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ENGINEERING MODEL ON TRAFFIC VOLUME AT BOCIMI TOLL GATE

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The Bocimi Toll Road, connecting Bogor, Ciawi, and Sukabumi, represents a critical infrastructure development in Indonesia, aimed at enhancing regional connectivity across West Java and Banten Provinces. Designed to facilitate access between satellite cities such as South Jakarta, Cianjur, and Rangkasbitung, the toll road is also anticipated to boost tourism in Bogor, Ciawi, and Sukabumi by improving accessibility. This study focuses on two primary objectives: analyzing traffic volume at key toll gates during peak hours and determining average travel times along the Bocimi Toll Road. The findings reveal that the Cigombong Toll Gate experiences high traffic volumes, predominantly from large trucks and heavy vehicles, necessitating the separation of heavy vehicle lanes to optimize traffic flow. Furthermore, the average travel time analysis indicates that the highest traffic flow, recorded at 703.04pcu/hour, occurs in the afternoon at Cigombong, while the lowest, at 506.26pcu/hour, occurs in the morning at the Ciawi Toll Gate. These results underscore the importance of targeted traffic management strategies to enhance the operational efficiency of the Bocimi Toll Road and support its role in regional economic and tourism development.

Keywords: toll gate, speed, volume, Bocimi

1 INTRODUCTION

The construction of toll roads in Indonesia continues to progress rapidly, including the implementation of an automatic payment system through toll gates. Since October 2017, the use of electronic money or e-money has become mandatory for all toll road users in Indonesia. Until September 2021, the Bocimi Toll Road has become a significant project at the construction stage that represents the development of toll roads in Indonesia. With the abbreviation of Bogor-Ciawi-Sukabumi/Bocimi. The Bocimi Toll Road is designed to connect satellite cities such as South Jakarta, Cianjur, and Rangkasbitung in the provinces of West Java and Banten. The Bocimi Toll Road has several toll gates as strategic entrances and exits. Toll rates are determined based on the type of vehicle and the distance traveled which is the responsibility of vehicle owners who use this toll road. Toll road managers are not only responsible for routine maintenance tasks, such as road repairs, cleaning, and lighting, but are also responsible for the safety and comfort of users. In addition, the Business Entity as a toll road management company that operates this project in accordance with the agreement established with the government. Along with technological advances and demands for efficiency, the implementation of an e-money system at toll gates is a significant step in supporting smooth travel on Indonesia's toll roads. The first research objective is to analyze traffic volume at toll gates during peak hours, and the second is to obtain the average travel time on the Bocimi toll road.

The construction of toll roads plays a role in improving the local economy by increasing the participation of micro, small and medium-sized business products in the business space of rest areas and toll road services. Business entities must allocate at least 30% (thirty percent) of the total commercial area for micro, small and medium-sized businesses, both for toll roads that are already operating and for toll roads that are still in the planning and construction stages [1].

By providing fast and smooth access between three important cities in West Java, the Bocimi Toll Road will improve connectivity and facilitate the mobility of people and goods in the region. The Bocimi Toll Road is also expected to support the development of the tourism sector in the Bogor, Ciawi and Sukabumi areas. With better access, the tourism potential in the region can be more affordable and attract more tourists [2], [3].

Bogor-Ciawi-Sukabumi Toll Road or Bocimi Toll Road is a toll road that stretches 53.6kilometers. The performance of a toll road is an evaluation of the extent to which a toll road operates efficiently and effectively in meeting its main objectives. Studies on toll road traffic volume usually involve various aspects that include technical, operational, economic, and social aspects. The background of this study is related to improving the quality, safety, and efficiency of toll roads and optimizing benefits for the community and the economy as a whole. Through this study, the government and other related parties can make better decisions in managing and improving toll roads for the benefit of the community and the economy as a whole. Toll road services are services provided by the toll road management to ensure the smoothness and comfort of toll road users, both when vehicles enter and exit the toll road. The toll road services in terms of vehicles entering and exiting consist of Toll Gates, Toll Payment Points, Automatic Toll Kiosks, Toll Officers, Information and Directional Signs, Street Lighting, User Service Centers, Supervision and Security. All

these efforts aim to provide the best service to toll road users, maintain smooth traffic flow, and improve safety during travel on toll roads. The existence of modern facilities such as automatic toll booths also helps reduce congestion and waiting time at toll gates, thereby facilitating vehicle mobility. The purpose of research on toll road performance is to identify, understand, and improve aspects of toll roads in order to achieve the objectives of toll road performance research, including: Analyzing traffic volume at toll gates during peak hours, and average travel time on the Bocimi toll road [3].

