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Analysis of Accident-Prone Areas along the Ciawi–Puncak Road, Bogor

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Abstract

Purpose: This research aims to identify accident-prone locations along the Puncak road in Bogor and provide recommendations to the local government, especially the Department of Transportation, to improve traffic management and safety. The road is a strategic corridor connecting Bogor and Cianjur and serves as a key tourism route.
Research Methodology: The study applies a descriptive quantitative approach using literature review and primary and secondary data from relevant agencies. It incorporates spot speed analysis to measure vehicle speed at specific points using a radar meter, along with road characteristic analysis.
Results: The findings show that the average effective lane width of Jalan Raya Puncak is 4.2 meters, with a road capacity of approximately 3,565 pcu/hour. Traffic support facilities are still inadequate, with only about 7 traffic signs per kilometer in both directions. A total of 119 signs were identified, consisting of 16 prohibition signs, 24 directional signs, 5 command signs, and 74 warning signs. Field observations confirm that road equipment, particularly traffic signage, is insufficient.
Conclusions: Inadequate traffic facilities, particularly signage, contribute to accident risks. Improvements in infrastructure and traffic regulation are necessary to enhance road safety.
Limitations: The study focuses only on the Ciawi–Puncak segment and uses limited data, which may not reflect long-term patterns. It also does not consider external factors such as weather, driver behavior, and technology.
Contributions: This research provides input for the Department of Transportation to improve traffic control and safety measures in accident-prone areas.

Keywords: *Accident, Area, Ciawi-Puncak Road, Prone*

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1. Introduction

Traffic accidents are one of the big problems in every city. This is due to the increase in population and the increasing number of people who are traveling (traveling) (Mohammed et al., 2019). The existence of a well-planned road is a good solution to be able to reduce the problem of accidents, because this can provide better safety and can reduce the number of misperceptions and concentrations in running a vehicle. Traffic accidents generally occur due to various causes simultaneously, namely humans, road conditions, vehicle conditions, weather, obstructed views, but driver error is a major factor in many road

transport traffic accidents, among others due to fatigue, negligence, carelessness, boredom (Chand et al., 2021). Drivers can be in various conditions that threaten traffic safety, for example: lack of anticipation, carelessness, sleepiness, drunkenness, ignoring the distance to the vehicle in front of them (Khan et al., 2020).

In Bogor Regency itself, most of the highest total accidents occurred on primary arterial roads in the city. This is because the primary arterial roads are not only a crossing lane but also as access to meet the transportation needs of the local population (Rifai & Farhan, 2021). Judging from the condition of the road surface in Bogor Regency, repairs still need to be done. Because many roads have been damaged. Where the damage can be the cause of an accident. Puncak Tourism Area, Bogor is one of the capital's color destinations for recreation, especially on weekends. The peak area is 70 kilometers south of Jakarta. After identifying the data from the Dishub Kab. Bogor then can be known. From the initial identification data, the road section with the most frequent accidents is the Ciawi-Puncak highway, Bogor, where the Ciawi-Puncak highway is a crossing route to the Puncak tourism area and is also a district / city crossing road that can be used as a transitional route from one city to another. Where is the transitional route between Bogor-Cianjur-Sukabumi-Bandung which has the characteristics of roads with high volume and small road capacity as well as fairly extreme geographical conditions.

In the discussion of blackspot analysis at this time, there are several issues that become the main problem. Mitigation Problems in the study area are as follows: (1) Increase in traffic volume on Jl. Raya Ciawi-Puncak during weekends and long holidays. (2) Lack of safety facilities in the form of signs, markers and other facilities in the form of pedestrians (sidewalks) on Jl. Raya Ciawi-Puncak around the Tourist Attraction Location. (3) The high speed of vehicles passing Jl. Raya Ciawi-Puncak from the Peak to Gadog / Bogor due to downhill road conditions. (4) The need for traffic control at activity centers such as Cisarua Market and Several Rest Areas along Jalan Ciawi-Puncak. (4) The need for School Safe Zone facilities in front of the Primary School on Jl. Raya Ciawi-Puncak. (5) The number of side obstacles at each leg of the intersection, resulting in decreased performance of the intersection where there are frequent queues and vehicle delays. (6) The number of public transports that pick up, drop off and wait for passengers along the Ciawi-Puncak Bogor road; and (7) The large number of people crossing Jalan Ciawi-Puncak but not yet equipped with adequate road safety facilities.

