, delay, and level of service at the intersection.

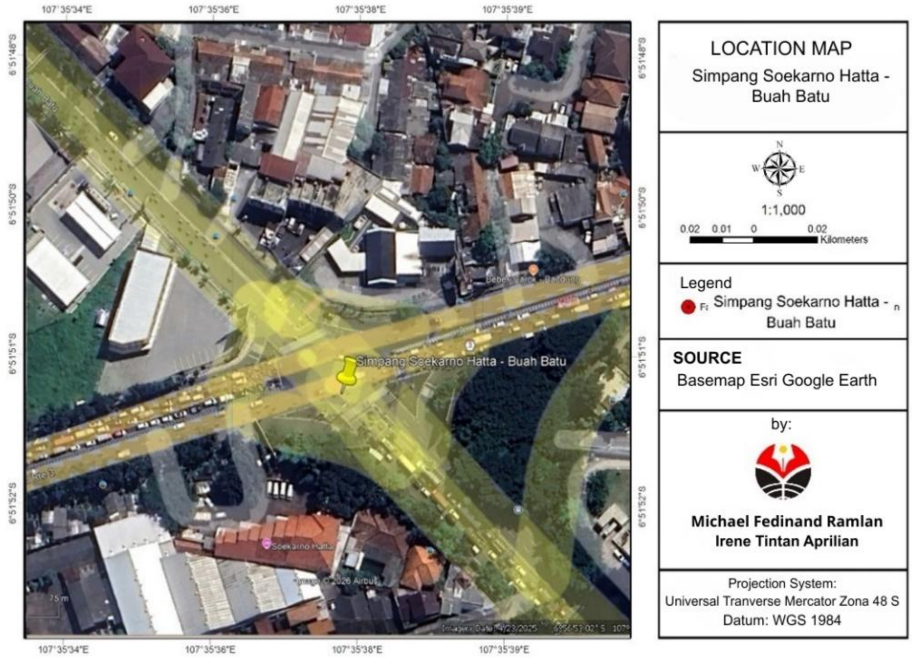


Fig. 1. Research Location

2.3 Data source and data collection

Primary data were collected from traffic observations at the Soekarno Hatta–Buah Batu intersection through ATCS CCTV footage. The observed traffic data were categorized by vehicle type—light vehicles (LV), heavy vehicles (HV), and motorcycles (MC)—and by movement type, including left turn, through, and right turn. The traffic model was developed using actual traffic data obtained from road traffic monitoring systems as well as direct field observations (Ziemska – osuch & osuch, 2022).

Accordingly, actual field data were collected and compiled, including classified traffic volumes at each intersection approach and turning movement by vehicle types, signal cycle durations, traffic composition, road geometry, classified average vehicle dimensions, and mid block traffic volumes, spot speed measurements, and observational data on traffic operations. These datasets were used as essential inputs for building and validating the VISSIM simulation models, following established practices in traffic microsimulation studies (Desta & Bräunl, 2021).

2.4 Traffic performance analysis

The analysis of existing conditions was conducted in accordance with the Indonesian Highway Capacity Manual (MKJI, 1997) and the Indonesian Road Capacity Guidelines (PKJI, 2023). Intersection performance was evaluated using key traffic characteristics, including the volume-to-capacity ratio (V/C ratio), traffic speed, and traffic density. These three indicators were subsequently used to determine the level of service (LOS) at the intersection.

2.4.1 Capacity analysis

The basic equation for determining capacity is as follows. This equation is used to estimate the maximum traffic flow that can be accommodated by a road segment under specific geometric and environmental conditions. It also considers several adjustment factors that reflect roadway characteristics and surrounding traffic conditions.

$$C = Co \ x \ FCw \ x \ FCsp \ x \ FCsf \ x \ FCcs \qquad \text{(Eq. 1)}$$

Where C represents highway capacity in passenger car units per hour (pcu/h), C_0 refers to the basic capacity, FCw denotes the lane width adjustment factor, FCsp represents the directional separator adjustment factor, FCsf indicates the side friction (side resistance) adjustment factor, and FCcs refers to the city size adjustment factor, as defined in the Indonesian Highway Capacity Manual (MKJI). These adjustment factors are applied to reflect the influence of roadway geometry, traffic environment, and urban characteristics on road capacity. By incorporating these factors, the calculated capacity becomes more representative of actual traffic conditions at the observed location.

