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Original Article

Analysis of the Causes and Impacts of Traffic Congestion (Case Study of Jl. MH Thamrin, Sentul)

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Abstract

Traffic congestion is a complex problem that has wide-ranging impacts on various aspects of community life, particularly in rapidly urbanizing suburban areas such as Sentul, a satellite city located in the Bogor Regency of West Java, Indonesia. This study aims to identify the main causes of congestion and analyze its impacts on social, economic, and environmental aspects. The research focuses on MH Thamrin Street in Sentul, a strategic corridor with high traffic intensity. A mixed-methods approach was used, incorporating field observations, questionnaire surveys, and in-depth interviews. The research findings indicate that the primary causes of congestion at the site include high vehicle volume, ineffective traffic management, roadside obstacles, and undisciplined road user behavior. The resulting impacts include increased travel time, fuel waste, commuter stress, and reduced local economic productivity. As such, these findings are expected to inform the formulation of more responsive and sustainable urban transport policies in similar areas.

Keywords: Congestion Causes, MH Thamrin Street, Sentul, Socioeconomic Impact, Traffic Congestion.

1. Introduction

The growth of satellite cities such as Sentul has shown very rapid development in recent years. This is marked by increasing population, residential area development, and significant economic activity growth. Such development directly impacts the increasing mobility needs of the population. MH Thamrin Street in Sentul is one of the main road segments connecting various strategic areas such as residential zones, offices, shopping centers, and industrial areas. As a primary connecting route, this road segment is vital in supporting the smooth flow of daily community activities.

However, along with increasing mobility, the intensity of vehicles passing through Jl. MH Thamrin has also increased significantly. This has caused traffic congestion, particularly during morning and afternoon peak hours (Bogor Regency Transportation Agency, 2021). The recurring congestion indicates an imbalance between vehicle volume and road capacity. This condition not only causes a decline in transportation efficiency but also impacts the comfort and productivity of road users (Zein et al., 2024).

Several previous studies have identified various main factors causing congestion in urban areas, including the high growth of private vehicles, unintegrated land use, and suboptimal traffic management (Tamin, 2000a). Additionally, the lack of adequate public transportation facilities has further encouraged people to use private vehicles, thereby worsening congestion conditions.

Traffic congestion does not only impact technical aspects of transportation but also causes widespread negative effects on society and the environment. These include increased fuel consumption, exhaust emissions, air pollution, longer travel times, and increased stress levels among road users. The economic impacts include reduced labor productivity, increased transportation costs, and decreased investment attractiveness in affected areas.

Given the important role of MH Thamrin Street as a strategic corridor in the Sentul transportation system, an in-depth analysis of the causes and impacts of traffic congestion on this road segment is necessary. A more comprehensive understanding of congestion problems is expected to help formulate effective, targeted, and sustainable solutions. Furthermore, the results of this study are also expected to contribute to the formulation of urban transportation policies that are applicable and adaptive to the dynamics of regional development.

The state of the art of traffic congestion research shows significant development in approach, shifting from descriptive approaches toward more integrative approaches utilizing technology, spatial analysis, and socioeconomic factors. In the early period of 2021, research focused heavily on congestion modeling and prediction using artificial intelligence and analysis of main causal factors. Akhtar and Moridpour (2021) demonstrated that Artificial Intelligence is effective in predicting congestion, while Kothai et al. (2021) developed a CNN-LSTM deep learning model to improve prediction accuracy based on spatial data. Yue et al. (2022) found that traffic signal settings are one of the dominant factors causing congestion, while Dadashova et al. (2021) and Moyano et al. (2021) confirmed that socioeconomic factors and economic conditions significantly influence congestion patterns in urban areas.

From 2022 to 2024, research evolved toward broader analysis involving urban structure, road user behavior, and the use of spatial and real-time data. Rahman et al. (2022) emphasized that city scale influences the level of congestion, while Choudhary et al. (2022) showed that urbanization can worsen congestion and pollution. Fattah et al. (2022) added that congestion has a major impact on the economic sector, particularly in industrial and port areas. Berhanu et al. (2023) began integrating accident and congestion analysis using GIS and machine learning to spatially identify vulnerable points. In 2024, Kan et al. (2024) used GPS trajectory data to analyze the contribution of travel activities to congestion, while Yang et al. (2023) developed a real-time data-based traffic risk model for a more adaptive monitoring system.

Entering 2025, research is increasingly directed toward the integration of intelligent transportation systems and road user behavior aspects. Sawalha (2025) confirmed that Intelligent Transportation Systems (ITS) are the primary solution in congestion mitigation, while Osei et al. (2025) showed that the cognitive factors of road users also significantly influence the level of congestion. Overall, the development of research shows a transition toward multidisciplinary approaches that combine technology, human behavior, and structural factors. However, most studies remain separate, locally contextual, and have not yet fully integrated all variables simultaneously, so a more comprehensive approach is still needed to fully understand the phenomenon of congestion.