The condition of the roads on the Ciawi-Puncak highway has a poor surface, and there are still lack of facilities - traffic safety facilities, pedestrians, and lack of infrastructure for street lighting. Another cause that can be put forward is the lack of awareness of the population about traffic order, so that many accidents involve pedestrians and slow vehicles. Accidents that occur in Bogor Regency, especially on the Ciawi-Puncak road section, Bogor need to be conducted a study as a reference in determining the effective and efficient prevention efforts. For this reason, it is necessary to make a report that can carry out the preventive steps more effectively later (Widyawan et al., 2019).

According to (Law of the Republic of Indonesia Number 22 of 2009 concerning Road Traffic and Transportation, 2009) Law of the Republic of Indonesia Number 22 of 2009 what is meant by: Roads are all parts of the Road, including complementary buildings and equipment designated for public traffic., which is at ground level, above ground level, below ground level / or water, as well as above water level, except rail and cable roads. Traffic signs are parts of Road equipment in the form of symbols, letters, numbers, sentences, and / or combinations that serve as warnings, prohibitions, orders, or directions for road users. A road marking is a sign that is on the road surface or on the road surface which includes equipment or signs forming longitudinal, transverse, oblique lines, as well as symbols that serve to direct the flow of traffic and limit areas of traffic interest (Babić et al., 2020; Chengula, 2018). Traffic signaling devices are electronic devices that use light signals that can be equipped with sound signals to regulate traffic of people and / or vehicles at intersections or road sections. Several studies on traffic accidents on

the Bogor peak highway have also been conducted (Chrisdianto et al., 2015; Nasution, 2019; Ryanto, 2019; Sudiatmono & Santosa, 2010).

In road safety terminology, there are two strategies to improve safety, namely a traffic accident prevention strategy and a traffic accident reduction strategy (Sudiatmono & Santosa, 2010). Accident prevention is oriented towards improving traffic safety, which is carried out through improving road geometry design, while accident reduction is oriented towards handling existing problems (Islam et al., 2019). Based on a predetermined route. Based on the preliminary survey, the average vehicle speed is known to be around 40 km / hour, so the observation distance for the spot speed survey (according to Bina Marga regulation No. 001 / T / BNKT / 1990) is 50 m. Along with the increasing production of motorized vehicles, it is not uncommon to find problems that arise in road traffic, with road traffic conditions so busy that they often cause congestion and accidents (Aswan et al., 2006).

The number of accidents in Indonesia has increased every year. Understanding Accidents are unexpected events. Classification of Accidents: Light traffic accidents, moderate traffic accidents, heavy traffic accidents, according to the fact that one of the causes of accidents is because the motorists (humans) do not obey the regulations, the lack of accident signs and the physical condition of the road. Based on these data, the main steps that need to be taken to overcome the risk of traffic accidents are to determine and analyze accident-prone areas (black sites) and traffic black spots (Ryanto, 2019). From the problems that arise regarding traffic accidents, it is necessary to have the right solution to minimize and anticipate traffic accidents.

Some of the solutions that can be given include the following: Installing warning signs at blackspot locations, Installing road medians so that drivers avoid front-to-front collisions, Installing pedestrian light controlled crossings equipped with rumbling ribbons for pedestrians, Observation of police officers on a regular basis. periodically at blackspot locations (Widiyanti, 2016). Identification of vulnerable locations is called the "Hazard Indicator Counting Method", which is by comparing the "severity value" from year to year. The value of the severity level is obtained from the number of hazard indicators raised by the parameters (Fahza & Widyastuti, 2019).

In improving traffic safety on the road, there are three parts that are interconnected with traffic operations, namely: drivers, vehicles and roads (Hu et al., 2020; Sun et al., 2019). The existing accident data from Jasa Marga from year to year shows that the biggest cause of accidents is caused by human factors (drivers). The cause of the accident that was carried out done because the vehicle, especially the road (geometric) has very little effect. This contradicts the fact that traffic engineers can only control one part, namely; Highway. Traffic accidents need greater attention, safety, smoothness and safety of road users are factors that are disrupted when an accident occurs (Dela Cruz et al., 2021). Road accidents always have an impact on the damage to motorists who are involved in the accident. In addition, accidents result in losses for accident victims and road users in the vicinity (Sekaryadi et al., 2019).