2.4.2 Speed analysis

To evaluate operational performance in terms of mobility, the average vehicle speed is calculated using the following equation. This approach helps describe the efficiency of traffic movement along a road segment. Average speed is an important indicator used to assess the level of service and the overall quality of traffic flow.

$$V = \frac{L}{TT} \qquad \text{(Eq. 2)}$$

Where V represents the average vehicle speed in kilometers per hour (km/h), L denotes the segment length in kilometers, and TT is the average travel time of light vehicles along the road segment expressed in hours. This formulation enables the estimation of operating speed based on observed travel time data and provides a fundamental parameter for evaluating roadway performance. By integrating speed analysis with capacity and volume measurements, a more comprehensive assessment of traffic conditions can be achieved (Ministry of Public Works, 1997).

2.4.3 Level of Service (LOS)

Subsequently, the discussion focuses on the concept of Level of Service (LOS). LOS represent a qualitative measure that characterizes the operational conditions of a traffic flow and the perceived quality of service experienced by drivers or passengers under specific traffic circumstances. According to Transportation Engineering: An Introduction, LOS reflects factors such as speed, travel time, freedom to maneuver, traffic interruptions, comfort, and safety. Therefore, LOS serves as an essential indicator in traffic engineering studies to classify roadway performance into standardized categories ranging from free-flow to highly congested conditions (Khisty & Lall, 2003).

Table 1. Description of Level of Service (LOS)

Level of Service (LOS)	Characteristics	V/C ratio
A	Traffic flows frely with very low vehicle volume: average travel speed is about 80 km/h: traffic density is low	0.00 – 0.20
B	Traffic flow remains stable with moderate vehicle volume: average speed decreases to around 70 km/h traffic density is still low.	0.20 – 0.44
C	Traffic flow stable with moderate traffic volume: the average speed is reduced to about 60 km/h; traffic density becomes moderate.	0.45 – 0.74
D	Traffic conditions begin to approach instability due to high vehicle volume; the average speed drops to arround. 50 km/h; traffic density is moderate.	0.75 – 0.84
E	Traffic flow becomes unstable as volume approaches road capacity; the average speed is approximately 30 km/h for roads connecting cities and about 10 km/h for urban roadways; traffic density is high due to internal disturbances.	0.85 – 1.00
F	Traffic flow becomes forced or congested with frequent queues; the average speed is less than 30 km/h; traffic density becomes very high	>1.00

(The Ministry of Transportation of the Republic of Indonesia, 2015)

To ensure a comprehensive evaluation of intersection performance, this study employs several quantitative performance indicators commonly used in urban traffic analysis. These indicators include average delay per vehicle, queue length, degree of saturation, travel speed, and intersection capacity. Delay and queue length are used as the primary indicators for assessing intersection efficiency, as they directly reflect operational performance and driver experience. Meanwhile, the values of degree of saturation and capacity are utilized to assess the balance between traffic demand and available roadway infrastructure. The combination of these indicators allows for an integrated assessment of both operational and functional performance under different traffic conditions.

2.5 Simulation modeling using PTV Vissim

VISSIM is a microscopic traffic simulation model based on time step and driver behaviour principles, developed to analyze various types of road networks as well as public transportation operations (Papageorgiou et al., 2006). In this study, the development and validation of the simulation models require comprehensive and detailed input data to accurately represent existing traffic conditions. Simulation refers to the process of imitating real systems together with their environmental conditions (Karunia et al., 2021). PTV Vissim applies the Wiedemann car following model, which incorporates a leader follower driving behavior approach to represent vehicle interactions at micro scale level (Kaths et al., 2021). VISSIM is a modeling application developed by PTV. VISSIM requires data such as traffic volume, road geometry, and vehicle speed, and it can be used to calculate congestion levels as well as to solve traffic problems through simulation modeling.

Traffic modelling is an effective approach in transportation construction and engineering, as it enhances the ability to analyze and solve complex transportation problems. It is commonly applied to evaluate alternative designs, test new traffic management strategies, identify and diagnose problem areas, and asses environmental and safety impacts. One of the main advantages of traffic modelling is that it enables the analysis of existing transportation systems without interrupting their operation. Most simulation tools utilize computer technologu, allowing the simulation process to be repeated multiple times with different input data, either in real time or accelerated time. Furthermore, advancements in computer technologu and the availability of appropriate software enable the modelling and simulation of larger transportation networks. As a result, the developed models, can be easily interpreted, implemented in real world environments, and used to generate relevant and useful data (Krivda et al., 2021).