The entirety of previous research shows that studies on traffic congestion have a relatively uniform focus on technological aspects such as ITS, AI, GPS, and big data, as well as socioeconomic aspects, road user behavior, and transportation infrastructure. These studies are generally conducted in urban areas with high activity levels in various countries such as the United States, Ethiopia, Bangladesh, and Spain. In general, the research objectives are to identify causes of congestion, measure its impacts on social, economic, environmental, and safety aspects, and develop prediction methods and traffic management policy recommendations.

In terms of variables, previous research has widely used combinations of technical and non-technical factors such as ITS, road infrastructure conditions, economic conditions, travel activities, and socioeconomic indicators. The methods used are also diverse, ranging from quantitative approaches such as VISSIM, regression, SEM, and machine learning, to qualitative approaches such as literature reviews, surveys, interviews, and field observations. In general, research findings show that congestion is a complex phenomenon influenced by many interrelated factors. However, limitations remain in data integration, analytical methods, and cross-regional generalization, thus opening opportunities for further research that is more comprehensive, integrated, and contextual.

Based on the results of problem identification, the objectives of this study are to identify the factors causing congestion, analyze the socioeconomic and environmental impacts, and formulate effective solutions to address traffic congestion on MH Thamrin Street, Sentul.

2. Literature Review

2.1. Urban Traffic Concept

Urban traffic is a complex system of movement of people, goods, and vehicles that is influenced by the interaction between humans, infrastructure, and land use. This system develops along with population growth, economic activities, and mobility patterns of society concentrated in certain areas, thus requiring integrated management between transportation and spatial planning (Tamin, 2000b). High land use intensity in areas such as commercial, office, and residential zones will increase trip attraction and vehicle volume, which if not balanced with road capacity can cause congestion (Warpani, 2002).

Furthermore, urban traffic is characterized by heterogeneity of vehicles and diverse road user behavior, which triggers movement conflicts and makes the traffic system dynamic and unstable (Khisty & Lall, 2005). Traffic performance is also heavily influenced by road capacity and level of service, where an imbalance between vehicle volume and capacity will reduce speed and increase delays (Directorate General of Highways, 2022). Therefore, addressing urban traffic problems requires a systemic approach that considers sustainability, efficiency, and safety aspects through strategies such as public transportation development, traffic engineering, and private vehicle use control (Morlok, 1991).

2.2. Traffic Congestion Concept

Traffic congestion is a condition in which the flow of vehicles no longer moves optimally due to an imbalance between traffic volume and road capacity, characterized by reduced speed, vehicle queuing, and increased travel time. This condition reflects the inefficiency of the transportation system because high travel demand cannot be accommodated by the available infrastructure (Tamin, 2000). Additionally, congestion is also related to the distribution pattern of community travel and obstacles on the road network that cause prolonged delays (Warpani, 2002).

In urban areas, congestion has characteristics such as high vehicle volume during peak hours, low and unstable speed, vehicle queuing, and a decline in road level of service. This condition is influenced by vehicle heterogeneity, road user behavior, and movement conflicts at certain points such as intersections (Khisty & Lall, 2005). Its causal factors include vehicle growth that is not balanced with road capacity, infrastructure limitations, and poorly planned land use that increases traffic load (Morlok, 1991).

2.3. Intersections and Traffic Conflict Points

Congestion in urban areas is also influenced by various operational factors on the road network, particularly at intersections that serve as meeting points of vehicle flows, thereby triggering movement conflicts, speed reduction, and increased delays (Tamin, 2000b). Additionally, the dominance of private vehicle use compared to public transportation also significantly increases the traffic load due to the high community dependence on that mode (Warpani, 2002).

Another contributing factor is the large number of uncontrolled entry and exit accesses to areas, such as from residential areas and commercial zones directly onto main roads, thereby disrupting the smooth flow of vehicles (Khisty & Lall, 2005). On the other hand, the lack of effectiveness in traffic management, including signal regulation and road engineering that have not been optimally implemented, further worsens congestion conditions and reduces road level of service (Tamin, 2000).

2.4. Road Transportation System and Management

The road transportation system is a unity of infrastructure, modes, users, and regulations that interact to support movement and economic and social activities in urban areas. This system is influenced by the interconnection between land use, travel demand, and infrastructure provision, thus requiring integrated management to achieve a balance between mobility needs and road capacity (Ortúzar & Willumsen, 2011). Transportation management plays a role in regulating travel demand and road network utilization through operational policies and traffic engineering, with the goal of improving efficiency, safety, and sustainability of the transportation system (Meyer et al., 1965). Additionally, modern transportation management also needs to consider economic and environmental impacts such as congestion and pollution (Button, 2010).

