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TRAFFIC ACCIDENTS AND ROAD SAFETY ANALYSIS IN BOGOR CITY, INDONESIA

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Abstract

Bogor City is experiencing rapid development; one of the reasons is its strategic location, which is close to the capital city of Jakarta. As a developing city, transportation is one of the sectors that has an important and strategic role in supporting development in all fields, but in everyday life transportation also has an impact on traffic safety. Therefore, it is felt that there is a need to mitigate traffic accidents to reduce the rate of traffic accidents that occur on highways, especially secondary arterial roads in Bogor City. To make it easier to analyze areas prone to traffic accidents, GIS (Geographic Information System) approach is used, which can integrate various databases, be it spatial data such as maps, photos, and satellite images, or non-spatial or better known as textual data such as attribute and numeric data, thus allowing the location prone to traffic accidents to be described in a two-dimensional form that can be edited and revised quickly so that it can always produce actual information that can be used as a basis for analysts in decision making. Based on the results of the analysis, the highest number and distribution of traffic accidents are in Central Bogor District and North Bogor District, while West Bogor District has a moderate accident rate and South Bogor, North Bogor, and Tanah Sareal Districts have a low accident rate. Most accident-prone points are located in locations that are the center of community activities. With the land use plan in Bogor City in the form of converting green open spaces into residential, trade, and service areas, as well as education and office areas, population growth and the need for transportation will increase. In line with that, the number of accidents will also increase, so it is necessary to mitigate traffic accidents to prevent or suppress the surge in the number of accidents that will occur.

Keywords: Road Safety, Transport, Urban

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INTRODUCTION

Bogor City is one of the cities that has experienced rapid development in its development. The area of Bogor City is recorded at 11,850 Ha or 0.27% of the area of West Java Province. As a developing city, transportation is one of the sectors that have an important and strategic role in supporting development in all fields. In carrying out transportation activities, one of the things that must be considered is the problem of traffic accidents. The problem of traffic accidents is an interesting discussion in terms of humanity and the economy. Billions of rupiah have been spent due to traffic accidents. Based on the results of a secondary survey compiled by the Bogor City Police, in the last five years, namely, from 2004 to 2008, there have been material losses of Rp. 859,500,000, with a total number of accidents of as many as 466 cases, with a total of 87 fatalities, 157 serious injuries, and 430 minor injuries. While in 2009 there has been an increase in the number of accidents from the previous year, whereas in 2008 there were 57 incidents which increased to 127 incidents the following year.

Given that the number of traffic accidents is increasing in Bogor City, it is felt necessary to know locations that are prone to traffic accidents so that they can be used as a means of handling road traffic safety to reduce the rate of traffic accidents that occur on highways, especially secondary arterial roads because most accidents in Bogor City occur on secondary arterial roads[1]. In the case study of identifying locations prone to traffic accidents, a vulnerability analysis approach was carried out, based on physical aspects. The economic aspect is also influential but its contribution to an accident prone compared to the other two aspects (Sembiring, 2000). Physical aspects that can affect the vulnerability of traffic accidents are also referred to as environmental factors, both natural and built environments (Warpani, 2003). In this case, some of the physical factors referred to are population density, rainfall, slope and land use.

RESEARCH AIM AND OBJECTIVES

The purpose of this study is to identify areas prone to traffic accidents on the secondary arterial roads of Bogor City, while the targets of this study are:

i) To study the number and distribution of traffic accidents.
ii) To identify the location that is prone to traffic accidents in Bogor City.
iii) To analyse the relationship between land use patterns and traffic accidents.

OVERVIEW OF THE STUDY AREA

The details about the administrative area of Bogor City according to the district by year 2020 can be seen in Table 1.

[1] Result Interview with Polresta Bogor in January 2020

Table 1: Bogor City Administration by District

No	District	Area (Ha)	%
1	North Bogor	1,772	14.95
2	West Bogor	3,285	27.72
3	East Bogor	1,015	8.57
4	South Bogor	3,081	26.00
5	Central Bogor	813	6.86
6	Tanah Sareal	1,884	15.90
	Bogor City	11,850	100.00

