LEADER
Civil Engineering and Architecture Journal

Civil Engineering and Architecture Journal Vol 2 No. 2 (2024) 3026-622X
DOI 10.37253/leader.v2i1.9543

ANALYSIS OF SPEED AND TRAFFIC DENSITY OF JALAN RAJAGALUH - MAJALENGKA

M. Nanda Fajar Arij Rachman[1], Indrastuti[2].
[1]Civil Engineering, Faculty of Engineering, Universitas Majalengka
[2]Faculty of Civil Engineering & Planning, Universitas Internasional Batam, Indonesia
Email korespondensil: nandafajar298@gmail.com

ARTICLE INFO

Keywords:

Speed
Traffic
Density

ABSTRACT

Concerns about the density of roads and acceleration have been brought up globally by the increase in motorized vehicles, especially in urban areas where infrastructure development is still in progress. The issues of road density and congestion are the main focus of this study, with a particular concentration on road speeds on Pangeran Muhammad's road, which leads to Cirebon Street in Rajagaluh, about 100 meters away. This study's principal goal is to ascertain the average speed and vehicle density on the road by applying qualitative research techniques and on-the-ground observations. We looked at the volume of traffic, the passing velocity, and the density of the road. to gather primary data. The quantity of automobile traversing was ascertained using Traffic Counter software and Microsoft Excel 2021.; MKJI 1997 provided secondary data. In street data analysis involving two-way double-track (2/2 UD), cut line road markings designate the column separator, and each column has a width of ± 3.5 meters. The traffic and congestion on the road under review are reflected in the density data. Monitoring and evaluating these parameters is required to obtain data regarding traffic density and road performance in the area under study. The data indicates that most vehicles crossed the reviewed street between 4 and 5 p.m., when the highest vehicle volume occurred, with a peak of 2505.6 vehicles per hour (Smp/Hour). Additionally, observations show that on Sunday, between 11 a.m. and 12 p.m., when traffic is smoother, vehicles reach their average peak speed of 50.51 km/h, allowing for relatively high speeds.

1. Introduction

Speed and road density have become concerns worldwide in the era of modern mobility. Across the world, the increase in the number of motor vehicles has led to highway density problems, leading to severe congestion, impeding productivity, and endangering the environment. Based on global research and analysis, road design, traffic management, and low-emission vehicle usage trends are some factors that impact speed and traffic density. Many countries have adopted new approaches such as technology-based transport networks, clever road construction, and emissions reduction to solve this issue. In present-day India, traffic congestion is detected with the help of human eyes and with their response to weather, road conditions, and other external factors [1]. Even though efforts have been made globally, this problem still needs to be solved in efforts to increase transportation efficiency and maintain environmental balance.

The problem of speed and road density is a significant problem that affects the mobility and growth of the region as a whole. The rise in traffic has caused highway congestion in some places, which hurts the ease of transportation and the quality of life of the people there. This issue is largely influenced by factors such as the design of roads, traffic management policies, economic growth, and urbanization

in specific areas. Therefore, finding the right solutions to these problems, such as promoting smart road infrastructure and sustainable transport, requires in-depth analysis and regional cooperation. To improve traffic safety, in 2012, the Shanghai Municipal Government started to compile a Transportation White Paper that identified safety as a primary objective and aimed to reduce the fatality rate by 25% within the next ten years [2]. Collaboration between local governments, transport agencies, and private companies is crucial to achieving effective solutions to increase mobility and minimize the adverse impact in specific areas.

The speed and density of roads are a worrying issue in Indonesia. The congestion and traffic density in big cities, especially the City of Makassar, with its large population and rapid growth of motor vehicles, are problems. Frequent traffic jams on Makassar Highway, mainly during busy hours, are triggered by the rapid growth of private vehicles [3]. Long-term congestion disrupts production, environment, and quality of life. To address this problem, the Indonesian government has improved road infrastructure and public transportation systems. In addition, new technologies such as traffic sensors and transport-based applications have improved traffic management. However, a more efficient solution in Indonesia requires a thorough examination of the problem of speed and road density.