Road capacity and traffic volume are the two main variables in determining the performance of the transportation system. Road capacity describes the maximum ability of a road segment to accommodate vehicle flow, influenced by geometric, environmental, and operational conditions (Transportation Research Board, 2010). Meanwhile, traffic volume indicates the level of travel demand on a road segment (Papacostas & Prevedouros, 2001). The relationship between speed, volume, and density shows that increasing volume will reduce speed until reaching a saturated condition that potentially causes congestion (Greenshields et al., 1935). When volume approaches or exceeds capacity, road level of service declines and traffic flow becomes unstable (Khisty & Lall, 2005).

2.5. Traffic Engineering

Traffic engineering is a branch of transportation engineering that focuses on planning, designing, operating, and controlling traffic flow to achieve safe, efficient, and comfortable movement through geometric regulation, signaling, and management of vehicle and pedestrian flow (Oglesby & Hicks, 1993). This approach not only covers the physical aspects of roads but also considers road user behavior and movement patterns that influence overall traffic conditions (Mannering & Washburn, 2007). Its main objective is to achieve a balance between travel demand and road capacity through techniques such as signal regulation, intersection management, access control, and one-way systems, so as to improve efficiency while reducing congestion (McShane & Roess, 1990). Additionally, traffic engineering also plays a role in improving safety by reducing conflicts between vehicles through road design, speed regulation, and the appropriate use of signs and markings (Khisty & Lall, 2005).

3. Methods

This research is descriptive research with a quantitative approach aimed at objectively describing the condition of traffic congestion on MH Thamrin Street, Sentul. Data were collected through questionnaires, field observations, and other supporting data, with data collection conducted cross-sectionally at a specific point in time. The data obtained were then analyzed using descriptive statistics to identify the dominant factors causing congestion, the socioeconomic and environmental impacts produced, and alternative solutions that can be applied, so that the research results can serve as a basis for consideration in transportation planning and policy making. The overall research design is illustrated in Figure 1.

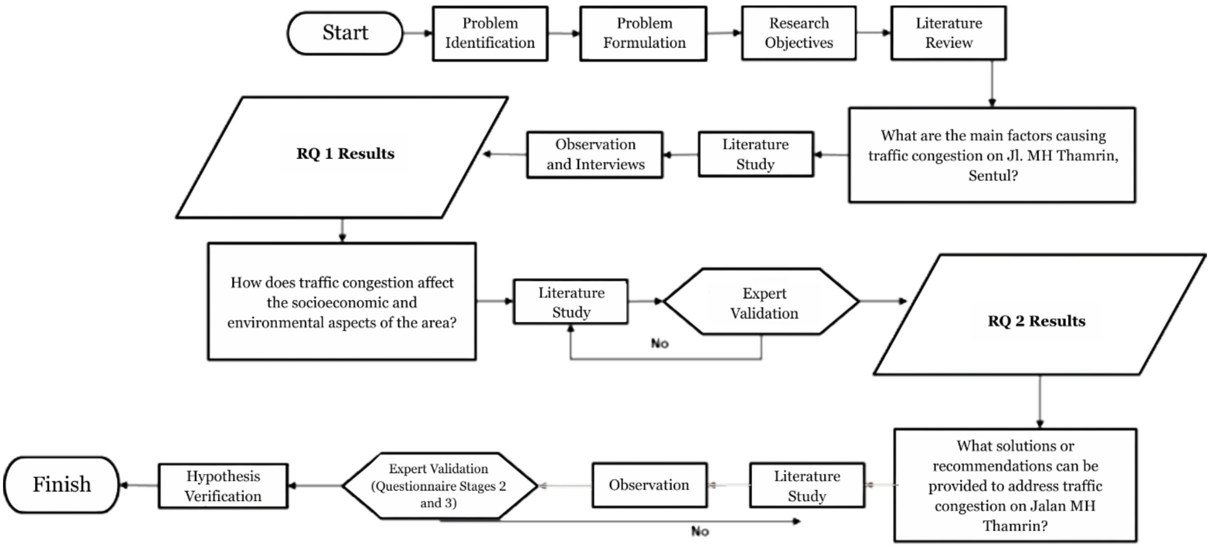

Figure 1. Research Design

3.1. Research Location and Time

This research was conducted on MH Thamrin Street, Sentul, which was selected because it has a high traffic density level and a strategic role as a connecting route for various community activities. Research activities took place from December to March 2026, covering preparation, data collection, processing, analysis, and report writing. Data collection was conducted on weekdays and weekends, particularly during congestion-prone hours, to obtain a representative picture of traffic conditions.