Research on risk management analysis of toll road construction implementation (Case study: Bekasi-Cawang-Kampung Melayu Toll Road Construction Project). This study uses a qualitative method using a descriptive approach. Qualitative descriptive research is to describe the opinions of respondents as they are in accordance with the research questions, then analyzed with the words behind the respondents' behavior, reduced, triangulated, concluded, and verified. The results of this study are based on project risk, namely by calculating the exact and fast material requirements in sending materials to the project location. Meanwhile, the traffic itself has not been handled properly so that risk mitigation against congestion has not been calculated. So, the difference between this study and the author's study is very different [4]. Research on the impact of the existence of toll roads on physical, social and economic conditions and their environment. This study uses a case study method. In general, case studies are a more suitable strategy when the main question of a study concerns how and why, researchers only have a little opportunity to control the events to be investigated, and when the focus of the research lies in contemporary phenomena (present) in the context of real life. The research design used is a holistic multi-case design with four cases, namely: Brebes Regency, Cirebon City, Indramayu Regency and Subang Regency. Observations were conducted exploratively for each case on the changes that occurred after the operation of the toll road, then analyzed using before after analysis. This study also found that toll roads can affect the increase in land and building tax revenues, and the high toll rates that cause many trucks not to use toll roads, indicating that the goal of building toll roads to increase connectivity between regions so that logistics costs can decrease has not been achieved. Factors that influence regional development after the operation of toll roads include: (1) completeness and reach of regional facilities; (2) tourist locations; (3) geographical location [5]. Furthermore, research entitled toll road maintenance management based on project management (Case study: To X) University of Indonesia Thesis examines the management of toll road maintenance in the city based on project management from PMBOK, namely using the Project Management Book of Knowledge model systematically. The research technique uses a direct survey method in the field using qualitative and quantitative descriptive based on PMBOK. The results obtained are that the PMBOK method is very good and is a study of toll road access that has become better [6]. Study of the influence of the Semarang-Demak toll road development on the performance of the Kaligawe highway, a transportationgrant research from the Sultan Agung Islamic University of Semarang. The purpose of this study is to: (1) Calculate the level of service of the Existing Kaligawe Highway. (2) Determine the magnitude of the diversion of traffic loads on the Kaligawe Highway after the Semarang-Demak Toll Road is operated and (3) Calculate the predicted increase in performance of the Kaligawe Highway after the Semarang - Demak Toll Road is operated. The analysis technique used in this study is the formulation of traffic loading around the location due to construction, both during and after, added with base traffic. The results of this study show that the planned Arteri Pelabuhan toll intersection, for reasons of smoothness and optimization of the main section because it is a National access road, it is more appropriate to use 2 phases. Judging from the delays that will arise, the arrangement using 2 phases is better and does not cause many delays on the Nationalroad. If the traffic flow is outside normal days (religious holidays), then the intersection can be regulated by officers and APILL will activate the yellow signal lights (flashing) [7].

Priority of handling occupational safety and health issues in efforts to improve the implementation of toll road projects in Indonesia. This study describes activities such as the number of work accidents in infrastructure projects, especially toll roads in the last three years, indicating problems related to the implementation of Occupational Safety and Health (K3) in the field. This study was conducted to further examine three K3 problems, namely Efforts to Reduce Risky Behavior, Efforts to Increase Worker Compliance with K3, and Efforts to Increase the Success of Implementing K3 Procedures, especially in toll road construction in Indonesia. The study was conducted using a questionnaire on three toll road projects in the Jakarta area with a total of 222workers as respondents. The results of the study indicate that there are three things that need to be considered in implementing K3 in the construction sector, especially toll roads. The first is an effort to minimize risky behavior in workers by providing sufficient knowledge and a good supervision system. The second is an effort to increase worker compliance in implementing K3 procedures by creating policies and programs that are manifested in the form of providing supporting K3 facilities and infrastructure as a form of top management commitment. The third thing is an effort to improve the implementation of K3 procedures by implementing proper supervision and supported by the application of strict penalties in accordance with applicable regulations. These three things must be considered in order to support the success of the implementation of the K3 program to minimize accidents, especially on toll road projects in Indonesia [8].

2 STUDY LITERATURE

2.1 Definition of Toll Roads

Toll roads are public roads that are part of the road network system and as national roads whose users are required to pay. The implementation of toll roads themselves is intended to realize equitable development and its results as well as balance in regional development by paying attention to justice, which can be achieved by developing a road

network whose funds come from road users. Meanwhile, the purpose of toll roads is to increase the efficiency of distribution service services in order to support increased economic growth, especially in areas with high levels of development [2].

Service standards on toll roads at least cover several service substances, including:

- Toll road conditions
- Average travel speed
- Accessibility
- Mobility
- Safety
- Rescue/assistance units and service assistance
- Environment
- Rest Areas (TI), and Service Rest Areas (TIP) [2].

2.2 Toll Gate

On toll roads or what are called toll roads, there are toll gates. According to the 2005 toll info, a toll gate is a place for toll transaction services intended for toll users consisting of several booths and other equipment. Toll gates or toll booths are used as a place for workers to serve the toll ticket payment transaction process for toll road users. There are several rules at toll gates, including the following:

- Entry booths are for serving the provision of entry tickets to toll road users.
- Exit booths are for serving transactions to toll users.

2.3 Toll Gate System

A toll road is a system built on a road that is intended to provide facilities for road users by reducing average travel time, increasing speed, safety and increasing the capacity of the road section. 8 Toll roads have become a means of generating revenue in building toll roads by reducing congestion problems in many existing road networks. There are two systems at toll gates, namely:

- A closed system is a toll collection system in which users are required to take an entry ticket at the entrance gate and pay tolls at the exit gate.
- An open system is a toll collection system in which users are required to pay tolls when passing through the entrance gate or exit gate [1].