Traffic speed and density are significant parameters impacting road performance and service level. An accurate and representative traffic data analysis is required to determine the relationship between speed and traffic density. The conclusions drawn from the research show that the relationship between speed and traffic density on the street follows linear and logarithmic patterns. [4]. Capacity and traffic performance of a highway are interdependent factors used to determine its effectiveness.

This paper aims to investigate issues related to speed and density on roads in the context of infrastructure development and urbanization, as well as problems of density and speed of roads discussed in this paper. Analyzing these problems aims to understand their impact on urban mobility and the environment. The research also seeks solutions and suggestions that governments and stakeholders can use to improve transport efficiency and reduce the adverse effects of highway density. Therefore, the aim is to better understand mobility and urban development issues. So the title of this paper is "Analysis of Speed and Density of Traffic on Roads: Case Study of Pangeran Muhammad Street."

2. Literatur Review

2.1 Traffic

Traffic is the Flow of vehicles and people moving on a regulated highway—all kinds of transport involving people and goods comprising pedestrians, public transport, and private vehicles. Modern transportation systems encompass road vehicles, rail transport, and various shared travel modes that have emerged in recent years, including online ride-hailing, bike-sharing, and e-scooter sharing. Traffic signals, alarms, and traffic regulations regulate traffic to be safe and efficient. In urban planning and transportation infrastructure development, traffic is crucial to addressing problems of road density, travel time, and environmental impact. Early intervention based on traffic forecasting is seen as the key to improving the efficiency of a transportation system and alleviating transportation-related problems [6]. Therefore, to develop a city or urban area, it is essential to understand regulations, traffic dynamics, and creative solutions to manage them.

Several sections form the traffic system, each responsible for regulating the number of vehicles and pedestrians on the highways. The highway serves as the main route of vehicle movement, and traffic signals regulate the Flow of vehicles and pedestrians at the crossroads. Part of the traffic alarm is to give clear visual clues about rules and important information to road users. Separate road column sections

are made for different types of vehicles or speeds, which helps regulate traffic more efficiently. Finally, the sidewalk and pedestrian facilities ensure a harmonious interaction between vehicles and pedestrians and make a safe area for people walking. A functioning traffic system consists of a combination of these components that work together well. Scholars' research focuses on considering the correlation between road sections in traffic prediction models due to the complex spatiotemporal correlations between road sections. [7]

Traffic functions include regulating and managing the ow of both vehicles and pedestrians to create an effective and secure mobility system. Road safety involves the road quality defined by the level of accidents and reflecting the degree of safety of traffic participants from road traffic accidents and their consequences [8]. First, traffic helps the movement of people and goods, enables interregional connectivity, and supports economic activity. Second, traffic also helps urban growth and building transportation infrastructure, an important component of urban planning. Traffic flows must be regulated through traffic signals, alarms, and navigation systems to stay organized and avoid chaos.

Moreover, traffic authorities' rules, safety standards, and law enforcement improve road safety. Lastly, traffic shows mobility and progress in an area and reflects social, economic, and infrastructure progress in a society. Reduced congestion and smooth traffic flow are also likely to improve safety and reduce psychological stress on drivers. Concentrating on the safety issue, our objective in this paper is to demonstrate that researchers are beginning to understand the relationship between safety and improved traffic flow [9].

2.2 Speed and traffic density

The speed of a vehicle is not only influenced by the vehicle's velocity directly ahead. There are many other possible sources of influence, including the driver's determination to maintain her desired speed [10]. The ratio between the distance a vehicle has traveled and the time it takes to travel the distance is called road speed. This definition covers the speed of the vehicle. Things like road conditions, traffic rules, and the speed of other vehicles around it influence the speed of a street. The speed of a highway greatly affects the efficiency of transportation, traffic safety, and the experience of road users, so it is vital for planning and managing the transportation system. Road safety authorities often recommend time headways of three seconds to account for drivers' preparedness to respond to avoid a crash [11].