An accident is an event that is caused by many factors, which are basically due to the ineffectiveness of the main factors, namely road users / humans, vehicles, roads and the environment (Sairo et al., 2018). Speed is the speed of travel, usually expressed in kilometers per hour (Km / hour) and is generally divided into three types, namely as follows (Teuku, 2017): Local speed (spot speed) is the speed of the vehicle at one time measured from a specified place. The running speed is the average speed of the vehicle on a line when the vehicle is moving and is obtained by dividing the length of the lane divided by the length of time the vehicle is moving along the route. Journey speed is the effective speed of a vehicle traveling between two places, and is the distance between two places divided by the length of time the vehicle completes the journey between these places, with this length of time covering each stop time caused by the time of the obstacle delay) traffic. Collecting local speed data (spot speed) is done manually, using surveyors by placing two surveyors on the upstream and downstream links of each (Haqqi et al., 2017).

2. Literature Review & Hypothesis Development

2.1 Road Safety and Traffic Accidents

Road safety is a crucial aspect of transportation systems, particularly in areas with high traffic density such as the Ciawi–Puncak Bogor road segment. Traffic accidents generally result from a combination of factors, including human behavior, vehicle conditions, road infrastructure, and environmental influences. Among these, human factors—especially driver behavior—are often identified as the dominant cause of accidents. Efforts to improve road safety can be categorized into two main strategies: accident prevention, which focuses on improving road design and infrastructure, and accident reduction, which focuses on mitigating existing accident-prone conditions (Shah & Ahmad, 2019).

2.2 Traffic Characteristics and Performance

Traffic performance is typically measured using three main indicators: volume, speed, and density. Traffic volume refers to the number of vehicles passing a specific point within a given time period, while speed represents the distance traveled per unit of time, and density indicates the number of vehicles per unit length of road. One of the key indicators used to assess road performance is the Volume-to-Capacity (V/C) ratio. A higher V/C ratio indicates that a road is approaching or exceeding its capacity, which may lead to congestion and an increased risk of accidents (Retallack & Ostendorf, 2019).

2.3 Spot Speed Method in Traffic Analysis

The spot speed method is widely used to measure vehicle speed at a specific point along a road. The 85th percentile speed (P85) is commonly used as a reference for determining safe speed limits, as it reflects the speed at which the majority of drivers operate under normal conditions. This method is frequently applied in transportation studies to analyze traffic characteristics and evaluate road performance and safety (El-Shourbagy, 2020).

2.4 Road Infrastructure and Traffic Environment

Road infrastructure and environmental conditions significantly influence traffic performance and safety. Factors such as road width, road type, side friction, and roadside activities can disrupt traffic flow and increase accident risks. High levels of side friction—such as roadside parking, pedestrian activity, and street vendors—can reduce road capacity and create unsafe conditions (Papadimitriou et al., 2019).

2.5 Accident Analysis and Safety Improvement

Accident data analysis plays a crucial role in identifying patterns of traffic incidents and determining effective mitigation strategies. By examining variables such as time of occurrence, level of severity, and contributing factors, researchers are able to formulate more targeted safety interventions. Several measures can be implemented to improve road safety, including the installation of traffic signs, development of road medians, provision of pedestrian crossing facilities, and strengthening of traffic law enforcement. These efforts are intended to minimize accident frequency and enhance overall road safety conditions (Batishcheva & Ganichev, 2018).

2.6 Hypothesis Development

Based on the literature reviewed above, the following hypotheses are proposed:

H_1: The traffic volume and road conditions on Jalan Raya Ciawi-Puncak significantly contribute to the frequency of accidents.

H_2: Lack of traffic signs and safety measures increases the accident risk on the Ciawi-Puncak Bogor road segment.

H_3: Roadside friction factors, such as parked vehicles and pedestrian activities, negatively impact

traffic safety and contribute to accidents.