3.2. Population and Sample

The population in this study is all users and parties who carry out activities on MH Thamrin Street, Sentul, who are directly related to traffic conditions. Samples were drawn from a portion of this population using purposive sampling technique, in which respondents were selected based on certain criteria such as frequently passing through or having direct experience with congestion, so that the data obtained is more relevant and representative.

3.3. Research Variables and Operational Definitions

In this research, the dependent variable (Variable Y) analyzed is the Traffic Congestion Level. This variable was selected because it is the main phenomenon to be understood in the context of its causes and impacts, and serves as the basis for formulating transportation policy recommendations. According to Tamin (2000) and Directorate General of Land Transportation in BBC (2016), traffic congestion can be defined as a condition in which the volume of traffic passing through a road segment exceeds the capacity of that road, resulting in significant deceleration or stoppage of vehicle flow. The traffic congestion level can be measured through various physical indicators and road user perceptions. These indicators reflect both objective (quantitative) and subjective (qualitative) dimensions of congestion, thereby providing a comprehensive picture of the phenomenon under study. The operational definition and indicators of this variable are presented in Table 1.

Table 1. Competitiveness Dimensions as the Dependent Variable

Variable Y	Operational Definition	Indicators	Source
Traffic Congestion Level	A condition of imbalance between traffic volume and road capacity causing deceleration of vehicle mobility.	Vehicle Volume (veh/hours), Average Speed (km/hour), Delay Level (minutes), Road user perception	Tamin (2000) and Directorate General of Land Transportation in BBC (2016)

In this research, Variable X or the independent variables are the factors causing traffic congestion. The traffic congestion variable is multicausal in nature, meaning it is caused by a combination of road physical factors, user behavior, environmental conditions, and transportation policies. According to Tamin (2000), Sari and Basuki (2019), and Bogor Regency Transport Department (2021), the causes of congestion can be grouped into several main categories: road capacity, traffic volume, traffic management, road user behavior, and public transportation facilities. The independent variables and their corresponding indicators are summarised in Table 2.

Table 2. Factors as Independent Variables

Variable X	Sub-Variables / Indicators	Source
Road Capacity and Geometry	Road width, Number of lanes, Intersection conditions (estimated degree of saturation)	Tamin (2000); Directorate General of Land Transportation in BBC (2016)
Traffic Volume	Number of vehicles per hour, Dominance of private vehicles	Bogor Regency Transport Department (2021)
Traffic Management	Availability of signs and markings, Parking enforcement, Traffic engineering	Tamin (2000)
Road User Behavior	Illegal parking, Jaywalking, Undisciplined driving	Tamin (2000)
Availability of Public Transportation	Number and routes of public transport, Comfort level, Frequency and waiting time	Tamin (2000)
Area Activity	Presence of markets, commercial centers, or schools along the roadside, Entry and exit vehicle activity from roadside buildings	Tamin (2000)
Area Activity	Presence of markets, commercial centers, or schools along the roadside, Vehicle entry and exit activity from roadside buildings	Tamin (2000)

3.4. Data Collection Techniques

Data collection is a very crucial stage in research because the quality of the data obtained will determine the validity and reliability of the research results. The appropriate data collection technique allows researchers to obtain information that can be used empirically in answering the research problem formulation or research questions (RQ). In this study, a mixed-method approach was used with qualitative and quantitative data obtained through observation, questionnaires, interviews, and literature review.

Data collection to answer RQ1 was conducted through field observations, interviews with relevant parties, and distribution of questionnaires to road users and the public. This process was strengthened by the Delphi method involving practitioner and academic experts to identify and filter the main causal factors of congestion more objectively and systematically. Meanwhile, to answer RQ2, data were collected through Likert scale questionnaires given to residents, road users, and business actors, as well as in-depth interviews with community leaders and environmental experts. The Likert scale used in this study is presented in Table 3. This approach was used to analyze the impact of congestion on social, economic, and environmental aspects in the area.

Table 3. Likert Scale

Scale	Assessment	Description
1	Strongly Disagree	No influence
2	Disagree	Very low influence
3	Neutral	Moderate influence
4	Agree	Significant influence
5	Strongly Agree	Very significant influence

Data collection to answer RQ3 was conducted through literature review, interviews with transportation experts, and Delphi questionnaires in stages 2 and 3 involving the same experts as in RQ1. At this stage, respondents were asked to assess various alternative solutions based on aspects of feasibility, effectiveness, and sustainability. This approach aims to produce recommendations that are most technically and socially appropriate, avoid solutions that are difficult to implement in the field, and filter policies based on expert consensus.