2.4 Toll Road Services

Toll road services are an important thing that must be provided by managers to toll road users so that users get services according to the fees they have paid. There are two types of toll road services, namely:

- Transaction services are clearly visible to toll collectors because they are directly facing the driver. The dynamics and development of demands from toll road users, it is necessary to provide a good image to the public regarding services when making transactions. Toll collectors/toll gates are an important part of toll road services.
- Traffic services can be seen from incidents along the toll road. For example, reducing the number of accidents on toll roads, by providing patrol facilities, ambulances, fire engines, and rescue vehicles that can be used by toll road users when experiencing difficulties, and overcoming landslides/floods that occur on several parts of the toll road.

The toll gate that meets international standards and is currently being studied is shown in Figure 1 below.

Fig. 1. Cigombong toll gate

2.5 Toll Road Capacity

Toll road capacity refers to the ability of a toll road segment to accommodate traffic volume in a certain period. This involves several factors, including road geometry, number of lanes, and vehicle types that can affect traffic flow. Factors that affect capacity consist of road geometry (curve radius, elevation), number of lanes, and traffic characteristics (vehicle density, vehicle type) contribute to determining toll road capacity. The toll road capacity calculation methods are as follows:

- Mathematical and Empirical Approaches
- Toll road capacity calculation methods involve mathematical approaches and empirical calculations. Models such as MKJI and HCM provide guidelines in measuring capacity based on traffic volume, speed, and service level.
- Indonesian Road Capacity Manual (MKJI)
- MKJI is the main reference for assessing road capacity in Indonesia, providing practical guidance and calculations to evaluate the capacity of various types of roads including toll roads [9].

2.6 Traffic Performance Indicators

- Traffic Volume
- Traffic volume is the number of vehicles passing through a point or segment of a toll road in a certain period of time.
- Traffic Density
- Traffic density refers to the number of vehicles in a space at a certain time. It can be calculated by dividing the traffic volume by the length of the road segment.
- Average Speed
- The average speed of a vehicle is an important parameter that reflects the efficiency and smoothness of traffic flow.
- Travel Time
- Travel time includes the duration required to cover a distance on a toll road and is a vital indicator of transportation comfort and efficiency [9].

2.7 Role of Traffic Simulation and Models

- Traffic Simulation
- Traffic simulations enable modeling of complex traffic conditions and provide insight into the impact of design or policy changes on toll road capacity.
- Traffic Models
- Traffic models help in understanding traffic flow dynamics and can be used to forecast toll road capacity in specific scenarios.

2.8 Challenges and Recent Developments in Toll Road Capacity Evaluation

- Current Technologies
- The use of technologies such as smart sensors and big data analytics has enabled real-time traffic monitoring and provided more accurate data.
- Environmental and Sustainable Factors
- Capacity evaluation must also consider environmental and sustainable factors to optimize the toll road network in the long term [1], [9].

2.9 Vehicle Speed on Toll Roads

Speed is the ability to cover a certain distance in a unit of time expressed in kilometers per hour. Speed is expressed as the rate of a vehicle movement calculated in distance per unit of time (km/h) [10].

When driving on a toll road, of course, you must comply with the predetermined driving rules. The purpose of the speed limit regulation on toll roads is to keep vehicles focused and aware of the maximum speed limit when driving a car to prevent accidents, especially at several points that are prone to accidents. Driving speed must be considered and by applicable regulations [11].

Local speed is the speed of a vehicle measured when the vehicle passes a specified point. In measuring local speed, it can be done with a measuring instrument with a radar system, for example using a kilometer gun. There are 2 (two) types of local speed analysis used for traffic flow speed studies, including Time Mean Speed (TMS) and Space Mean Speed (SMS).

- Time Mean Speed is the average speed of time which is the average of local speed data at the same place. Surveys are conducted on many vehicles at the same place, the average value of the survey results becomes the average local speed (Times Mean Speed).
- Space Mean Speed is the average speed of all vehicles occupying a section of the road during a certain time interval, the average speed of space can be calculated mathematically [10].

2.10 Speed limit on toll roads

The speed limit on toll roads is 60km/hour–100km/hour, according to the installed traffic signs. The regulation states that the speed limit on toll roads is at least 60km/hour and at most 100km/hour. For driving on toll roads within the city, the minimum speed is 60km/hour, the maximum speed is 80km/hour. Then for driving on toll roads outside the city, the minimum is 60km/hour and the maximum is 100km/hour. Although there are speed limits for each, drivers must pay attention and always concentrate to avoid accidents with other vehicles around them [10].

2.11 Types of vehicles that passthrough toll roads

Currently, 6 groups of vehicles are permitted to pass through toll roads, namely:

- Group I, namely small vehicles, jeeps, pick-ups/small trucks, and buses
- Group II, namely large trucks with two axles (truck axles).
- Class III, namely large trucks with three axles.
- Class IV, namely large trucks with four axles.
- Class V, namely trucks with five axles [12].

Traffic safety is a very important aspect in highway traffic management. Traffic accidents can result in serious injuries or even death, as well as major material losses. The government and related organizations often conduct safety campaigns to raise awareness among drivers of the importance of driving safely and obeying traffic regulations. Safe driving training is also provided to help drivers develop good driving skills [13].