3. Methodology

The research methodology is a plan that clearly states the rules and procedures for analyzing the required data and ensures that the assessment process is relevant to the problem of investigation in addition to the use of more efficient procedures. In data analysis using primary survey data and secondary data as a complement to primary data. This type of research used in this research is descriptive quantitative research. It is said to be quantitative because it uses an empirical study approach to collect, analyze, and display numerical or numeric data. And including descriptive research because it describes systematically the meaning and results of the data obtained.

The mindset of this study with the following explanations: (1) Input the current condition of the accident-prone areas on the Ciawi-Puncak Bogor road at this time. (2) The research subjects who were the research subjects (data sources) were the Bogor Regency Transportation Agency and the Bogor Regency Public Works Office, and the Police. (3) The research object which becomes the object of research is on the Ciawi-Puncak Bogor road related to accident-prone areas related to the provisions / regulations in force. (4) The method in this research will use descriptive qualitative analysis methods and quantitative descriptive, while for primary data collection is done by making observations in the field using hawyeke cancellation. (5) The output of this research is identified accident-prone areas of the completeness of road facilities and recommendations for these accident-prone areas. (6) The output is to improve the safety and security of the Ciawi-Puncak Bogor road, so as to reduce the number of road accidents.

3.1 Research Design

This study employs a survey-based research design with a descriptive quantitative approach. The research uses an empirical method to collect, analyze, and present numerical data systematically. Primary data were obtained through field observations and surveys, while secondary data were used to support and complement the findings. The study focuses on identifying accident-prone areas on the Ciawi–Puncak Bogor road.

The research subjects include the Bogor Regency Transportation Agency, the Bogor Regency Public Works Office, and the Police, while the research object is the Ciawi–Puncak Bogor road related to accident-prone areas and applicable regulations. The analysis combines descriptive qualitative and quantitative methods, with the aim of identifying accident-prone locations, evaluating road facility completeness, and providing recommendations to improve road safety and reduce traffic accidents.

3.2 Data Collection

Data is needed as material for information and evaluation of the conditions at issue. Secondary data required as material for analysis in this study are: Traffic Accident Data, Population Total Population of Bogor Regency; and daily traffic volume, Transportation Agency Kab. Bogor. Meanwhile, primary data collection is carried out based on the results of field observations in the accident-prone area on Jalan Ciawi-Puncak Bogor including: Road Inventory Survey, Accident-Prone Location Identification, Instantaneous Speed Survey and Traffic Conflict Survey. Field study by observing directly in the study object area with observation, observation and research of an object or direct activity.

3.3 Data Analysis

This research is a literature study and uses primary and secondary data from related agencies in the study of documents regarding legality / policies and applicable laws and regulations relating to accident-prone areas. Meanwhile, to see the existing conditions is done through observation / observation using Hawkeye equipment.

3.3.1 Calculation of Local Speed

Local speed calculations are required to calculate the required deceleration and braking distance. The data needed for spot speed analysis is the travel time survey data.

Rata-Rata Kecepatan		Panjang Pengamatan (d)	
Mph	*Kph*	ft	m
Dibawah 25	Dibawah 40	88	25
25-40	40-65	176	50
Diatas 40	Diatas 65	264	75

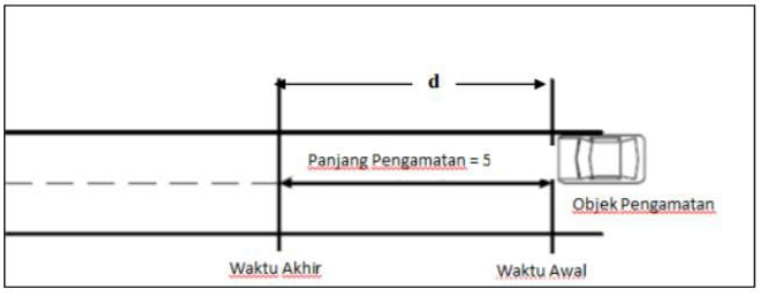

Figure 1. Spot Speed Survey Observation

The steps in observing the spot speed survey are: (1) Prepare survey equipment and forms to be used. (2) Determine the starting and ending points along the route as well as the points considered to be control points. (3) Activating the stopwatch when the vehicle passes the specified starting point. (4) Time and distance readings are made at the designated control point to indicate the vehicle has passed. (5) When a delay occurs or the vehicle is forced to move slowly, the stop time is recorded using the second stopwatch, the location or distance and the cause of the delay (numeric codes can be used to identify the cause of congestion). (6) Deactivate the stopwatch when it reaches the end point of the study route so that data will be obtained which will later be used during data analysis.