3.5. Data Analysis

After all data were obtained through field observations, interviews, and questionnaire distribution, data analysis was conducted systematically to answer each research question. To answer RQ1 regarding the main causal factors of congestion on Jl. MH Thamrin, Sentul, qualitative-based content analysis was used on observation data, documentation, and interviews. This process includes a description or orientation stage to record field findings, data reduction to filter the most relevant information, and focus selection to identify dominant causes such as vehicle volume, illegal parking, unregulated intersections, and land use. These results were strengthened by Delphi stage 1 data from transportation experts.

To answer RQ2 regarding the impact of congestion on socioeconomic and environmental aspects, quantitative analysis was used based on questionnaire data with a Likert scale. The analysis includes data sufficiency tests, validity and reliability tests using Pearson Correlation and Cronbach Alpha, and normality and homogeneity tests using Kolmogorov-Smirnov and Levene Test. If the data are not normally distributed, non-parametric tests such as Mann-Whitney, Wilcoxon, and Kruskal-Wallis are used. Additionally, descriptive statistical analysis was used to describe the level of congestion impact on variables such as travel time, operational costs, air quality, and comfort.

Meanwhile, to answer RQ3 regarding congestion handling solutions, a combination of content analysis and advanced Delphi methods (stages 2 and 3) was used to obtain expert consensus on the most effective and implementable solutions. The analysis includes assessment of the effectiveness and feasibility of solutions, as well as comparison with practices in other cities (benchmarking). The final results were formulated in the form of recommendations compiled based on the level of Delphi consensus and re-validated to suit local conditions.

4. Results and Discussion

4.1. Research Results

4.1.1. Saturation Flow Calculation

Saturation flow is calculated based on the effective width of each road approach.

Table 4. Saturation Flow Calculation

Approach	Effective Width (m)	Saturation Flow S (pcu/hour)
West	13.5	8100
North	11.5	6900
East	9.0	5400
South	10.5	6300

Based on Table 4, the west approach has the largest effective width of 13.5 metres, resulting in the highest saturation flow of 8,100 pcu/hour. The north and south approaches have moderate widths of 11.5 metres and 10.5 metres, with saturation flows of 6,900 and 6,300 pcu/hour respectively. The east approach has the narrowest effective width of 9.0 metres, producing the lowest saturation flow of 5,400 pcu/hour. These results indicate that road width directly determines the capacity of each approach to accommodate vehicle flow, with wider approaches able to process a greater number of vehicles per hour.

4.1.2. Saturation Flow Ratio Calculation

Table 5. Saturation Flow Ratio

Approach	Q (pcu/hour)	S (pcu/hour)	Y
West	1467.1	8100	0.181
North	702.0	6900	0.102
East	1442.3	5400	0.267
South	669.6	6300	0.106

Total flow ratio:

$SY = 0.181 + 0.102 + 0.267 + 0.106 = 0.656$ .... (1)

Based on Table 5, the east approach records the highest flow ratio of 0.267, indicating that it bears the greatest traffic load relative to its capacity. The west approach follows with a ratio of 0.181, driven by its high traffic volume of 1,467.1 pcu/hour despite having the largest road width. The north and south approaches have comparatively lower flow ratios of 0.102 and 0.106 respectively, reflecting lower traffic demand on those approaches. The total flow ratio of 0.656 will be used as the basis for determining the optimal cycle time in the subsequent calculation.

4.1.3. Cycle Time Calculation

Cycle time is calculated using the Webster formula:

$C = \frac{1.5\,L + 5}{1 - \sum Y}$ .... (2)

$C = \frac{1.5\,(16) + 5}{1 - 0.656} = \frac{24 + 5}{0,.344} = 84$ seconds

4.1.4. Green Time Distribution

Total effective green time:

C - L = 84 - 16 = 68 seconds.. (3)

Green time distribution based on the proportion of flow ratios produces the following allocation:

Table 5. Green Time Distribution

Phase	Approach	Effective Green (seconds)
1	West	19
2	North	10
3	East	28
4	South	11

Table 6. Signal Timing Recapitulation

Approach	Green	Yellow	All Red	Red
West	19	3	1	61
North	10	3	1	70
East	28	3	1	52
South	11	3	1	69

As shown in Tables 5 and 6, the results of analysis using the Webster method produced an intersection cycle time of 84 seconds with 4 phases. The longest green time was given to the East and West approaches because they have the largest traffic volume compared to other approaches. The cycle time value is still within the recommended range for a four-phase signalized intersection, namely between 70 and 120 seconds, so it can be said that the resulting signal settings are still in optimal condition for regulating traffic flow at the research location.