The traffic model was developed using actual traffic data collected from road traffic monitoring systems as well as direct field observations (Ziemska – osuch & osuch, 2022). Subsequently, the model was constructed and calibrated using PTV Vissim software, which is widely recognized as a standard tool for microscopic traffic modelling. To develop a traffic model in PTV Vissim, several types of input data are required, particularly geometric network data. Information related to the geometry of intersections and connecting road segments can be efficiently input into the software by utilizing a previously prepared situational plan or by employing a digital map integrated within the program, such as Bing Maps (Bing). The map base used for modelling purposes may consist of various graphic or vector file formats, including *dwg or *dxf files.

In PTV Vissim environment, road sections are constructed using a combination of straight segments and curved alignments, providing usesrs with a high degree of flexibility in defining and shaping the geometric characteristics of the road network. During the process of drawing consecutive links and connectors, several geometric parameters must be specified, including the number and width of traffic lanes, the distance of stop lines from the edge of the intersecting road, the length of exclusive turning lanes, the width of lane separators, and the radii of horizontal curves. With respect to vehicle load at intersections or at the boundaries of the simulated network. In addition, the general composition of vehicles operating within the network must be defined. This composition is represented as the percentage distribution of each vehicle type. Traffic intensity values may vary according to the selected hourly time intervals, reflecting fluctuations in traffic demand over time.

The subsequent step involves defining the directional disribution of vehicles at locations where drivers are provided with more than one routing option, particularly at intersection approaches. Route definition is carried out by identifying decision points and specifying the available route alternatives at each of these points, followed by assigning a percentage share of traffic flow to each direction. This process requires the transformation of proportional traffic volumes corresponding to individual movement relations originating from a given approach. It should be noted that the application of predefined routes is applicable only when a static routing option is adopted, whereas it is not utilized under dynamic traffic assignment conditions.

In addition to defining conflict areas within the traffic model (Van, 2014), it is also necessary to establish priority rules or to specify collision conflict zones during the model development process (Liang et al., 2020). Priority rules serve a similar function to conflict areas in managing interactions between conflicting traffic streams; however, they provude greater flexibility in representing temporal gaps and spatial distances between conflicting movements. Within the developed model, the implementation of priority rules is applied at the central island of intersection. Traffic signal programs are incorporated based on control logic embedded within the signal controller software. The development of the signalized intersection model requires the use of actual field data, including the allocation of signal groups to specific traffic streams, detailed traffic signal timing plans, and green timme matrices. Furthermore, the model applies existing fixed time signal control programs that differentiate traffic operations according to time of day conditions, such as morning peak hours, afternoon peak hours, and off peak periods.

In addition, the timetables of public transportation services, including buses and trolleybuses operating within the modeled network section, were incorporated into the simulation model. Passenger platforms, including edge platforms and designated waiting areas, were also added at each public transport stop to represent traveler facilities. The scheduled departure times of buses at each stop were adjusted to closely reflect actual operational conditions. Furthermore, because conditional right turn signal phases were applied at signalized intersections within the model, it was necessary ti incorporate pedestrian movements at pedestrian crossings. Without the presence of pedestrians in the simulation, the resulting the crossing capacity is estimated to be unrealistically high, as conditional right turn movements would not experience any interference. Therefore, pedestrian traffic and the associated pedestrian infrastructure, such as sidewalk areas represented in the form of designated zones, were incorporated throughout the entire modeled network section to reflect existing field conditions. Part of the pedestrian movement simulation was performed using the PTV Viswalk tool (Kretz, 2006).