The main objective of transportation system engineering is to find and determine the most optimum combination of transportation means and methods for their operation in a certain area. The problem faced by transportation is actually more complicated, namely involving a wider area with different types of cargo or passengers. Basically there are three main characteristics of traffic, namely: (1) Volume (Flow), namely the number of vehicles passing through a point at a given point. path per unit time, and therefore usually measured in units of vehicles per unit time. (2) Density, namely the average number of vehicles per unit length of motion at any one time in time. (3) Speed, namely the distance traveled by the vehicle per unit time. This speed consists of three components utama, yaitu : Spot speed, namely the instantaneous speed of the vehicle at one reference point (one point). The influencing factors are: a. Driver b. Vehicle c. Highway d. Traffic e. Environment.

Running speed, namely the average speed of the vehicle in terms of a certain distance when the vehicle is moving, is obtained by dividing the length of the road under review by the travel time. Journey speed, namely the effective speed of the vehicle during the trip between two destination points and is the distance between the two points divided by the total time taken from the vehicle during the trip where the time includes the stop time and the delay that occurs. Space Mean Speed The average speed of space (km / h). Time Mean Speed (Ut) The average speed of a vehicle passing a point or piece over a certain time interval (km / hour).

In this research, the analysis used is descriptive qualitative analysis and quantitative descriptive with reference to legality / policies and provisions of the prevailing laws and regulations, as well as referring

to previous studies related to road equipment facilities. Includes: Macro Analysis, Macro analysis can be carried out in the following steps: (1) Looking at the characteristics of accidents on the National Highway of Jalan Raya Puncak, Bogor by identifying the pattern of accidents in general from the factors that cause them. (2) Determine the road segment with the highest score using the Z-score, AEK and BKA. After obtaining the most accident-prone road segments, then determining the most accident-prone points using the Cumulative Summary method. Micro Analysis, After the location of the most vulnerable point (black spot / black section) is known with the results of macro analysis, then a more detailed analysis is carried out with micro analysis to obtain a violation diagram. A collision diagram in the accident data is needed to show: Time of incident, severity of accidents on road users, types of accidents, pedestrian facilities; and Analysis of conflict data. The statistical analysis performed to process the spot speed survey data was the 85th percentile (P85).

y85 percentile speed is a traffic speed where 85% of drivers drive their vehicles on the road without being affected by lower traffic speeds or bad weather. In other words, the 85th percentile speed is the speed used by the 85th percentile of drivers which is expected to represent the speed that drivers often use in the field. So, the purpose of this method is to determine the ideal speed limit on the road section under review based on the average speed of the vehicle. The survey using the spot speed was carried out at a point awal dan akhir pada setiap link dari rute yang telah ditentukan dan telah banyak dilakukan penelitiannya (Chrisdianto et al., 2015; Haqqi et al., 2017; Irfan, 2018; Mauliza et al., 2019)

4. Results and Discussion

4.1 Results

Bogor Regency is one of the areas directly adjacent to the capital city of the Republic of Indonesia and geographically it is located at the position of 6019 ’- 6047’ south latitude and 10601 ’- 1070103’ east longitude. The area based on the latest data is 2,301.95 Km2, with the following boundaries, (1) North: Depok City, (2) West: Lebak Regency, (3) East: Purwakarta Regency, and (4) South: Sukabumi Regency. Based on the results of the 2017 Socio-Economic Data Collection, Bogor Regency has 40 sub-districts, 427 villages / wards, 13,541 RTs and 913,206 households. Of these 234 villages have an altitude of less than 500 m above sea level (asl), 144 villages are between 500-700 m and the remaining 49 villages are around more than 500 m asl. Most of the villages in Bogor Regency have been classified as Swakarya villages, namely 236 villages, the other 191 are Swasembada villages and there are no Swadaya villages. Based on the regional classification, seen from the aspect of potential business fields, population density and social conditions, there are 199 urban villages and 228 rural villages.