Technology also plays a significant role in improving road safety, with innovations such as advanced driver assistance systems helping to reduce the risk of accidents. Motorized traffic also has a significant impact on the environment. Exhaust emissions from motor vehicles are a major source of air pollution, which can lead to a variety of health problems such as respiratory and heart disease. In addition, traffic noise can be detrimental to public health and well-being. Efforts to reduce the environmental impact of traffic include promoting the use of electric vehicles, improving fuel efficiency, and implementing stricter environmental policies. Technology continues to change the way we manage and experience road traffic. Navigation apps and digital maps help drivers find the best routes and avoid traffic congestion [14].

Autonomous vehicles, although still in their infancy, have the potential to reduce accidents and improve traffic efficiency. Intelligent transportation systems that integrate information and communication technologies are being used to optimize traffic management and improve safety. The role of the public in regulating road traffic is also very important [15].

Drivers are expected to obey traffic rules, drive safely and responsibly. Awareness of the importance of safety and efforts to reduce environmental impact must be increased. Active community participation in traffic safety programs and environmental initiatives can help create a safer, more efficient, and more sustainable traffic system. Overall, motorized traffic activities on the road require effective management and collaboration between the government, related organizations, and the community to ensure smoothness, safety, and sustainability [16], [17].

Road users, both in big cities and in rural areas, must always be careful to ensure the safety of themselves and others. Road safety is the result of various factors, including compliance with traffic regulations, awareness of road conditions, and driver attitudes and behaviors. The following is an explanation of the importance of being careful on the road and how to do it. Preparation before driving is a very important first step. Before starting the trip, make sure the vehicle is in prime condition. Routine checks such as checking tire pressure, brake conditions, and fuel availability are mandatory. Also, make sure all vehicle lights are working properly, including brake lights, turn signals, and headlights. This check helps reduce the risk of mechanical damage that can cause accidents [18], [19].

When driving, drivers must always obey the specified speed limit. Speed limits are made to maintain traffic safety and smoothness. Driving too fast can increase the risk of accidents because it shortens the driver's reaction time to unexpected situations. On the other hand, driving too slow can also be dangerous because it can hinder traffic flow and cause other drivers to make dangerous maneuvers to overtake. Therefore, maintaining a safe speed within the specified limit is very important. Maintaining a safe distance from the vehicle in front is another thing that must always be considered. A safe distance gives the driver enough time to react if the vehicle in front suddenly stops or slows down [20].

Heavy traffic conditions often tempt drivers to drive too close to the vehicle in front, even though this is very dangerous and can cause accidents repeatedly. In rainy conditions or slippery roads, this safe distance must be increased because braking will take longer. Being aware of the surrounding conditions is also very important. Drivers must always be aware of road conditions, including potholes, puddles, and traffic signs. In areas with lots of pedestrians, drivers must be more careful and be ready to stop if there are pedestrians crossing the road [21], [22].

At intersections and traffic lights, pay attention to other vehicles that may be breaking the rules. This alert attitude helps drivers to react quickly and avoid potential dangers. In addition, wearing a seat belt is an obligation that should not be ignored. Seat belts are a very effective safety device in protecting drivers and passengers from serious injury in the event of an accident. Make sure all passengers, including those in the back seat, always wear seat belts. Drivers must also ensure that children use child seats that are appropriate for their age and weight. Weather conditions also affect driving safety. During bad weather such as heavy rain or thick fog, drivers must reduce speed [23].

Utilization of toll roads as an alternative to reduce congestion can affect traffic density and driving comfort. So, every driver must pay attention to their environment, including the materials that make up the road pavement, including rigid pavement [24], [17].

3 RESEARCH METHODOLOGY

3.1 Place and Time of Research

The research location is in the area from Ciawi to Cigombong. The map and toll gate entry locations are shown in Figures 2 and 3 below.

Fig. 2. Map of research location. Source: Bocimi Toll Management

Fig. 3. Bocimi toll road journey. Source: Googlearth Bocimi toll map, accessed August 28, 2023 at 15.00BBWI

3.2 Data Collection

The data used to analyze this study is primary data to suit the needs required. Data is obtained by obtaining data from the Bocimi toll road manager.

3.3 Primary Data

Is data obtained by conducting a direct survey in the field. From the survey conducted, data was obtained in the field with actual conditions.

- Data on the number of vehicles entering the Toll Gate
- Data on the number of vehicles exiting the Toll Gate
- Number of vehicles entering the Toll Gate per day and weekly accumulation
- Number of vehicles exiting the Toll Gate per day and weekly accumulation
- Number of vehicles entering the Toll Gate per day and monthly accumulation
- Number of vehicles exiting the Toll Gate per day and monthly accumulation
- Number of vehicles entering the Toll Gate per day and annual accumulation
- Number of vehicles exiting the Toll Gate per day and annual accumulation
- Number of officers on duty and length of working hours

3.4 Data Analysis Method

In conducting research, a series of research steps will be needed first to make it easier to analyze. In this research, it is necessary to plan the steps taken so that the research process can be carried out effectively. The following are the steps in the research of data collection at toll gates:

- Primary data taken based on vehicles entering and exiting the toll gate at the research location. The duration of this data was taken during peak hours, namely morning rush hour, afternoon rush hour and evening rush hour every day for one day.
- Data processing with Microsoft Excel program.

3.5 Flowchart

The research method used is presented in a flowchart, as shown in Figure 4 below.