2.6 Model calibration and validation

All microsimulation models developed using PTV Vissim are required to undergo a calibration process at the final stage of model development to ensure reliability and accuracy (Bandi & George, 2020). In this study, the constructed model was calibrated using the GEH statistic. which is an empirical measure designed to allow relatively larger deviations for lower traffic volume values while imposing stricter tolerance limits for higher traffic volumes. The term GEH is not acronym; rather, it is derived from the initial letters of the first name and surname of the method's author. This statistic represents the relationship between observed vehicle traffic volumes collected from field measurements and the corresponding traffic volumes generated by the simulation model. Following the calibration process, the model produced GEH values lower than 5, indicating that the simulated traffic volumes were consistent with the observed data.

$$GEH = \sqrt{\frac{2\,(Mi - Ci)^2}{Mi + Ci}} \qquad \text{(Eq. 3)}$$

In this formula, M represents the hourly traffic flow generated by the simulation model, expressed in vehicles per hour, where C denotes the observed hourly traffic volume measured under real world conditions, also expressed in vehicles per hour. Model calibration and validation constitute essential stages in the modelling process, as they are necessary to ensure that the simulation outputs reliably and accurately reflect actual traffic conditions in the field. Calibration was conducted by adjusting key driver behavior parameters within the Wiedemann car following model, including desired speed distribution, standstill distance, headway time, and lane changing aggresiveness. These parameters were iteratively modified to minimize discrepancies between simulated and observed traffic volumes and queue lengths. Model validation was subsequently performed by comparing simulated outputs with observed field data using statistical measures, including traffic volume consistency and the GEH statistic. A GEH value below the accepted threshold indicates that the model reliably reproduces actual traffic conditions. Only after achieving satisfactory calibration and validation results was the model used for scenario analysis and performance evaluation, ensuring the robustness and credibility of the simulation outcomes.

Within the PTV VISSIM modeling framework, traffic behavior is represented using vehicle following and lane changing movements models to simulate interactions among vehicles within the traffic stream. These behavioral models are further refined during the model development and calibration stages to ensure that vehicle movements accurately reflect real world driving characteristics. The calibration and adjustment of parameters related to lane changing behavior and intersection link operations are critical steps in aligning the simulation model with observed traffic conditions. Following calibration, a model validation process is conducted, during which the calibrated model is evaluated against actual field traffic data to assess its accuracy and reliability. If the validation criteria are not satisfied, the model parameters are readjusted and the calibration process is repeated until acceptable performance is achieved. Once the model has been succesfully validated, the analysis proceeds to traffic performance evaluation and traffic signal timing optimization. In the results stage, the performance of the improved traffic signal control strategies is systematically compared with existing or condition before optimization. The outcomes are presented using key performance indicators under both before optimization and after optimization scenarios. In conclusion, the study summarizes the effect of optimized traffic signal control measures on overall traffic performance, highlighting their importance in reducing congestion and enhancing traffic flow at intersections (Qadri et al., 2024).

2.7 Scenario development

The development of simulation scenarios in this study is based on both operational necessity and strategic planning considerations. The existing condition scenario represents the current operational state of the intersection and serves as the baseline for comparison. The traffic engineering scenario focuses on signal cycle optimization, which is selected due to its practicality, low implementation cost, and immediate impact on congestion reduction. The integration of high capacity bus based public transportation is introduced as a complementary strategy aimed at reducing private vehicle demand and enhancing person throughput efficiency. By combining short term traffic engineering measures with demand management through public transportation optimization, the proposed scenario reflects a more sustainable and realistic approach to urban congestion mitigation. Both scenarios (the existing condition and the integrated traffic engineering public transport scenario) were then simulated using PTV VISSIM 9 software to evaluate the intersection's performance. The simulation results demonstrated that queue lengths were significantly reduced under the traffic engineering scheme.

3. Results and Discussion

3.1 Existing condition

The analysis of the Soekarno Hatta–Buah Batu intersection was conducted using ATCS CCTV data and evaluated based on the PKJI 2023 and MKJI 1997 methodologies. The interpretation of existing traffic conditions at the Soekarno Hatta–Buah Batu intersection is presented in table 2. This table summarizes the key traffic performance indicators derived from the collected data.

Table 2. Existing traffic volume and turning movement percentage data

St. Buah Batu (North)					
Movement	HV	LV	MC	Volume (smp/hour)	
LT	18	129	840	897	37.96
ST	24	135	684	843	32.42
RT	25	145	600	770	29.62
TOTAL	67	409	2,124	2,600	100
St. Terusan Buah Batu (South)					
LT	33	267	300	600	16.86
ST	25	300	1,133	1,458	40.98
RT	80	680	740	1,500	42.16
TOTAL	138	1,247	2,173	3,558	100
St. Soekarno Hatta (East)					
LT	42	342	257	641	18.58
ST	158	783	788	1,729	50.12
RT	97	437	546	1,080	31.30
TOTAL	297	1,562	1,591	3,450	100
St. Soekarno Hatta (West)					
LT	21	87	288	396	18.18
ST	41	397	598	1,036	47.57
RT	20	197	529	746	34.25
TOTAL	82	681	1,415	2,178	100