Understanding real traffic behavior requires quantifying basic traffic flow characteristics such as speed, ow, and density [12]. Road density refers to the number of vehicles that cross or are in a road area in a given period. The number of vehicles unit of road length or surface area can be calculated to determine road density. Planning, managing, and improving transport infrastructure to optimize mobility depends on a good understanding of road density, which is a significant indicator in evaluating the capacity of a highway, which can affect traffic performance and the level of road service. High levels of road density can lead to congestion, longer travel times, and a decrease in the transportation system's efficiency. Other studies found that driveway density, unsignalized minor street density, and different media types are significantly correlated with crash frequency [13]

Public health and safety concerns have always been central to planning [14]. The performance and safety of the transportation system are heavily influenced by road speed and density. First, high speeds can increase the risk of traffic accidents; however, despite the long experience of rules for better safety in traffic, drivers' behavior could be safer [15], especially if it needs to be balanced with proper infrastructure and traffic regulations. Second, uncontrolled speed can worsen congestion and transportation efficiency, increase travel time, and consume more fuel. Third, high road density can

impede smooth ow and lower road service levels. Lastly, a safe, sustainable, and efficient transportation system depends on speed and density management. The problems of road accident rates currently belong to the most significant health and social policy problems of the countries on all continents [16].

2.3 Roads

A street refers to a particular traffic section stretching between two specific locations. It is a term that refers to the length of a road that can consist of one or more paths and can include components such as intersections, crossings, and other supporting facilities. The toll road, the main artery, the local road, and other types are some streets, depending on their function and the characteristics of their environment. Roads are a significant component of transportation systems because they connect different locations. Road planning and management requires a thorough understanding of spatial planning, capacity, and special features that affect pedestrian and vehicle movement. Driving a vehicle is essential to our daily lives, but traffic congestion increasingly leads to significant delays [17].

The highway network has a variety of routes designed to meet specific purposes and mobility. The issues raised by highway transportation will likely intensify as mobility needs increase in the U.S. and globally [18]. Firstly, toll roads are designed to make fast and efficient travel, with toll facilities supporting long-distance travel. Secondly, an arterial road is the main road that connects economic and social activity centers within a city or region. Thirdly, a local road is a road that serves the needs of local transport, such as roads in residential neighborhoods or wagons. Lastly, special roads, like buses, bicycle roads, or sidewalks, are highways designed for special needs, like prioritizing public transport or enhancing sustainable mobility. Understanding this type of street is important to build a city space and an efficient transportation system.

Street networks are considered one significant component of urban structures that serve various urban functions [19]. Wide roads have a specific purpose to support the survival and efficiency of the transportation system. First, the highway serves as a fast and efficient route that connects significant cities or regions, accelerates long-distance travel, and reduces the density of non-custom roads. Second, the arterial route functions as the main route in the urban or regional highway system, connecting the centers of economic and social activity and distributing local traffic. Third, the circular road surrounds or circles a region, giving traffic around it. Finally, special routes, such as buses or bicycles, aim to improve environmentally friendly mobility by prioritizing public transport or cycling, reducing emissions and congestion. Road network planning and management requires understanding this specific function for a robust and sustainable transportation system.

3. Methodology

3.1 Types of Research

Qualitative research is research that usually uses analysis and is descriptive. In qualitative research, data are used to decide which way interpretation should move forward, using data to generate hypotheses and new research questions [20].

3.2 Research Location

The location of this research is at Rajagaluh, that is, Pangeran Muhammad's road, which will lead to Cirebon Street about $\pm$100 meters. To be more precise, it is in Figure 1 Research Location.