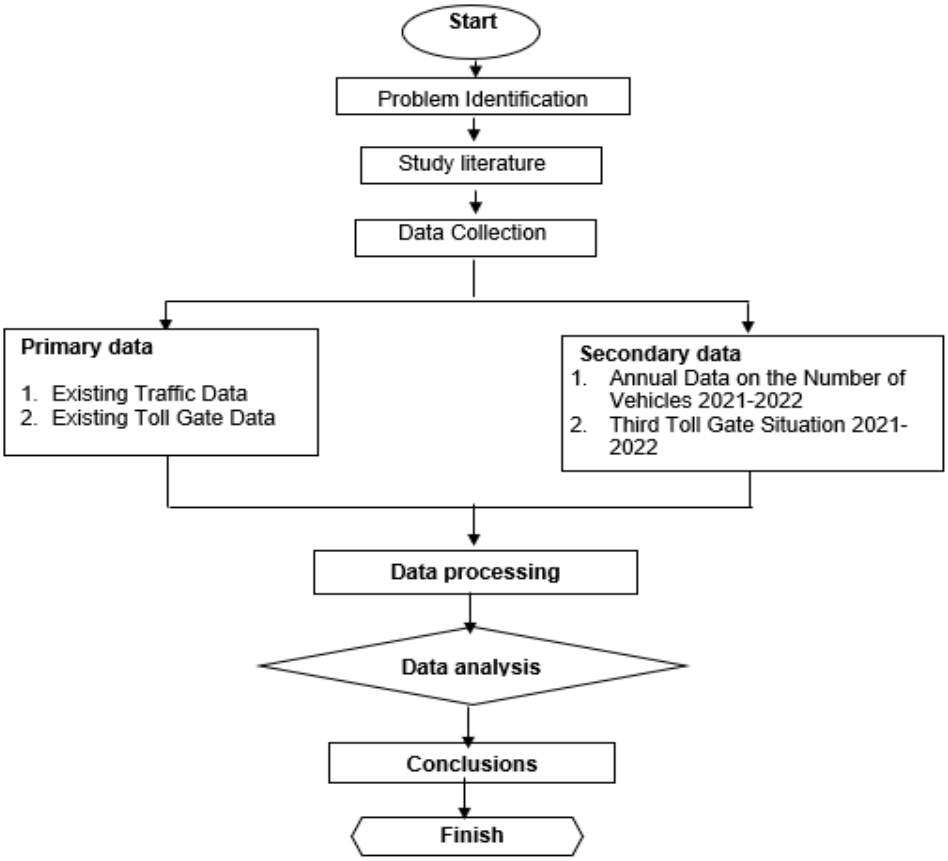

Fig. 4. Research flowchart

Data collection in this study is divided into two, primary data collection and secondary data collection, what distinguishes the two data collections is the type of data. Primary data collection is carried out through several stages, namely:

- In collecting this primary data, what is needed is the number of vehicles passing through the toll gate in the research area.
- Secondary data itself is data obtained from the Toll Road Manager (PT. Trans Jabar Tol).
- The data above is then grouped according to the type of vehicle and the number of vehicles with a time interval of 15minutes using Microsoft Excel.
- The data that has been analyzed will provide the amount or results needed to provide conclusions on the research conducted.

4 RESULTS AND DISCUSSION

4.1 Results of data collection in the field

Primary data collection in the field was carried out on Monday, September 25, 2023. There are three points where this primary data was taken, namely the Cigombong toll gate, the Caringin toll gate and the Ciawi toll gate. The results of the calculation of data collection in the field in the morning, daytime and afternoon are displayed in the table 1 until table 9 below.

Table 1. Vehicle Volume at the Cigombong Toll Gate in the Morning

Transportation type	Times					Units	Volume
	07:00	07:15	07:30	07:45	08:00		SMP/hours
Private car	50	64	76	66	56	1	267,20
Goods vehicles	29	25	22	36	34	1	118,80
Big bus	12	11	16	19	12	1,3	78,52
Heavy vehicle	30	34	42	38	32	1,3	195,52
Total							660,04

The research that has been carried out can be seen from table 1 above based on a study from the Cigombong Toll Gate in the morning is dominated by private cars with a traffic volume of 267.20pcu/hour. Furthermore, heavy vehicles are 195.52pcu/hour and goods cars are 118.80pcu/hour and finally large buses are 78.52pcu/hour.

Table 2. Vehicle Volume at Caringin toll gate in the Morning

Transportation type	Times					Units	Volume
	07:00	07:15	07:30	07:45	08:00		pcu/hour
Private car	77	82	65	55	45	1	288,00
Goods vehicles	22	32	24	43	42	1	129,40
Big bus	14	12	18	17	12	1,3	82,42
Heavy vehicle	10	12	16	11	13	1,3	67,08
Total							566,90

Table 2 above shows that private cars still dominate the traffic volume in the morning at the Caringin toll gate, which is 288.00pcu/hour, goods cars at 129.40pcu/hour, then large buses at 82.42pcu/hour and finally heavy vehicles with a traffic volume of 67.08pcu/hour.