The initial assessment indicates that the intersection operates under a high level of saturation, reflecting severe congestion during peak periods. Based on the PTV VISSIM 9 traffic simulation results, the average queue length at the intersection reaches 267.74 meters, with a traffic flow rate of approximately 2,600 pcu/hour/lane. This value substantially exceeds the basic capacity of an arterial road, which is 1,700 pcu/hour/lane according to PKJI (2023). These findings confirm that the existing operational conditions of the intersection are inefficient and require immediate intervention to improve traffic performance.

3.2 Engineering scenario and public transportation optimization

Based on observations of existing conditions at the Soekarno Hatta–Buah Batu intersection, during a single 360-second traffic signal cycle, more than 400 vehicles per lane are observed to queue, while only approximately 260 vehicles are able to pass through the intersection. This imbalance indicates that the existing cycle time is excessively long, resulting in queues that fail to dissipate between cycles and leading to persistent congestion. Consequently, it is necessary to adjust the signal cycle to create a traffic flow pattern that is more responsive to actual vehicle demand and operational conditions.

The proposed reduction of the signal cycle to 150 seconds is intended to better align the intersection's operational capacity with observed traffic volumes, prevent prolonged queue formation, and increase the frequency of traffic discharge. The allocated green phase durations are 27 seconds for the north approach, 38 seconds for the east approach, 39 seconds for the south approach, and 22 seconds for the west approach. These adjustments are based on the Indonesian Highway Capacity Manual (MKJI, 1997), which recommends a maximum yellow interval of 3–4 seconds and an all-red interval of 2 seconds, while also accounting for total traffic volumes exceeding 10,000 pcu/hour at heavily loaded intersections.

Table 3. Traffic volume and turning movement percentage data after engineering implementation