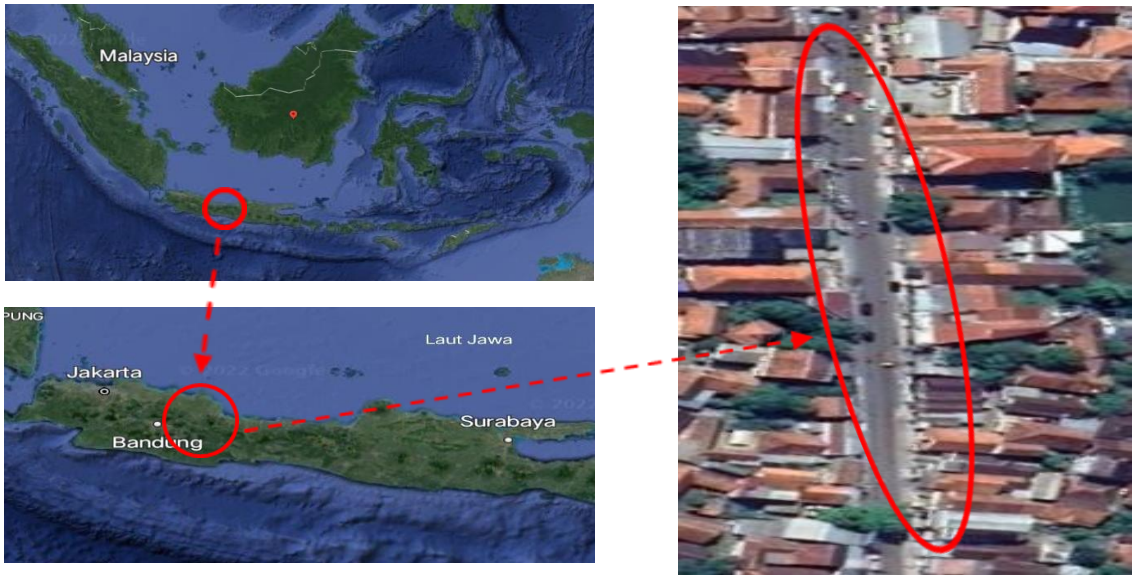

Figure. 1 Research Location

3.3 Data collection

The data collected is in the form of primary and secondary data. Primary data is obtained by direct survey at the research location to obtain a real picture of the situation and conditions. Meanwhile, secondary data is data obtained by collaborating with related agencies, such as research location, vehicle travel time data, and road situation maps. This research was carried out on Monday, 18 December 2023, at 08.00 WIB – 18.00 WIB, Thursday, 21 December 2023, at 08.00 WIB – 18.00 WIB, and Sunday, 24 December 2023, at 08.00 WIB – 18.00 WIB.

4. Result and Discussion

4.1 Road Segment Data

Pangeran Muhammad Road is an artery. Light goods transport vehicles and buses for city services can be allowed to use this road. The road data is as follows:

1. Two-lane two-way road (2/2 UD).
2. The width of each lane is ±3.5 meters
3. Lane direction dividers consist of road markings in broken lines.

4.2 Road Volume Analysis Results

Vehicle volume is a term used to describe the number of vehicles that all pass through a road section or segment within a certain period, usually measured in units of vehicles per hour (pcu/hour). Measuring vehicle volume is crucial for understanding traffic flow in a particular place. In transportation planning and management, vehicle volume data is very important. Vehicle volume helps determine the level of traffic load that occurs on the road section under review. Road capacity analysis can be done by knowing how many vehicles pass through it. The results of vehicle volume measurements are in Table 1.

Table. 1 Density Volume Test Results

Senin	Jumlah Kendaraan (ken/jam)					Jumlah kendaraan (Smp/jam)				
Waktu	LV	HV	MC	UM	Total	LV	HV	MC	UM	Total
07.00-08.00	998	19	1227	23	2257	988	24,7	490,8	18,4	1521,9
08.00-09.00	1238	15	1677	25	2955	1238	19,5	670,8	20	1792,9
12.00-13.00	1224	25	1910	13	3172	1224	32,5	764	10,4	2030,9
13.00-14.00	1176	17	1449	19	2661	1176	22,1	579,6	15,2	1792,9
16.00-17.00	983	19	1965	27	2994	983	24,7	786	21,6	1815,3
17.00-18.00	1283	23	1687	27	3020	1283	29,9	674,8	21,6	2009,3
Kamis	Jumlah Kendaraan (ken/jam)					Jumlah kendaraan (Smp/jam)				
Waktu	LV	HV	MC	UM	Total	LV	HV	MC	UM	Total
07.00-08.00	1186	30	1354	23	2593	1186	39	541,6	18,4	1785
08.00-09.00	975	7	1379	9	2370	975	9,1	551,6	7,2	1542,9
12.00-13.00	966	28	1718	26	2738	966	36,4	687,2	20,8	1710,4
13.00-14.00	953	18	1061	21	2053	953	23,4	424,4	16,8	1417,6
16.00-17.00	1219	26	1589	19	2853	1219	33,8	635,6	15,2	1903,6
17.00-18.00	994	35	1717	32	2778	994	45,5	686,8	25,6	1751,9
Minggu	Jumlah Kendaraan (ken/jam)					Jumlah kendaraan (Smp/jam)				
Waktu	LV	HV	MC	UM	Total	LV	HV	MC	UM	Total
07.00-08.00	952	14	1165	24	2125	925	18,2	466	16,8	1426
08.00-09.00	14,6	13	2416	46	3881	1406	16,9	966,4	36,8	2426,1
12.00-13.00	1286	16	2043	13	3358	1286	20,8	817,2	10,4	2134,4
13.00-14.00	1485	22	2081	29	3617	1485	28,6	832,4	23,2	2369,2
16.00-17.00	1499	14	2441	30	3954	1499	18,2	964,4	24	2505,6
17.00-18.00	1455	37	2336	30	3858	1455	48,1	934,4	24	2461,5