Source: Bapeda Kota Bogor, 2020

The average rainfall in the Bogor City area ranges from 4,000 to 4,500 mm/year. Bogor is a rainy city. Bogor City has an area of 118.50 km^2 with a total population density in Year 2020 is 7,638 people / km^2, with a medium density category. The road network in Bogor City has a concentric radial pattern with the following characteristics: In the downtown area, there is a road network around the Bogor Botanical Garden (ring). The circular road network is a merger of Jalan Ir. H. Juanda, Jalan Otista, part of Jalan Pajajaran, and Jalan Jalak Harupat. Road networks originating from other regions are concentrically connected to this circular road network. Some of these roads include Jalan Surya Kencana, Jalan Sudirman, Jalan Pajajaran, Jalan Veteran, and Empang. In the eastern part of Bogor City bordering Bogor Regency, there is Jagorawi Toll Road, which connects the center of Bogor and Ciawi with Jakarta.

At the northern part of Bogor City (Tanah Sareal and West Bogor Districts), there is a ring road. This ring road connects Sindang Barang (in West Bogor District) with Bogor Highway (in Tanah Sareal District). The Bogor City Government has also planned the construction of a ring road from the western part to the southern part of the city, namely the ring road connecting Jalan Sindang Item to the Rancamaya area, then continuing to Ciawi (part of this planned ring road passes through Bogor Regency). In addition, the construction of ring roads in the northern part is also planned, which connects the Bogor Highway with the Jagorawi toll road. The road network with a concentric radial pattern has the consequence of accumulating all movement towards the city center because this area is the only access to reach other areas. The road width capacity profile is lane width (3-3.5m) and road width (6-18.5 m). Bogor City has six sub-districts crossed by National Roads that stretch for a total of 34,199 m, with Jalan Soleh Iskandar the status of the longest national road in Bogor City with a length of 7,946 m, then followed by Jalan Pajajaran along 6,400 m (Dinas Bina Marga Kota Bogor, 2020). Based on the results of the primary survey, according to data compiled by the Bogor City Police Traffic Administration section, the number of accidents recorded on secondary arterial roads in Bogor in the last five years has experienced ups and downs every year. Table 2 shows the number of traffic accidents in Bogor City.

Table 2: Number of Traffic Accidents in Bogor City by 2016-2021

Year	2016	2017	2018	2019	2020	2021
Sum	14	178	104	113	57	127

Source: Bogor City Police 2021

LITERATURE REVIEW

Road Traffic Safety

Based on Law Number 22 of 2009 concerning road traffic and transportation, the Government is responsible for ensuring the safety of road traffic and transportation, therefore a national general plan for road traffic and transportation safety was established. This includes the compilation of a national program for road traffic safety and transport activities, the provision and maintenance of traffic and road transport safety facilities and equipment, the document of assessment of traffic and road transport safety issues and the traffic and road transport safety management.

Traffic Accidents

Traffic accidents can be defined as a series of events that usually result in accidental death, injury, or property damage and occur on roads or places that are open to the public and used for vehicular traffic (Miro, 2005).

Traffic Accident Factors

Based on the results of an interview with the Head of the Bogor Police Traffic Accident Unit in 2020, the factors that cause land traffic accidents are classified into 2 parts, that is

- Natural factors: accident factors caused by natural factors, some of which are heavy rainfall, slope, and humans.
- Artificial factors: accident factors caused by human creation, such as vehicle damage, vehicle design, driver defects, road surface, and road design.

Prevention of Traffic Accidents

In the implementation of traffic management and engineering, one can use 3 (three) basic strategies to reduce traffic accidents, namely:

- Single Sites (Black Spot Program): namely handling certain types of accidents on one road.
- Mass Action Plans: The use of previous coping patterns for locations that have common problems.
- Route Action Plans: Use of varied treatment patterns covering large areas (cities).

Traffic Management

Traffic management is an urgent and short-term plan to improve traffic conditions. Four objectives of traffic management have been set up which is first; is to gain efficiency and overall traffic movement with a high level of accessibility by balancing demand with available supporting facilities, secondly is to increase and improve safety levels as best as possible, thirdly; to protect and improve the environmental conditions where the traffic flow is located and fourthly is to promote efficient use of energy or the use of other energy which has a less negative impact than another energy. Traffic management can be sorted into three types that are closely related to basic strategic goals (Morlok, 1985), namely: the Management of Capacity; relating to traffic management measures to increase infrastructure capacity, so that it is an approach from the Supply side. Secondly is the Management of Demand; relating to the act of regulating and controlling traffic requests, which are generally regulatory and restrictive to travel requests. Finally, is the Management of Priority; related to giving priority to certain traffic that can improve efficiency and or traffic safety.