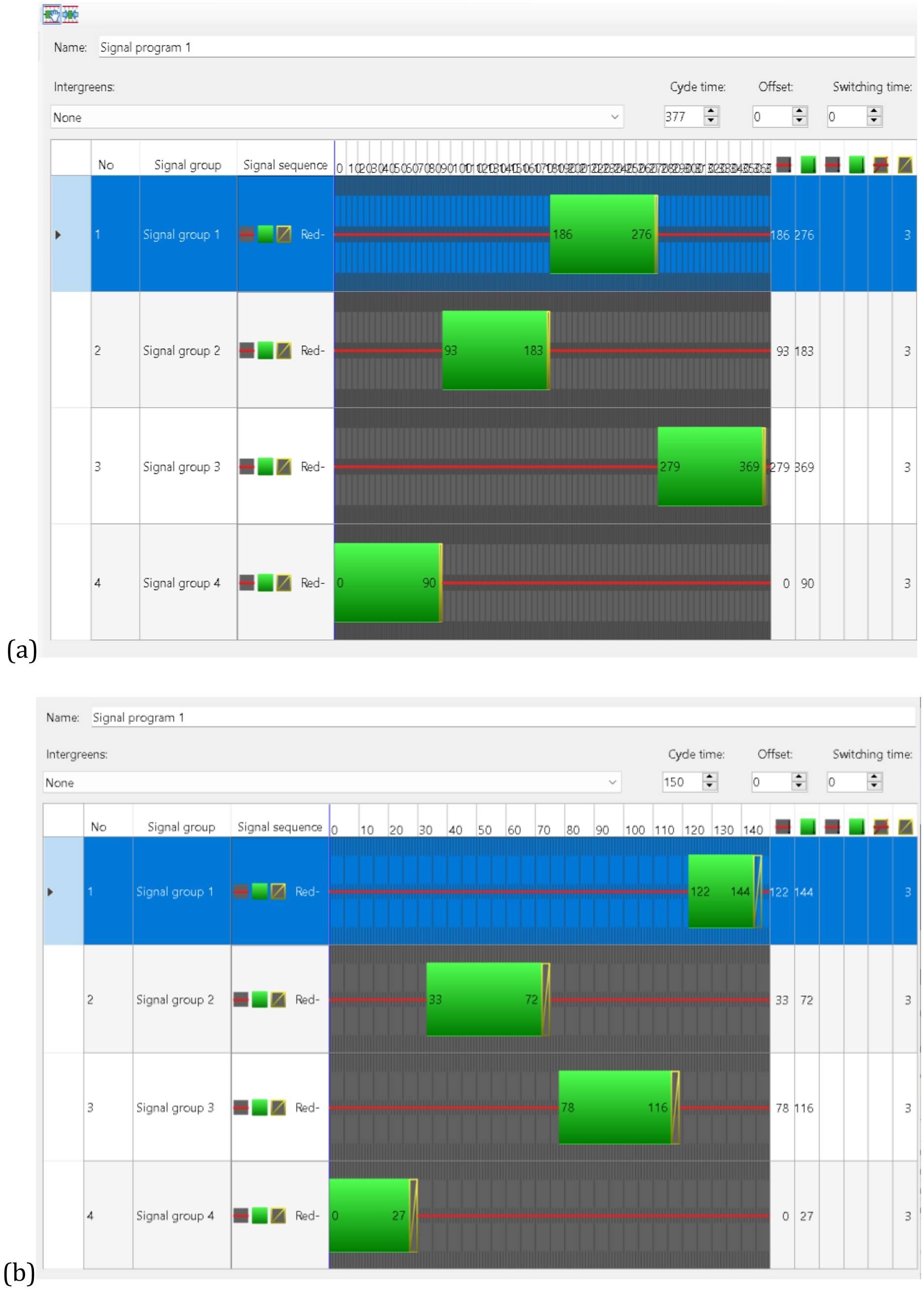
St. Buah Batu (North)					
Movement	HV	LV	MC	Volume (smp/hour)	
LT	19	129	780	928	41.33
ST	28	135	444	607	27.02
RT	26	145	540	711	31.65
TOTAL	73	409	1,764	2,246	100
St. Terusan Buah Batu (South)					
LT	34	267	240	541	16.88
ST	29	300	893	1,222	38.14
RT	81	680	680	1,441	44.98
TOTAL	144	1,247	1,813	3,204	100
St. Soekarno Hatta (East)					
LT	43	342	197	582	18.80
ST	162	783	548	1,493	48.22
RT	98	437	486	1,021	32.98
TOTAL	303	1,562	1,231	3,096	100
St. Soekarno Hatta (West)					
LT	22	87	228	337	18.47
ST	45	397	358	800	43.86
RT	21	197	469	687	37.67
TOTAL	88	681	1,055	1,824	100

In addition to signal timing optimization, integration with public transportation is proposed through the introduction of high-capacity bus services, with an estimated capacity of approximately 60 passengers per unit and a headway of 10 minutes. Each bus is projected to replace around 20 private cars or 30–40 motorcycles. With a service frequency of six buses per hour, the potential reduction in traffic volume is estimated at approximately 4.6% of the total peak-hour flow. Over a 16-hour daily operational period, this service could reduce up to 1,920 vehicles per day in one direction. The proposed route serves the Soekarno Hatta–Buah Batu–Terusan Buah Batu corridor, linking densely populated residential areas with the city center and industrial zones. To maximize effectiveness, the service should be integrated with existing public transport systems, such as Trans Metro

Pasundan (TMP), through well-designed bus stops, electronic payment systems, and the provision of real-time digital schedule information.

3.3 Modelling with PTV Vissim 9

To evaluate traffic performance at the Soekarno Hatta – Buah Batu intersection more accurately and realistically, a simulation model was developed using PTV Vissim 9. The simulation was conducted under two main scenarios: the existing condition and the post-engineering condition. The model was designed to replicate real-world traffic characteristics, including traffic volume, vehicle composition, and signal timing parameters, in order to ensure a reliable representation of actual intersection operations.