4.1.5. Data Analysis Results

A. Descriptive Statistics Test Results

Table 7. Descriptive Statistics Test Results

Variable	Minimum	Maximum	Mean
Road Capacity (pcu/hour)	2839	4368	3484.75
Vehicle Flow (pcu/hour)	2248	2699	2487.25
Degree of Saturation	0.5310	0.8394	0.7314

Table 7 shows that the difference in values between variables is not too large, but the degree of saturation value approaching 1 in some segments indicates that traffic conditions at the research location are at a fairly high-density level. This indicates that road capacity is beginning to approach its maximum limit so that more optimal traffic management is needed to reduce the potential for congestion in the area.

B. Validity and Reliability Test Results

The r table value was obtained from the Pearson distribution with a number of respondents N = 91 at a significance level of a = 0.05, which is 0.206. An item is declared valid if the r count value > r table and the significance value < 0.05. Based on the test results in the table above, all items on both Variable X and Variable Y have r count values greater than r table and a significance value of 0.000 (< 0.05), so it can be concluded that all statement items in the research instrument are valid and can be used in further analysis.

Reliability testing was conducted using the Cronbach's Alpha method. A variable is declared reliable if the Cronbach's Alpha value is greater than 0.60. Based on the reliability test results in the table above, it is known that the Cronbach's Alpha value of Variable X is 0.755 and Variable Y is 0.735. Both values are greater than the minimum reliability threshold of 0.60, so it can be concluded that the research instrument has a good level of consistency and is declared reliable. Thus, all questionnaire items in this study are suitable for further analysis.

C. Data Normality Test Results

Table 8. Data Normality Test Results

One-Sample Kolmogorov-Smirnov Test		
		Unstandardized Residual
N		91
Normal Parameters[a,b]	Mean	.0000000
	Std. Deviation	.37240739
Most Extreme Differences	Absolute	.217
	Positive	.217
	Negative	-.189
Test Statistic		.217
Asymp. Sig. (2-tailed)		.075[c]

a. Test distribution is Normal.
b. Calculated from data.
c. Lilliefors Significance Correction.

Based on the normality test results using the One-Sample Kolmogorov-Smirnov Test displayed in the Table 8, a data count (N) of 91 was obtained with a residual mean value of 0.0000000 and a standard deviation of 0.37240739. The Kolmogorov-Smirnov test statistic value shows a value of 0.217 with a significance value (Asymp. Sig. 2-tailed) of 0.075. This significance value is greater than the significance level used, which is 0.05 (0.075 > 0.05), so it can be concluded that the residual data in this study are normally distributed. Thus, the normality assumption in regression analysis has been fulfilled so that the research data is suitable for use in subsequent statistical testing.

D. Multicollinearity Test Results

Multicollinearity testing can be viewed through the Tolerance and Variance Inflation Factor (VIF) values. A regression model is declared free from multicollinearity if the Tolerance value > 0.10 and the VIF value < 10.

Table 9. Multicollinearity Test Results

Variable	Tolerance	VIF	Note
Road Capacity and Geometry	0.117	1.008	No multicollinearity
Area Activity	0.158	1.898	No multicollinearity
Road User Behavior	0.192	3.310	No multicollinearity
Traffic Congestion Level	0.215	4.646	No multicollinearity

Based on the multicollinearity test results in Table 9, it is known that all independent variables have tolerance values greater than 0.10 and Variance Inflation Factor (VIF) values less than 10. The road capacity and geometry variable has a tolerance value of 0.117 and a VIF value of 1.008, while the area activity variable has a tolerance value of 0.158 with a VIF value of 1.898. Furthermore, the road user behavior variable shows a tolerance value of 0.192 and a VIF value of 3.310, while the traffic congestion level variable has a tolerance value of 0.215 and a VIF value of 4.646. These values indicate that there is no high relationship or strong correlation between the independent variables in the regression model. Thus, it can be concluded that this research model does not experience multicollinearity symptoms, so the independent variables used can be used together in regression analysis to explain their influence on the dependent variable.

E. Linear Regression Test Results

Table 10. Regression Test Results

	Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-2.902	1.349		-2.151	.034
	Road Capacity and Geometry	1.598	.281	.641	5.689	.000
	Area Activity	1.128	.173	.319	6.527	.000
	Road User Behavior	2.081	.293	.837	7.110	.000
	Traffic Congestion Level	.721	.094	.245	7.689	.000

Coefficients[a]

a. Dependent Variable: Y

Based on the results of multiple linear regression analysis in the Table 10, it is known that the model constant value is -2.902 with a significance level of 0.034 (< 0.05), which indicates that when all independent variables are considered constant, the traffic congestion level has a base value of -2.902. The road capacity and geometry variable has a regression coefficient of 1.598 with a significance of 0.000, meaning it has a positive and significant influence on the traffic congestion level, so that every increase in this variable will increase congestion assuming other variables remain constant.