Meanwhile, in Tamin (1997), these types of handling can be grouped as traffic management, where in principle emphasizing the utilization of existing roads, such as effective utilization of road width, adequate completeness of road markings and signs so that roads can be optimally utilized both in terms of capacity and traffic safety which includes the system one way, parking, setting the location of turn signs, sidewalks, and turning. This type of treatment is carried out when the degree of saturation is between 0.6-0.8. The improvement of road reactions, including physical changes to road sections in the form of widening or adding lanes so that the capacity of road sections can be significantly increased. Performed when the degree of saturation is greater than 0.80. The construction of new roads is the last alternative. This type of handling is carried out when widening the road and adding lanes is no longer possible, especially due to limited land and the condition of the degree of saturation which is much greater than 0.8.

Secondary Arterial Road Requirements

Secondary Arterial Road is a road that connects the primary area with the first secondary area, connects the first secondary area with the first secondary area, or connects the first secondary area with the second secondary area (Sembiring, 2000). The requirements that must be met by the secondary artery area are:

- Design speed >30 km/h
- Road body width >8 m
- Road capacity is equal to or greater than the average traffic volume.
- Must not be disturbed by heavy traffic.
- The surface index is not less than 1.5.

The Relationship of Transportation Systems to Land Uses

According to (Miro, 2005) basically, the variables of Land Uses, transportation system, and the amount of traffic flow are variables that are interrelated and affect each other. The general goal of transportation planning is to make interactions between land uses as easy and efficient as possible. Ways of transportation planning to achieve general goals include the setting of policies on the following:

- Activity System. A good land-use plan (correct location of shops, schools, housing, jobs, etc.) can reduce the need for long commutes and make interaction easier.
- Network System. Things that can be done for example increasing the capacity of existing infrastructure services: widening roads, adding new road networks and others.
- Movement System. Things that can be done such as regulating traffic engineering and management (short term), better public transport facilities (short and medium term), or road construction (long term)

This research is done using the Geographic Information Systems (GIS). It is a system that is designed to work with the reference geographic or spatial coordinates and also non-spatial (Star, 1990; Ismail et al., 2023). GIS is the most popular technology because it provides suitable information in the spatial and temporal domain and intricate database (Mustaffa, et. al., 2023).

POSITION AND FUNCTION OF BOGOR CITY REGIONALLY

In the Regional Spatial Plan of West Java Province in 2010 and the Jabodetabek Regional Spatial Plan, Bogor City functions as a counter magnet for the development of DKI Jakarta. Later this area is directed as a regional activity centre which has main activities as a regional trade, service, settlement, and industrial city with a capacity of 1.5 million people in 2005. The direction of physical development of Bogor City is:

- The southern part tends to be a potential residential area with a low KDB (Basic Building Coefficient) and green open space.
- The northern part tends to have potential as a non-pollutant industrial area and as a support is settlements along with trade and services.
- Tanah Sareal sub-district tends to have potential as a residential area, trade and service area, and city service facility area.
- The western part tends to have potential as a residential area supported by tourist attractions.
- The eastern part tends to be a potential residential area.
- The Central Part tends to have the potential as a center of trade and services supported by offices and scientific tourism.

The geographical condition of Bogor City as a crossing route between *Provinsi DKI Jakarta* and *Provinsi West Java* has placed Bogor City as a city that has strategic value directed as:

- The center of activity for the development of the surrounding area with the main activity is Urban.
- A city that can accommodate population activities under the planned capacity in the Jabodetabek development system.
- A city that can serve residents in and around the region, especially those concerning the needs of residential land and trade in services and supporting facilities.
- Agricultural production collector and distribution center to accommodate and market agricultural products from the surrounding area.
- One of the buffers for the City of Jakarta in realizing the direction of the development of Bogor City in the regional scope, Bogor City functions as a regional service city, residential city, and industrial city.

RESEARCH METHODOLOGY

Time and Location of Research

Research on the identification of traffic accident-prone locations in Bogor City, conducted on all secondary arterial roads, for more details can be seen in Table 3.