(a)

Name: Signal program 1
Intergreens: None
Cycle time: 377
Offset: 0
Switching time: 0

No	Signal group	Signal sequence	🟥	🟩	🟥	🟩	🟥	▨
1	Signal group 1	Red-	186	276				3
2	Signal group 2	Red-	93	183				3
3	Signal group 3	Red-	279	369				3
4	Signal group 4	Red-	0	90				3

(b)

Name: Signal program 1
Intergreens: None
Cycle time: 150
Offset: 0
Switching time: 0

No	Signal group	Signal sequence	🟥	🟩	🟥	🟩	🟥	▨
1	Signal group 1	Red-	122	144				3
2	Signal group 2	Red-	33	72				3
3	Signal group 3	Red-	78	116				3
4	Signal group 4	Red-	0	27				3

Fig. 2. (a) Existing condition signal cycle time; and (b) Signal cycle time after engineering implementation

After implementing the two main interventions—namely, adjusting the signal cycle time and reducing vehicle volume through public transportation optimization—a re-simulation of the model was conducted. The updated simulation results were then compared with those of the existing condition to evaluate the effectiveness of the proposed measures. Key performance indicators, including average delay, queue length, level of service (LOS), and degree of saturation, were analyzed to determine the extent of improvement in intersection performance. This comparative approach ensures a systematic and evidence-based assessment of the implemented traffic engineering strategies.

Table 4. Maximum queue length in existing conditions

Queue counter	Qlen	Qlen max
North	84.54	197.06
East	63.59	457.41
South	87.54	190.88
West	100.07	225.60

The modeling results showed significant improvements following the implementation of signal engineering measures and public transport integration strategies. The average queue length decreased substantially from 267.74 meters to 22.9 meters, representing a reduction of more than 90%. Additionally, the average delay per vehicle declined considerably, indicating a marked enhancement in traffic flow efficiency.

Table 5. Maximum queue length in the condition after traffic management

Queue counter	Qlen	Qlen max
North	2.55	27.89
East	0.00	0.00
South	14.50	63.71
West	0.00	0.00

This reduction in queue length is consistent with the findings of Ulfah and Purwanti (2019), who stated that optimizing signal cycle settings can significantly improve intersection efficiency and reduce vehicle accumulation. However, the present study extends these findings by demonstrating that the combined implementation of signal engineering measures and enhanced public transportation strategies yields a more comprehensive improvement in overall intersection performance.

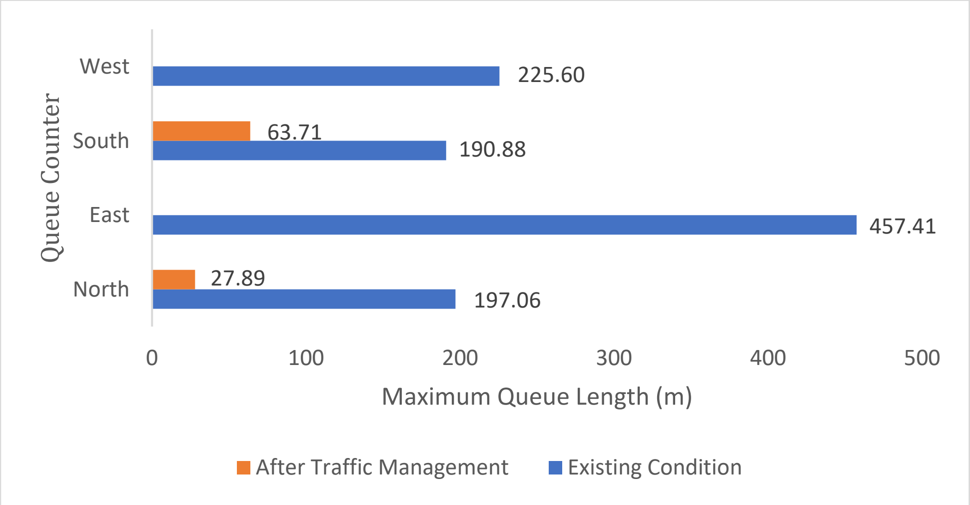


Fig. 3. Comparison of maximum queue length under existing and traffic management conditions

Beyond the numerical reduction in queue length and delay, the results reflect improved operational stability at the intersection. Shorter queues reduce the likelihood of spillback into upstream segments, which is common cause of secondary congestion and safety issues in highly saturated urban intersections. When compared with previous studies, the findings of this research are consistens with the result reported by Ulfah & Purwanti (2019) and Wulandari & Muchlisin (2021), which emphasize the effectiveness of traffic signal optimization in reducing delays and improving intersection capacity. However, this study extends prior research by integrating public transportation optimization info the traffic engineering framework.