Source: MKJI 1997

Data shows that the highest vehicle volume reached 2505.6 vehicle units per hour (Smp/hour) between 16.00 and 17.00 WIB when many vehicles passed the road section under review. High traffic volume at these hours can indicate rush hour or heavy traffic hours because many vehicles are passing through the road at that time.

4.3 Vehicle Speed Analysis Results

It is very important to know vehicle speed patterns during various hours and days to understand traffic flow characteristics on Jalan Pangeran Muhammad. Information about these speed patterns can be used to determine peak hours and potential congestion and plan more efficient traffic arrangements to improve road smoothness and safety. The results of speed measurements, transportation planning, and traffic management can be used. The results of the traffic speed test are in Table 2.

Table. 2 Vehicle Speed Test Results

No	Senin	Jarak Tempuh	Jumlah Data	Waktu Tempuh	Space Mean Speed	
	Waktu	(m)	pengamatan	(Detik)	(m/det)	(km/jam)
1	07.00-08.00	100	12	8,63	11,59	41,74
2	08.00-09.00	100	12	7,26	13,78	49,62
3	12.00-13.00	100	12	7,88	12,69	45,69
4	13.00-14.00	100	12	9,35	10,75	38,52
5	16.00-17.00	100	12	8,76	11,42	41,65
6	17.00-18.00	100	12	7,69	13,59	46,81
No	Kamis	Jarak Tempuh	Jumlah Data	Waktu Tempuh	Space Mean Speed	
	Waktu	(m)	pengamatan	(Detik)	(m/det)	(km/jam)
1	07.00-08.00	100	12	7,31	13,67	49,22
2	08.00-09.00	100	12	9,51	10,52	37,88
3	12.00-13.00	100	12	8,92	11,21	40,37
4	13.00-14.00	100	12	7,97	12,55	45,18
5	16.00-17.00	100	12	7,24	13,81	49,72
6	17.00-18.00	100	12	9,14	11,06	39,8
No	Minggu	Jarak Tempuh	Jumlah Data	Waktu Tempuh	Space Mean Speed	
	Waktu	(m)	pengamatan	(Detik)	(m/det)	(km/jam)
1	07.00-08.00	100	12	8,16	12,25	44,11
2	08.00-09.00	100	12	8,26	12,11	43,56
3	12.00-13.00	100	12	7,13	14,03	50,51
4	13.00-14.00	100	12	7,55	13,25	47,68
5	16.00-17.00	100	12	7,29	13,72	49,41
6	17.00-18.00	100	12	10,36	9,65	34,75

Source: MKJI 1997

Observations show that vehicles reach the highest average speed of 50.51 km/h on Sundays from 11.00 to 12.00 WIB when traffic tends to be smoother, and vehicles can move at relatively high speeds. At the same time, the lowest average vehicle speed occurred at 17.00 to 18.00 WIB, amounting to 34.75 km/hour. During this period, vehicle speeds decrease due to the possibility of vehicle volume decreasing.