Table 3: Research Location

No	District	Street Name
1	North Bogor	Jakarta-Bogor; Pajajaran; KH. Abdullah bin Nuh/BORR; Pandawa; Bangbarung
2	East Bogor	Pajajaran; Surya Kencana; Silwangi
3	South Bogor	Surya Kencana; Siliwangi; Bogor-Ciawi/Tajur
4	Central Bogor	Ir.H. Juanda; Merdeka; Pajajaran; Jendral Sudirman; RE. Martadinata, Jalak Harupat; Surya Kencana
5	West Bogor	Merdeka; Dr. Semeru; Semplak
6	Tanah Sareal	Jendral Ahmad Yani; Dadali; Pemuda; KH. Abdullah Bin Nuh/BORR

Source: DLLAJ, 2020

Data Collection Methods

- **Literature Study:** This literature study is taken from reading books, documents, theses, laws, and regulations as well as thoughts related to the research theme.
- **Agency Survey:** An agency survey is a data collection technique carried out by collecting data from related agencies, such as the Bogor City Police,

Bogor City Government, and the Bogor City Transportation Office (DLLAJ).

- **Observation:** Observation is a direct observation of the field of the object of study studied, namely by observing physical road factors in the form of the location of secondary arterial road networks and the slope of the road slope as well as the impact of rainfall on road conditions.

Methods of Analysis

a. **Quantitative Analysis Methods:** Quantitative analysis methods are forms of analysis carried out using mathematical models and equations. The quantitative analysis method used in the object of this study, namely an analysis of the number of traffic accidents using traffic accident data for the last 5 years (2004-2009).
b. **Geographic Information System (GIS) Approach:** The GIS is used to determine the location prone to traffic accidents and the relationship between accidents and the physical condition of the road. GIS approach method consists of several stages namely map editing and map overlay as in Figure 1.

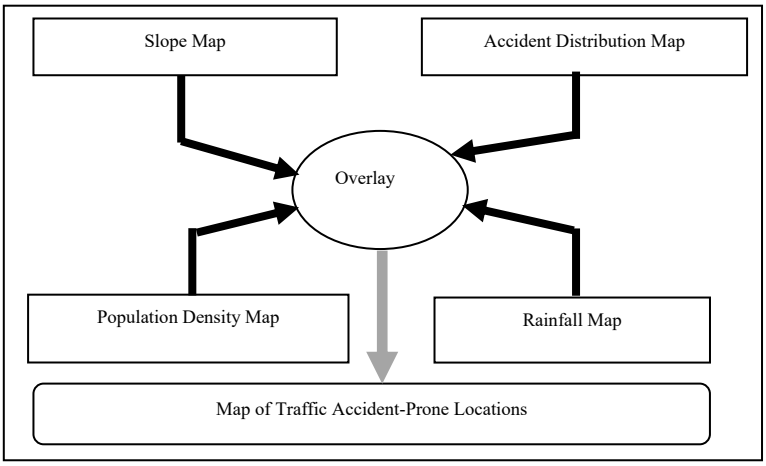

Figure 1: The flow of Identification Traffic Accident-Prone Locations

The weight value of each indicator used to determine areas prone to traffic accidents in Bogor City and it is used to conduct interviews with experts, namely the Head of Sub Highway, DLLAJ Bogor City, Kanitlaka Polresta Bogor and Head of Sub-Directorate of Physical and Prasarana Bappeda Bogor City. In addition, questionnaires were also distributed to road users, which contained questions related to traffic accident problems. The results of the interview were Traffic accidents that occur in Bogor City are mostly caused by human factors

(60-80%), followed by natural factors (10-20%) after that driver negligence/vehicle damage (5-10%) factors. Thus, to determine locations that are prone to traffic accidents, the ranking values used are obtained by approaching:

Total Value of Accident-Prone Locations =

$$\frac{(2.\ CH) + (1.\ KL) + (3.\ KP) + (1.KLL)}{4}$$

Remarks: *CH = RainfallKP = Population Density*
KL = slope KLL = Traffic Accident

Weighting is divided into 3 parts, namely:

a. Weight 1: given to a condition that has the fewest factors causing accidents based on the results of the interview.
b. Weight 2: given to a condition that has a moderate accident causative factor based on the results of the interview.
c. Weight 3: given to a condition that has the fewest factors causing accidents based on the results of the interview.