Figure 2. Map of District Administration, Bogor Regency

Bogor Regency is divided into development zoning which is the basis for the preparation of the development agenda and strategic plans for each development sector and program in the framework of balancing development between regions. The aims and objectives of regional development are to increase regional growth in a balanced manner between regions by utilizing resources optimally and sustainably. By considering regional characteristics and regional economic development, internal and external interaction patterns supported by service infrastructure networks both local and regional as well as policies for the development and distribution of population in a balanced manner according to the carrying capacity of the environment, the Bogor Regency area is divided into 3 (three) development areas, namely: the western, central and eastern development areas.

1. Transportation conditions Road length = 1,790,060 km. The road status is state roads = 72,444 km (3 sections) and provincial roads = 144,240 km (8 sections) and district roads = 1,300,740 km (251 sections). Good category road condition = 428,025 km, medium category = 329,510 km lightly damaged category = 289,240 km, heavily damaged category = 526,600 km.
2. Condition of Road Infrastructure Road infrastructure is a section of roads around the construction site that describes the physical condition and land use and activities side which affects the performance of these roads.
3. Jalan Raya Ciawi-Puncak Bogor The road that is the study location is Jalan Raya Ciawi-Puncak Bogor, where the status of the road is a national road and serves as the main road and the Ciawi-Puncak road section is an access in and out of Bogor Regency from the direction of Cianjur Residence with the characteristics of the speed and volume of vehicle traffic that is quite dense.

The Ciawi-Puncak road section has an undivided 2-lane 2-lane road type (2/2 UD). based on observations in the field, the effective lane width that should be used is 4.5 meters. With a population of under 500,000 people and a high enough level of side friction (such as: stopped vehicles, getting in and out of vehicles, as well as the activities of street vendors), the movement of vehicle movements on these roads is disturbed. The visualization and cross-section of the affected sections can be shown in the following Figure 3.

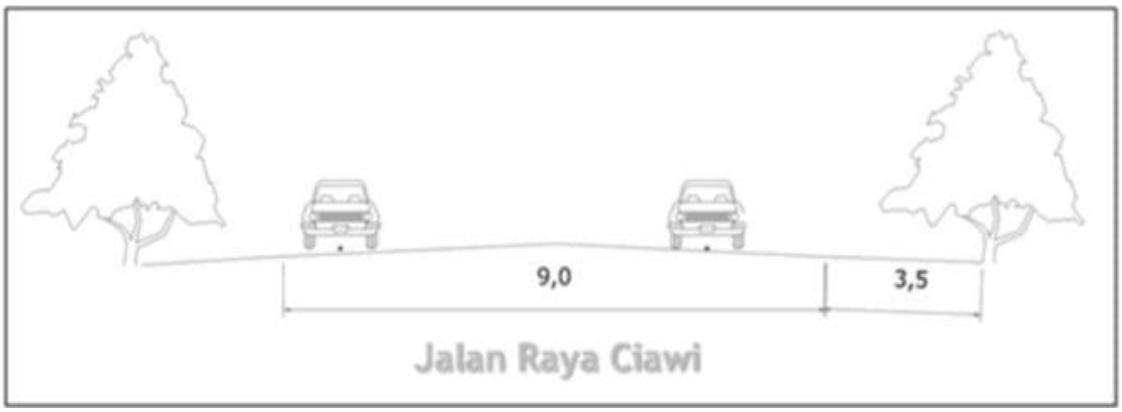

Figure 3. Visualization and Cross Section of Jalan Raya Ciawi-Puncak, Bogor

From the results of the survey and analysis, it was obtained the volume and value of the V / C ratio of the roads in the study location. On weekdays, the direction of Puncak has a volume of 1323.55 pcu / hour with a V / C Ratio of 0.37 and the direction of Bogor is 2050.60 pcu / hours with the highest V / C ratio of 0.58. The traffic volume on weekdays occurs at 07.00 - 08.00 WIB with 2050.60 pcu / hour and at 08.00 - 09.00 WIB with 1323.55 pcu / hour.

On holidays, the direction of Bogor has a volume of 1388.52 pcu / hour with a V / C Ratio of 0.39 and towards Puncak of 2181.67 pcu / hour with the highest V / C ratio of 0.61. The traffic volume occurs at 16.00 - 17.00 WIB with 1388.52 pcu / hour and at 08.00 - 09.00 WIB with 2181.67 pcu / hour. Traffic composition is dominated by motorbikes both on weekdays (50%) and holidays (48%), followed by private cars and public passenger cars. The average road speed is calculated using the spot speed method. During the 2-year period, namely 2015-2016, there were 65 accidents that occurred on the national route, Jalan Raya Puncak, Bogor. The number of victims reached 101 people, both dead and injured.