Table 3. Vehicle Volume at the Ciawi toll gate in the Morning

Transportation type	Times					Units	Volume
	07:00	07:15	07:30	07:45	08:00		pcu/hour
Private car	47	65	78	63	54	1	263,80
Goods vehicles	24	27	21	23	34	1	101,80
Big bus	11	13	12	10	16	1,3	63,96
Heavy vehicle	17	15	12	13	10	1,3	76,70
Total							506,26

Table 3 shows that private cars still dominate the traffic volume in the morning at the Ciawi toll gate, which is 263.80pcu/hour, goods cars at 101.80pcu/hour, then heavy vehicles with a traffic volume of 76.70pcu/hour, and finally large buses at 63.96pcu/hour.

Table 4. Vehicle Volume at the Cigombong toll gate in the Daytime

Transportation type	Times					Units	Volume
	12:00	12:15	12:30	12:45	13:00		pcu/hour
Private car	51	75	84	76	67	1	299,40
Goods vehicles	32	22	25	38	42	1	125,40
Big bus	10	15	13	17	21	1,3	76,96
Heavy vehicle	35	37	34	38	33	1,3	195,78
Total							697,54

Table 4 shows that private cars still dominate the traffic volume in the morning at the Cigombong toll gate during the day, which is 299.40pcu/hour, heavy vehicles have a traffic volume of 195.78pcu/hour, goods cars are 125.40pcu/hour, then, finally, large buses are 76.96pcu/hour.

Table 5. Vehicle Volume at the Caringin toll gate in the Daytime

Transportation type	Times					Units	Volume
	12:00	12:15	12:30	12:45	13:00		pcu/hour
Private car	65	71	76	56	59	1	279,80
Goods vehicles	12	21	32	42	43	1	115,60
Big bus	17	11	21	17	12	1,3	88,92
Heavy vehicle	13	12	11	13	12	1,3	66,82
Total							551,14

Table 5 above shows that private cars still dominate the traffic volume during the day at the Caringin toll gate, which is 279.80pcu/hour, goods cars at 115.60pcu/hour, then large buses at 88.92pcu/hour and finally heavy vehicles with a traffic volume of 66.82pcu/hour.

Table 6. Vehicle Volume at the Ciawi toll gate in the Daytime

Transportation type	Times					Units	Volume
	12:00	12:15	12:30	12:45	13:00		pcu/hour
Private car	65	58	68	56	69	1	260,80
Goods vehicles	20	26	45	43	25	1	139,00
Big bus	16	22	26	21	10	1,3	113,10
Heavy vehicle	9	12	21	13	17	1,3	75,92
Total							588,82

Table 6 above shows that private cars still dominate the traffic volume during the day at the Ciawi toll gate, which is 260.80pcu/hour, goods cars at 139.00pcu/hour, then large buses at 113.10pcu/hour and finally heavy vehicles with a traffic volume of 75.92pcu/hour.

Table 7. Vehicle Volume at the Cigombong toll gate in the Afternoon

Transportation type	Times					Units	Volume
	17:00	17:15	17:30	17:45	18:00		pcu/hour
Private car	45	81	86	78	65	1	303,00
Goods vehicles	21	27	22	34	32	1	110,40
Big bus	14	12	18	12	20	1,3	78,00
Heavy vehicle	36	35	42	41	44	1,3	211,64
Total							703,04

The results of the research that has been carried out can be seen from table 7 above based on a study from the Cigombong Toll Gate in the afternoon dominated by private cars with a traffic volume of 303.00pcu/hour. Furthermore, heavy vehicles of 211.64pcu/hour and goods cars of 110.40pcu/hour and finally large buses of 78.00pcu/hour.

Table 8. Vehicle Volume at the Caringin toll gate in the Afternoon

Transportation type	Times					Units	Volume
	17:00	17:15	17:30	17:45	18:00		pcu/hour
Private car	62	72	81	56	69	1	284,80
Goods vehicles	20	31	36	34	35	1	128,00
Big bus	11	15	17	11	21	1,3	75,66
Heavy vehicle	19	15	11	10	12	1,3	74,62
Total							563,08

Table 8 above shows that private cars still dominate the traffic volume in the afternoon at the Caringin toll gate, which is 284.80pcu/hour, goods cars at 128.00pcu/hour, then large buses at 75.66pcu/hour and finally heavy vehicles with a traffic volume of 74.62pcu/hour.

Table 9. Vehicle Volume at the Ciawi toll gate in the Afternoon

Transportation type	Times					Units	Volume
	17:00	17:15	17:30	17:45	18:00		pcu/hour
Private car	52	65	79	76	78	1	287,60
Goods vehicles	27	31	32	38	34	1	134,80
Big bus	11	16	13	22	18	1,3	85,28
Heavy vehicle	12	14	22	13	21	1,3	84,76
Total							592,44

Table 9 above shows that private cars still dominate the traffic volume in the afternoon at the Ciawi toll gate, which is 287.60pcu/hour, goods cars at 134.80pcu/hour, then large buses at 85.28pcu/hour and finally heavy vehicles with a traffic volume of 84.76pcu/hour.

4.2 Discussion of data collection

The results of the data collection and processing above can be summarized and presented in Table 10 below.