From a sustainability perspective, the integration of high capacity bus services contributes to reducing private vehicles dependency and increasing person throughput efficiency at the intersection. The estimated reduction in traffic volume, although relatively modest on a per cycle basis, yields cumulative benefits over daily operations, including reduced fuel consumption, lower greenhouse gas emissions, and improved air quality. Overall, the discussion highlights that traffic congestion at critical urban intersections cannot be effectively addressed through signal engineering alone. Instead, a combination of operational optimization and public transportation enhancement is required to achieve sustainable improvements in traffic performance. This integrated approach provides valuable insights for urban traffic management policies and can serve as a reference for similar congested intersections in other metropolitan areas.

4. Conclusions

The results of this study indicate that the Soekarno Hatta–Buah Batu intersection experiences a very high level of congestion, characterized by an average queue length of 267.74 meters and a traffic flow rate of approximately 2,600 pcu/hour/lane. This value significantly exceeds the basic capacity of the arterial road, which is 1,700 pcu/hour/lane, indicating a critical imbalance between traffic demand and roadway capacity. Therefore, targeted interventions are required through traffic engineering measures to reduce vehicle density and improve overall traffic performance. Traffic engineering was implemented by optimizing signal timing, specifically by adjusting the signal cycle length from 360 seconds, which previously featured prolonged red phases, to a more efficient cycle of 150 seconds. The green phases were reallocated based on traffic demand as follows: north 27 seconds; east 38 seconds; south 39 seconds; and west 22 seconds. The results demonstrate a substantial improvement in intersection performance, as reflected by a reduction in the average queue length from 267.74 meters to 22.9 meters.

In addition to signal optimization, the integration of public transportation through the deployment of high-capacity bus services was found to significantly reduce the volume of private vehicles. This strategy shows the potential to decrease private vehicle usage by up to 1,920 vehicles per day, thereby alleviating traffic pressure on the intersection. Overall, these findings confirm that the combined application of traffic engineering and public transport optimization offers a more comprehensive and effective solution compared to single, isolated interventions. The integration of both approaches not only enhances intersection efficiency and level of service but also encourages modal shift and contributes to the achievement of sustainable urban mobility goals in Bandung.

Acknowledgement

The authors would like to thank the Bandung Transportation Agency for providing the traffic data used in this research. Additionally, the author extends gratitude to the Indonesian University of Education for its support in conducting this research.

Author Contribution

M.F.R. was responsible for the conceptualization of the study, traffic data collection, simulation modeling using PTV VISSIM, and drafting the initial manuscript. I.T.A. contributed to data analysis, visualization of results, preparation of tables and graphs, as well as manuscript editing. N.A.P. as the supervising lecturer provided supervision, methodology validation, and guidance in the preparation and refinement of the manuscript.

Funding

This study did not receive any external funding. All research costs were borne by the authors with support from the facilities provided by the Indonesian University of Education.

Ethical Review Board Statement

This research did not involve humans or animals directly, and therefore, did not require ethical approval from the relevant institutions. As such, the ethical review statement is not applicable.

Informed Consent Statement

This research did not involve human subjects directly. All traffic data used were obtained from ATCS CCTV recordings from the Bandung City Transportation Agency. Therefore, informed consent is not applicable to this study.

Data Availability Statement

All data used in this study were obtained from ATCS CCTV recordings from the Bandung City Transportation Agency and data from previous research articles. These data are not publicly available due to access limitations and privacy concerns but may be obtained upon request from the relevant authorities with official permission.

Conflicts of Interest

The authors declare that there are no conflicts of interest. The funding bodies or institutions had no role in the design of the study, data collection, analysis, interpretation of results, or in the writing and publication of this article.

Declaration of Generative AI Use

The authors state that generative artificial intelligence was used in a limited capacity to assist with manuscript preparation, specifically in language formulation and grammatical editing. All ideas, methodological design, data analysis, and conclusions of the research are entirely the original contributions of the authors.

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Biographies of Authors

Michael Ferdinand Ramlan, is a student in the Civil Engineering Study Program at the Indonesian University of Education. His research interests include urban transportation, traffic engineering, and simulation-based modeling.

- Email: michaelfer22@upi.edu
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A

Irene Tintan Aprilian, is a student in the Civil Engineering Study Program at the Indonesian University of Education. Her research focuses on transportation, traffic data analysis, and urban infrastructure management.

- Email: irenetintan.03@upi.edu
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A

Naufal Ariq Pratama, is a lecturer in the Civil Engineering Study Program at the Indonesian University of Education.

- Email: naufalariqp@upi.edu
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A