4.2 Discussion

The high traffic volume and V / C ratio on both weekdays and holidays indicate significant traffic density on the Ciawi-Puncak road section. The dominance of motorbikes as the main mode of transportation reflects the mobility pattern of the community, which contributes to traffic complexity and potential accident risks. The road characteristics, including the undivided 2/2 UD type, limited lane width, and high side friction caused by roadside activities, significantly affect traffic performance and safety. These conditions can lead to disruptions in vehicle movement and increase the likelihood of accidents. The fluctuation of traffic volume during peak hours, especially in the morning and evening, indicates pressure on road capacity. Higher volumes during holidays further emphasize the role of this road as a major access route to tourist destinations, contributing to congestion and safety risks.

Accident data analysis shows recurring patterns and highlights the importance of identifying accident-prone locations (black sites and black spots). Understanding the characteristics of accidents, including severity, time, and contributing factors such as drivers, vehicles, road conditions, and environment, is essential for determining appropriate mitigation strategies. Overall, the findings emphasize the need for improved traffic management, infrastructure enhancement, and safety interventions to reduce accident rates and improve road performance on the Ciawi-Puncak Bogor corridor (Muhammed et al., 2021).

5. Conclusions

Based on the results of the direct survey in the field, some of the problems that arise can be explained. The results of direct observations in the field show that the road equipment facilities on the Raya Puncak Bogor road section, especially for road sign facilities, are still lacking. Traffic safety on an urban road is a government success in designing a traffic system that is comfortable and safe. Increasingly rapid traffic and an increasing number of vehicles are not matched by adequate road capacity so that the road network does not function optimally and reduces traffic safety. The high volume of traffic causes the speed of the vehicle to be slow even though the speed of the vehicle is very much needed for the mobilization of goods and services.

5.1 Research Limitations

This study has several limitations. First, the research was conducted only on the Ciawi–Puncak Bogor road segment, so the findings may not fully represent traffic conditions in other regions with different characteristics. Second, the study relies on traffic surveys and accident data within a limited observation period, which may not capture long-term traffic patterns and seasonal variations. Third, the analysis focuses mainly on traffic volume, speed, and accident characteristics without incorporating advanced modeling or simulation approaches. In addition, external factors such as weather conditions, driver behavior variability, and technological interventions were not examined in depth, which may influence the overall accuracy of the findings.

5.2 Suggestions and Directions for Future Research

Based on the conclusions and limitations described, the researcher provides the following suggestions:

1) Efforts to handle accident-prone locations, based on general causative factors, especially at night, it is necessary to add road equipment such as public street lighting and warning signs. Based on human factors, it is necessary to increase education and knowledge for drivers in the form of socialization about safe traffic. Based on the vehicle factor, it is necessary to improve safety technology in vehicles and an effective roadworthiness test inspection. For the road factor, it is necessary to improve road infrastructure. Based on the identified problems, there are four alternative traffic management arrangements as an option in preventing accident-prone points. Blackspot analysis on Jalan Raya Puncak, Bogor.
2) Future research is recommended to expand the study area to include multiple road segments with different classifications and traffic characteristics in order to improve the generalizability of the results. Further studies can also incorporate longer observation periods to capture more comprehensive traffic patterns and accident trends. In addition, future research should consider integrating advanced analytical methods such as traffic simulation models, geographic information systems (GIS), and real-time traffic data analysis. The inclusion of additional variables such as driver behavior, weather conditions, and the impact of intelligent transportation systems (ITS) is also suggested to provide a more holistic understanding of traffic safety and performance.

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Author Contributions

PCS contributed to the conceptualization, supervision, and review and editing of the manuscript, and also served as the corresponding author. RFS contributed to the research methodology, data curation, formal analysis, and drafting of the original manuscript. H contributed to data collection, investigation, and validation of the research data. BAP contributed to data analysis support, visualization, and provision of technical resources for the study.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper. The research was conducted independently without any financial or commercial relationships that could be construed as a potential conflict of interest.

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