Information about the formula for finding locations that are prone to traffic accidents in Bogor City is as follows:

i. Rainfall is an important factor and has a major influence as one of the causes of traffic accidents. The presence of high rainfall can cause:

    a. The visibility of the driver of the vehicle becomes limited,
    b. In rainy conditions, asphalt becomes more slippery.
    c. The braking distance of the vehicle becomes difficult to predict,
    d. In addition, high levels of rainfall can cause the life of road pavements in the form of both asphalt and concrete to be shorter, causing damage to roads which then have the potential to cause higher traffic accident rates.

Rainfall has 4 factors causing traffic accidents; therefore, rainfall gets a weight 2 times higher than the slope and the number of accidents. Rainfall is further divided into:

a. High rainfall (4,501-5,000 mm/yr) multiplied by weight 2.
b. Moderate rainfall (4,001-4,500 mm/yr) multiplied by weight 2
c. Low rainfall (3.5000-4000 mm/yr) multiplied by weight 2

ii. The slope is quite an important factor in traffic accidents, with uneven road conditions, it can cause vehicle traction to be more difficult to control, potentially causing traffic accidents. The slope of the slope has 1-factor causing traffic accidents; therefore, the slope of the slope gets a weight of 1. The slope is divided into:

a. Flat (0-2 %) multiplied by weight 1
b. Ramps (2-15%) multiplied by the weight of 1
c. Rather steep (15%-25%) multiplied by a weight of 1
d. Steep (25-40%) multiplied by weight 1
e. Very steep (>40%) multiplied by a weight of 1

iii. Population density is the highest cause that has the potential to cause traffic accidents, including:

a. The increasing number of vehicles, so that traffic activities are getting denser and causing vehicle movement to be more limited.
b. The increasing number of pedestrians, so that more conflicts are caused between vehicles and pedestrians.
c. Increased traffic density in a road network.
d. The increasing number of vehicles with heavy loads has the potential to quickly damage the condition of the road pavement surface so that the road becomes uneven and quickly damaged.
e. Increased community activities on the roadside, such as street vendors, so that sidewalks that should be placed for pedestrians have changed their functions.
f. The high number of vehicles if not adjusted to parking facilities, causes many vehicles to park not in the right place, thus potentially causing traffic conflicts.

Population density has 6 factors that have the potential to cause traffic accidents. Therefore, population density has weight 3 times higher than the slope and the number of traffic accidents. Density is divided into:

a. Height (>12,000 people/Ha) multiplied by weight 3.
b. Medium (5,000-12,000 people/Ha) multiplied by the weight of 3
c. Low (<5,000 people/Ha) multiplied by the weight of 3.

The number of traffic accidents is a real factor where traffic accidents are now occurring, thus used as comparison material to find out the location of traffic accidents. The weight given is only 1 time compared to other factors.

a. **Modeling:** Identification of areas prone to traffic accidents with a GIS approach using an analog model, where quantitative descriptive data is mapped into thematic maps, and then thematic maps containing specific information are overlaid to produce a *composite map*. This analog model of travel planning uses a digital database system.

b. **Limitations and Assumptions:** The identification of areas prone to traffic accidents with GIS approach is limited to covering 6 sub-districts within Bogor City and uses assumptions in the form of factors, categories, and weighting factors based on the level of traffic vulnerability.

TRAFFIC ACCIDENT-PRONE LOCATIONS IN BOGOR CITY

i. Analysis of Physical Condition Affected Traffic Accident

This analysis is intended to determine the level of traffic accident proneness along with the state of the physical condition of the study location (Table 4).

Table 4: Physical Condition of Bogor City in Each District

No	District	Rainfall (mm/year)	Slope (%)	Density Category
1	North Bogor	3500-4500	0 - >40	Keep
2	East Bogor	3500-4500	0 - >40	Keep
3	South Bogor	3500-4500	0 - >40	Keep
4	Central Bogor	4000-4500	0 - >40	Tall
5	West Bogor	3500-5000	0 - >40	Keep
6	Tanah Sareal	3500-4500	0 – 40	Keep

Source: Analysis Results,2020

ii. Analysis of Traffic Accident Distribution by District

Analysis of the distribution of traffic accidents by sub-district is carried out by determining the location of traffic accidents in each sub-district based on Bogor Police data so that the number and percentage of accidents in a sub-district traversed by secondary arterial roads can be known. More details can be seen in Table 5.