Furthermore, the area activity variable has a coefficient of 1.128 with a significance of 0.000, which indicates that the higher the activity in an area, the traffic congestion level will also increase significantly. Meanwhile, road user behavior has the greatest influence with a regression coefficient of 2.081 and a significance of 0.000, which indicates that the behavior factor is the dominant contributor to increasing traffic congestion.

Overall, the analysis results show that the three independent variables, namely road capacity and geometry, area activity, and road user behavior, simultaneously have a positive and significant influence on the traffic congestion level. This confirms that an increase in each of these factors will be followed by an increase in the traffic congestion level on the studied road segment.

4.2. Discussion

4.2.1. Main Causal Factors of Traffic Congestion on MH Thamrin Street, Sentul

Based on the research results obtained through quantitative and qualitative analysis, it is known that the main causal factors of congestion on MH Thamrin Street, Sentul are influenced by road capacity and geometry, area activity, and road user behavior. The results of regression analysis show that the three variables have a significant influence on the traffic congestion level. This is evidenced by the significance values of all variables that are below 0.05, so statistically they can be stated to influence the congestion level variable. Additionally, field observation results show that vehicle density occurs mainly during morning and afternoon peak hours, when community mobility toward workplaces, schools, and economic activity centers increases. Qualitative findings through interviews also reinforce these results, where informants stated that the increasing number of vehicles and entry and exit activity in the area are the main causes of congestion on that road segment.

This phenomenon is in line with the road capacity concept explained in the Indonesian Road Capacity Manual (MKJI) which states that congestion will occur if the volume of vehicles passing through exceeds the available road capacity. Road capacity is influenced by various factors such as road width, number of lanes, and side friction from activities around the road (Directorate General of Highways, 2021). If road conditions cannot accommodate the number of vehicles passing through, the road level of service will decline and cause vehicles to move at low speed.

In addition to road capacity, area activity also has a considerable influence on the occurrence of traffic congestion. The Sentul area is one of the regions that has experienced rapid development in recent years, particularly in the trade, service, and residential sectors. The development of this area has caused increased community mobility so that the volume of vehicles passing through MH Thamrin Street has become increasingly high. This is in line with research stating that the increase in community travel activity in urban areas has a significant contribution to the traffic congestion level (Kan et al., 2024).

The development of urban areas can also influence community mobility patterns. The more developed an area, the higher the intensity of population movement in that area. This condition causes increasing transportation needs that ultimately impact traffic density on main roads. Previous research shows that the growth of urban areas in the Sentul region has a close relationship with the increase in population mobility that impacts the increasing volume of vehicles on the road.

In addition to infrastructure factors and area activity, road user behavior also plays a role in worsening traffic congestion conditions. Based on observation results, road users were still found not complying with traffic rules such as stopping arbitrarily, using the shoulder of the road, or being disorderly when passing through intersections. Such behavior can disrupt the smooth flow of vehicles, thereby worsening the congestion conditions that have already occurred. Research on traffic behavior in urban areas shows that traffic violations committed by road users can increase the risk of congestion and reduce the level of transportation safety. The lack of discipline among road users in complying with traffic rules can cause vehicle movement conflicts that ultimately slow down traffic flow.

Furthermore, the increase in the number of private vehicles is also one of the factors influencing the level of traffic density. People tend to choose to use private vehicles because they are considered more flexible compared to public transportation. This condition causes the number of vehicles on the road to increase significantly, thereby putting pressure on the available road capacity. Research conducted in various cities shows that the increase in private vehicle use has a strong relationship with the increase in traffic congestion levels in urban areas. Socioeconomic factors such as population growth, increasing community income, and urban area development are factors that drive the increase in private vehicle ownership. Thus, traffic congestion on MH Thamrin Street is not only caused by physical road factors, but is also influenced by social, economic, and community behavior factors.

4.2.2. Impact of Traffic Congestion on Social, Economic, and Environmental Aspects

Based on the research results obtained through quantitative analysis and interviews, it is known that traffic congestion on MH Thamrin Street has an impact on various aspects of community life, particularly in social, economic, and environmental aspects. The research results show that congestion causes increased travel time, increased transportation costs, and reduced community comfort in carrying out daily activities. Interviewed informants also stated that congestion often causes delays in going to work or conducting other activities.

Traffic congestion is fundamentally a phenomenon that is not only related to the transportation system but also has a wide impact on the socioeconomic conditions of the community. Research shows that congestion can cause increased stress levels for road users because travel time becomes longer compared to normal conditions (Dadashova et al., 2021). This condition can affect the quality of life of the community, especially for those who have to travel long distances every day.