4.4 Vehicle Density Analysis Results

Measuring vehicle traffic density on a road segment within a certain period is important. Space average velocity (Us) is measured in kilometers per hour, volume (Q) is measured in vehicles per hour (Smp/hour), the flow velocity is also measured in vehicles per hour (Smp/hour), and density is measured in-vehicle units per kilometer per hour. All these parameters are used to perform this traffic density test. Volume (Q) is the number of vehicles that pass through a road segment in one hour based on the traffic intensity tested on that road segment. This volume of data is very important to know the amount of traffic crossing the road. The rate of Flow is the number of vehicles crossing a lane in one hour. This parameter is also helpful for understanding the traffic intensity on the tested road section. The results of the traffic density test are in Table 3.

Table. 3 Vehicle Density Test Results

No	Senin	Space Mean Speed	Volume (Q)	Rate Of Flow	Kepadatan (D)
	Waktu	(Us) (Km/Jam)	(smp/jam)	(smp/jam)	(smp/jam)
1	07.00-08.00	41,74	1521,9	6087,61	145,9
2	08.00-09.00	49,62	1948,3	6087,61	157,1
3	12.00-13.00	45,69	2030,9	8123,61	177,8
4	13.00-14.00	38,52	1792,9	7171,61	186,2
5	16.00-17.00	41,11	2009,3	8037,21	176,7
6	17.00-18.00	46,81	1815,3	7261,21	171,7
No	Kamis	Space Mean Speed	Volume (Q)	Rate Of Flow	Kepadatan (D)
	Waktu	(Us) (Km/Jam)	(smp/jam)	(smp/jam)	(smp/jam)
1	07.00-08.00	49,22	1785	7140,01	145,1
2	08.00-09.00	37,88	1542,9	6171,61	162,9
3	12.00-13.00	40,37	1710,4	6841,61	169,5
4	13.00-14.00	45,18	1417,6	5670,41	125,5
5	16.00-17.00	49,72	1903,6	7614,41	153,1
6	17.00-18.00	39,79	1751,9	7007,61	176,1
No	Minggu	Space Mean Speed	Volume (Q)	Rate Of Flow	Kepadatan (D)
	Waktu	(Us) (Km/Jam)	(smp/jam)	(smp/jam)	(smp/jam)
1	07.00-08.00	44,11	1426	5704,01	129,3
2	08.00-09.00	43,56	2426,1	9704,41	222,8
3	12.00-13.00	50,51	2134,4	8537,61	169,1
4	13.00-14.00	47,68	2369,2	9476,71	198,7
5	16.00-17.00	49,41	2505,6	10022,41	202,9
6	17.00-18.00	34,75	2461,5	9846,01	283,3

Source: MKJI 1997

The test results show that vehicles reach the highest density of 283.3 PCU/hour on Sundays from 17.00 to 18.00 WIB when traffic tends to be denser and vehicles can move slowly at relatively low speeds. At the same time, the lowest density of vehicles occurred on Thursday, 13.00 to 14.00 WIB, amounting to 125.5 PCU/hour. During this period, vehicle density appeared to decrease.

5. Conclusion

Based on data analysis and discussions that have been tested, vehicle volume between 16.00 and 17.00 WIB, vehicle volume reaches its peak, reaching 2505.6 vehicle units per hour, which indicates heavy traffic hours. The results of vehicle speed analysis show that on Sunday, the average vehicle speed reaches its highest peak at 11.00 to 12.00 WIB, amounting to 50.51 km/hour, indicating that traffic is relatively smooth. At the same time, the lowest average speed was recorded at 17.00 to 18.00 WIB, amounting to 34.75 km/h, indicating that vehicles decreased at that time, perhaps due to decreased vehicle volume. As well as the density of vehicles on Jalan Pangeran Muhammad, the highest density was 283.3 pcu/hour on Sunday from 17.00 to 18.00 WIB, and the lowest density was on Thursday from 13.00 to 14.00 WIT, amounting to 125.5 pcu/hour.

References

[1] J. N. B. &. L. M. Yoon, "Surface street traffic estimation.," *In Proceedings of the 5th international conference on Mobile systems, applications and services,* pp. 220-232, 2018.

[2] X. Wang, Q. Zhou, J. Yang, S. You, Y. Song and M. Xue, "Macro-level traffic safety analysis in Shanghai, China.," *Accident Analysis & Prevention,* vol. 125, pp. 249-256, 2019.