Table 10. Recapitulation of traffic volume at each toll gate on Monday

No	Toll Gate Name	Day	Times	Average volume	Highest volume	Lowest Volume
1	Cigombong	Monday, September 25, 2023	Morning	660,04		
	Caringin		Morning	566,90		
	Ciawi		Morning	506,26		Morning
2	Cigombong	Monday, September 25, 2023	Daytime	697,54		
	Caringin		Daytime	551,14		
	Ciawi		Daytime	588,82		

No	Toll Gate Name	Day	Times	Average volume	Highest volume	Lowest Volume
3	Cigombong	Monday, September 25, 2023	Afternoon	703,04	Afternoon	
	Caringin		Afternoon	563,08		
	Ciawi		Afternoon	592,44		

4.3 Discussion of Results

Next, the assessment results of vehicle traffic volume data at the Cigombong toll gate, Caringin toll gate, and Ciawi toll gate in the morning, afternoon, and evening are presented in Figures 5, 6, and 7 below.

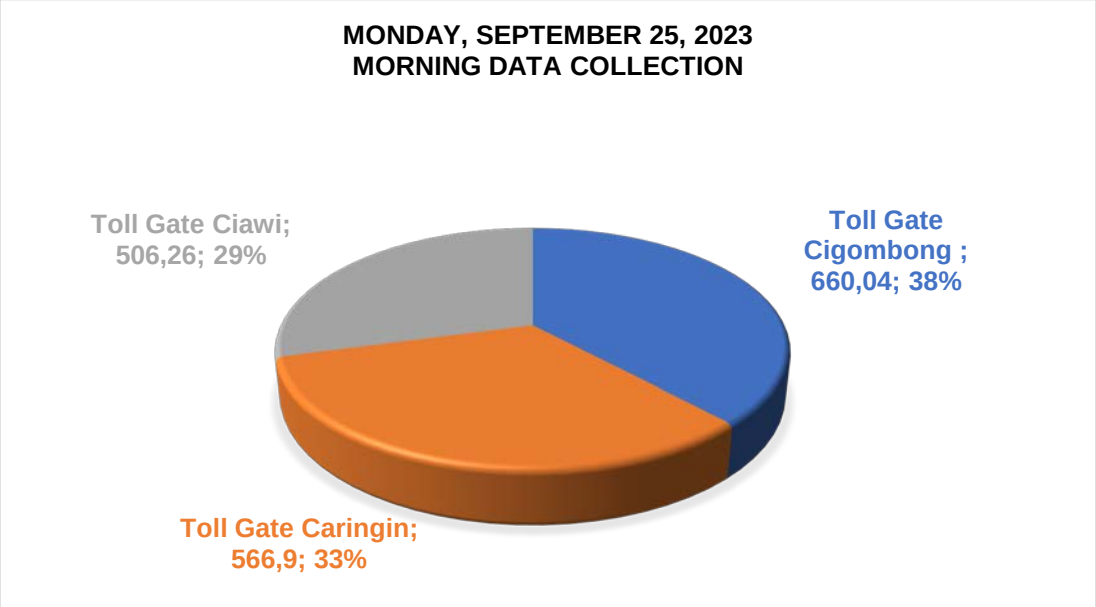

Fig. 5. Traffic volume of the three toll Gates in the morning

Figure 5 above shows that the average morning vehicle volume at the Cigombong toll gate is 38% (660.04pcu/hour), followed by the Caringin toll gate at 33% (566.90pcu/hour), and the Ciawi toll gate at 29% (506.26pcu/hour).

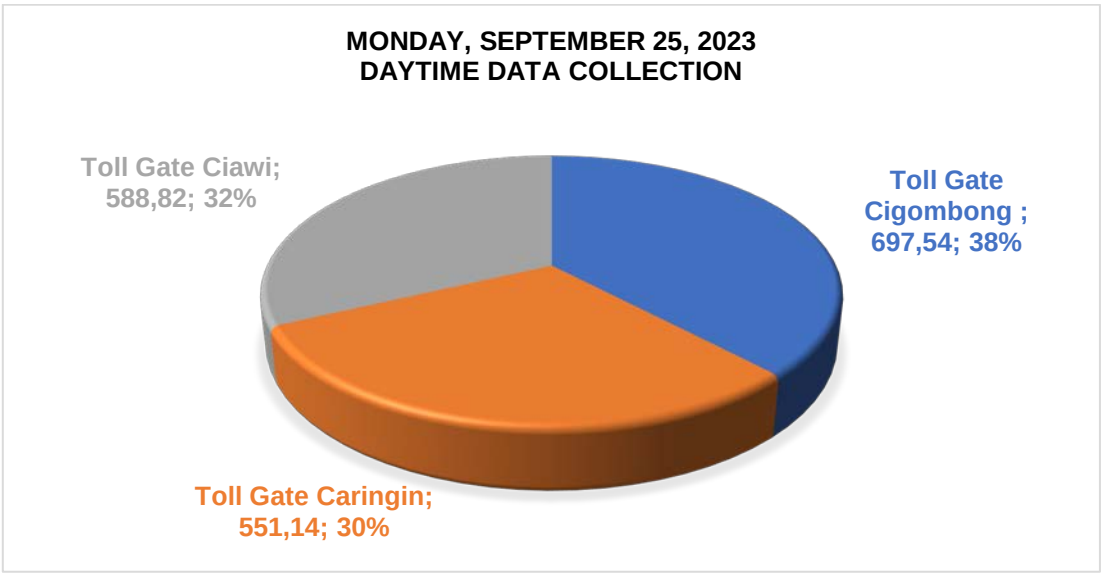

Fig. 6. Traffic volume of the three toll Gates the midday

Figure 6 above shows that the average daytime vehicle volume at the Cigombong toll gate is 38% (697.54pcu/hour), the Ciawi toll gate is 32% (588.82pcu/hour), and the Caringin toll gate is 30% (551.14pcu/hour).