From an economic aspect, traffic congestion can increase transportation operational costs. Vehicles stuck in congestion will consume more fuel because the vehicle engine remains on even though the vehicle is moving very slowly. This condition certainly increases community spending on transportation needs. Additionally, congestion can also hinder economic activity in an area. The distribution time of goods becomes longer, which can affect the smooth flow of trading and industrial activities. Research shows that traffic congestion can cause quite large economic losses due to reduced transportation efficiency and increased logistics costs (Fattah et al., 2022).

Congestion can also affect labor productivity. When workers have to spend more time on the road, the available working time decreases. This condition can impact reduced productivity and efficiency of economic activities in urban areas. From an environmental aspect, traffic congestion also causes increased levels of air pollution due to vehicle exhaust emissions. Motor vehicles produce various types of pollutants such as carbon monoxide and nitrogen oxides that can contaminate the air. If vehicles are stuck in congestion for a long time, the exhaust emissions produced will increase even further.

Research shows that traffic density has a direct relationship with the increase in air pollution levels in urban areas. The higher the congestion level, the greater the contribution of the transportation sector to air pollution (Rahman et al., 2022). In addition to air pollution, congestion also causes increased noise levels in the surrounding road environment. Vehicle sounds and horns used by riders can cause disturbances to people living in the vicinity of that area. Thus, traffic congestion on MH Thamrin Street does not only impact the transportation system, but also affects the social, economic, and environmental conditions of the community as a whole.

4.2.3. Solutions and Recommendations for Handling Congestion on MH Thamrin Street

Based on the research results obtained through observation, data analysis, and interviews with informants, it is known that handling congestion on MH Thamrin Street requires a comprehensive approach through various transportation policies. The research results show that more effective traffic regulation, increasing road capacity, and improving road user discipline are some of the steps that can be taken to reduce the congestion level in the area.

One effort that can be made is to improve traffic management in the area, especially during peak hours. Good traffic regulation can help optimize road capacity utilization so that vehicle flow can move more smoothly. The urban congestion identification guidelines also state that traffic management is an important step in reducing vehicle density on roads (Directorate General of Land Transportation, 2016).

Additionally, structuring activities around the road also needs to be done to reduce side friction that can slow down vehicle flow. Parking activities on the road body and vehicles entering and exiting commercial areas often become the cause of congestion. Therefore, better parking area regulation is needed so as not to disrupt traffic flow. Increasing road capacity can also be one of the long-term solutions. Road widening or construction of alternative routes can help reduce the traffic load on main roads so that the potential for congestion can be minimized.

In addition to infrastructure development, the development of public transportation systems can also be an important strategy in reducing private vehicle use. If the community has access to comfortable and efficient public transportation, the dependence on private vehicles can be reduced. Research shows that the development of public transportation can help reduce congestion levels in urban areas by diverting some travel from private vehicles to public transportation (Moyano et al., 2021).

Furthermore, increasing public awareness in complying with traffic rules is also very important in creating smooth vehicle flow. Road user discipline can help reduce vehicle movement conflicts that often become the cause of congestion. Evaluation of transportation policies also needs to be carried out periodically so that the government can adjust congestion handling strategies to continuously developing traffic conditions. The regional traffic evaluation report shows that periodic monitoring of traffic conditions is very important in formulating effective transportation policies (Bogor Regency Transportation Agency, 2021). Thus, handling congestion on MH Thamrin Street requires cooperation between the government, relevant authorities, and the community so that the solutions implemented can run effectively and sustainably.

5. Conclusion

This research shows that traffic congestion on MH Thamrin Street, Sentul is influenced by three main factors, namely road capacity and geometry, area activity, and road user behavior. Quantitatively, the three factors are proven to have a significant influence on the congestion level, while qualitatively it was found that the high volume of vehicles during peak hours, vehicle entry and exit activity in commercial areas, and the low discipline of road users are the main causes that worsen traffic conditions.

The impacts of congestion that occur are not only felt in one aspect but extend to social, economic, and environmental aspects. From the social side, congestion increases stress levels and reduces community interaction time. From the economic side, congestion causes increased transportation operational costs and hinders trading and distribution activities. Meanwhile from the environmental side, congestion contributes to increased air pollution and noise due to high vehicle emissions and continuous traffic density.

To overcome these problems, comprehensive handling efforts are needed through improved traffic management especially during peak hours, structuring area activities such as regulating parking and vehicle entry and exit access, and increasing community awareness in complying with traffic rules. Additionally, the development of public transportation and periodic evaluation of traffic policies are also important steps in reducing congestion levels. Therefore, the government and relevant agencies are expected to strengthen traffic regulation at vulnerable points, carry out more orderly area structuring, and encourage road user discipline so that traffic flow can run more smoothly and sustainably. This study has several limitations, including its focus on a single corridor, a limited observation period, and reliance on self-reported data. Future studies are encouraged to expand the spatial scope and incorporate longer observation periods for more comprehensive findings.

6. References

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