Table 5: Distribution of Traffic Accidents in Bogor City

No	District	Number of Accidents	Area (%)
1	Central Bogor	34	26,6
2	East Bogor	15	11,7
3	South Bogor	10	7,8
4	West Bogor	23	18
5	Tanah Sareal	12	9,4
6	North Bogor	33	27,3
	Total	127	100

Source: Analysis Results,2020

iii. Identification of Traffic Accidents on Secondary Arterial Roads

The identification process is carried out by determining the number of locations prone to traffic accidents, namely by determining the number of traffic accidents that are more than 1 time in the same location and giving weights/scores on physical factors that cause accidents, then overlaying road network maps and road physical condition maps that have been weighed in the form of rainfall maps (weight/score 2), population density maps (weight/score 3), and slope maps (weight/score 1), with traffic accident distribution maps (weight/score 1), then the results are divided by 4 to get a total traffic accident prone level score. The combination maps as shown in Figure 2 are the process in obtaining the information about the level of traffic accident vulnerability of each sub-district in Bogor City along with the condition of population density, rainfall, and slope in the study location.

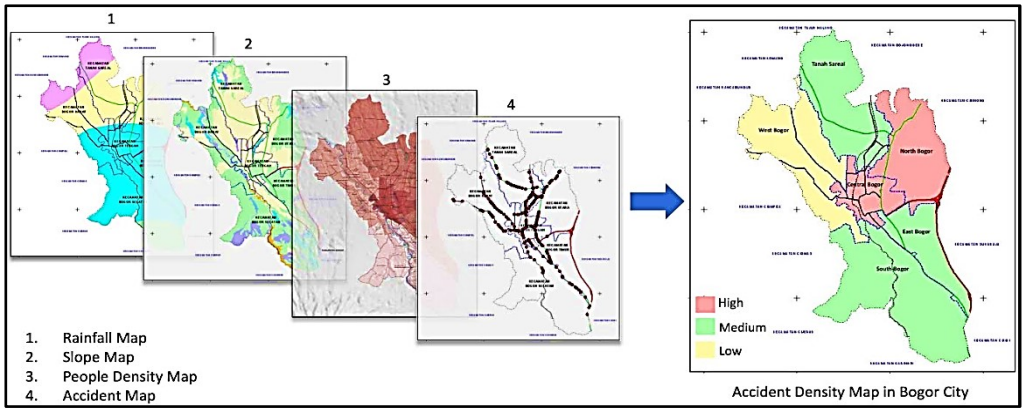

Figure 2: Traffic Accident Vulnerability in Bogor City

Traffic accident-prone locations have an average rainfall of 4000 mm/year, with an average slope of 20% and high population density. Reducing the number of accidents caused by the influence of rainfall can be done by installing traffic signs. Reducing the number of accidents caused by slopes, it can be done by providing road markings while reducing the number of accidents caused by population density, it can be done by adding zebra crossings, crossing bridges, or underpasses.

CONCLUSION

Based on the results of the analysis, it can be seen that there is a correlation between the incidence of traffic accidents with rainfall, population density, and slope. The number of traffic accidents throughout 2009 amounted to 127 incidents with the highest distribution of traffic accidents in Central Bogor

District, with several accidents of as many as 34 incidents. The Central Bogor District has 13 accident-prone points, namely on Jalan Ir. H. Juanda as many as 3 vulnerable points. Jalan Jendral Sudirman has 4 vulnerable points and Jalan Pajajaran has 2 vulnerable points. East Bogor District has 2 vulnerable points on Jalan Pajajaran, South Bogor District has 1 vulnerable point, Tanah Sareal District there are 3 vulnerable points, North Bogor District has 8 accident-prone points. The Linkage of Traffic Accident-Prone Areas with the RTRW of Bogor City. The highest number of traffic accidents is in Central Bogor District, following the pattern of the Bogor City road network which has a *concentric radial* pattern, which makes Central Bogor District the center of traffic movement where the flow of vehicles gathers both inside Bogor City, and from outside to inside / inside out of Bogor City.

In order to ensure the availability of transportation services and infrastructure, strict supervision efforts are needed. A safety audit is a part that needs to be applied to all sectors of transportation modes, this safety audit is a formal process to ensure that the operational scheme of traffic can run well.Traffic accident-prone locations in the study area require comprehensive, integrated, and sustainable transport management to minimize and avoid various transportation problems, especially traffic accidents, such as placing traffic signs, reducing or eliminating conflict points, increasing the freedom of view of motorists, reducing vehicle speed and adding Zebra Crossing, pedestrian bridges, and underpasses.

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