[3] Vogel and K., "What characterizes a “free vehicle” in an urban area?.," *Transportation research part F: traffic psychology and behaviour,,* vol. 5, pp. 15-29, 2018.

[4] Rahman, S. I., A. K., A. Massara and &. Gani, "Analisis Hubungan Kecepatan, Volume, dan Kepadatan Lalu Lintas Pada Ruas Jalan Antang Raya Makassar.," *Jurnal Ilmiah Mahasiswa Teknik Sipil,* vol. 1, no. 3, pp. 110-114, 2019.

[5] C. Manchanda, R. Rathi and N. Sharma, "Traffic density investigation & road accident analysis in India using deep learning.," *In 2019 international conference on computing, communication, and intelligent systems (ICCCIS),* pp. 501-506, 2019.

[6] T. L. Haven and D. L. Van Grootel, "Preregistering qualitative research," *Accountability in research, 26(3),* pp. 229-244, 2019.

[7] Jiang, W., Luo and J., "Graph neural network for traffic forecasting: A survey.," *Expert Systems with Applications,* vol. 207, p. 2, 2022.

[8] Jiang, W., Luo and J., "Graph neural network for traffic forecasting: A survey.," *Expert Systems with Applications,* vol. 207, p. 2, 2022.

[9] B. Huang, Zhang, Y., Lu, L., Lu and J. J., "A new access density definition and its correlation with crash rates by microscopic traffic simulation method.," *Accident Analysis & Prevention,* vol. 64, pp. 111-122., 2022.

[10] F. L. W. L. J. S. C. M. Y. W. J. &. X. H. Hu, "Urban function as a new perspective for adaptive street quality assessment.," *Sustainability,* vol. 12, p. 1296, 2020.

[11] Haven, L., Tamarinde, Grootel, Van, Leonie and Dr, "Preregistering qualitative research.," *Accountability in research,* vol. 26, no. 1, pp. 229-244, 2019.

[12] S. Haryati and &. Najid, "Analisis Kapasitas dan Kinerja Lalu Lintas Pada Ruas Jalan Jenderal Sudirman Jakarta," *JMTS: Jurnal Mitra Teknik Sipil,* vol. 4, pp. 95-108, 2021.

[13] K. Goniewicz, Goniewicz, M., Pawłowski, W., Fiedor and P., "Road accident rates: strategies and programmes for improving road traffic safety.," *European journal of trauma and emergency surgery,* vol. 42, pp. 433-438, 2018.

[14] Golob, T. F., Recker, W. W., Alvarez and V. M., "Freeway safety as a function of traffic flow.," *Accident Analysis & Prevention,* vol. 36, pp. 933-946., 2019.

[15] X. L. W. X. C. &. Z. X. Fu, "Short-term traffic speed prediction method for urban road sections based on wavelet transform and gated recurrent unit," *Mathematical Problems in Engineering,,* vol. 2020, p. 1, 2020.

[16] Ewing, R., Dumbaugh and E., "The built environment and traffic safety: a review of empirical evidence.," *Journal of Planning Literature,* vol. 23, pp. 347-367, 2019.

[17] R. K. Biswas, R. Friswell, Olivier, J., Williamson, A., Senserrick and T., "A systematic review of definitions of motor vehicle headways in driver behaviour and performance studies.," *Transportation research part F: traffic psychology and behaviour,* vol. 77, pp. 38-54, 2024.

[18] Batrakova, A., Gredasova and O., " Influence of road conditions on traffic safety.," *Procedia engineering,* vol. 134, pp. 196-204, 2019.

[19] Bartle, J. R., Devan and J., "Sustainable highways: destination or mirage?.," *Public Works Management & Policy,* vol. 10, pp. 225-354, 2020.

[20] Arasan, V. T., Dhivya and G., " Measuring heterogeneous traffic density.," *In Proceedings of International Conference on Sustainable Urban Transport and Environment, World Academy of Science, Engineering and technology, Bangkok,* vol. 36, p. 342, 2018.

[21] Åberg and L., "Traffic rules and traffic safety," *Safety science,,* vol. 29, pp. 205-215, 2018.