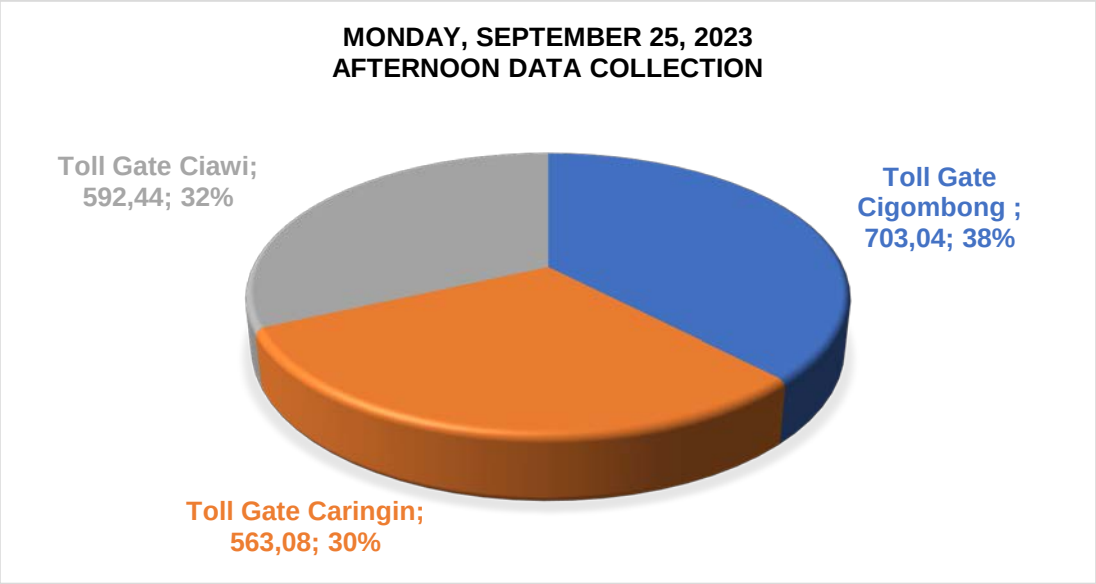

Fig. 7. Traffic volume of the three toll Gates in the afternoon

Figure 7 above shows that the average evening vehicle volume at the Cigombong toll gate is 38% (703.04pcu/hour), at the Ciawi toll gate is 32% (592.44pcu/hour), and at the Caringin toll gate is 30% (563.30pcu/hour).

At the Cigombong toll gate in the evening, vehicle speed decreases due to an increase in traffic volume. At the Caringin toll gate, the vehicle volume remains moderate throughout the morning and evening. Meanwhile, at the Ciawi toll gate in the evening, vehicle speed increases as the traffic volume slightly decreases. Overall, a reduction in vehicle volume allows drivers more freedom to increase their speed. Conversely, when traffic volume increases, vehicle speed tends to decrease. During the daytime at the Ciawi toll gate, vehicle speed increased due to low traffic volume, as the Cikereteg Bridge was closed (at the time of the study), causing vehicle diversion to the Caringin toll gate.

5 CONCLUSIONS

The novelty of this research lies in its comprehensive analysis of traffic dynamics on a newly constructed toll road in Indonesia, specifically focusing on the Bocimi Toll Road. While traffic volume and travel time studies are common in toll road assessments, this study provides novel insights into the specific characteristics of traffic flow, particularly the dominance of heavy vehicles at critical toll gates. It also examines the temporal variation in travel times, a factor that can significantly affect overall toll road efficiency. By considering the interaction between regional development and tourism, this research adds an important layer to the understanding of how toll road infrastructure influences both economic and social outcomes. Additionally, the study's findings contribute to the growing body of literature on infrastructure optimization in emerging markets, where road usage patterns can differ significantly from those in developed countries. Cigombong toll gate experiences high traffic volumes, predominantly from large trucks and heavy vehicles, necessitating the separation of heavy vehicle lanes to optimize traffic flow. Furthermore, the average travel time analysis indicates that the highest traffic flow, recorded at 703.04pcu/hour, occurs in the afternoon at Cigombong, while the lowest, at 506.26pcu/hour.

Toll gates, as the main entry points to expressways, play a crucial role in supporting highway activities by enhancing the efficiency and functionality of toll roads in several ways:

- Identifying the dominance of heavy vehicles at specific toll gates can inform the design of dedicated lanes to separate heavy and light traffic, thereby improving congestion management and safety.
- Understanding peak travel times at specific toll gates (e.g., Cigombong Toll Gate) can help toll operators implement targeted measures such as dynamic pricing, traffic signal adjustments, and lane optimization during peak hours to reduce congestion and improve traffic flow.
- The anticipated increase in tourism due to improved access via the Bocimi Toll Road highlights the need for integrated transportation planning. These findings can guide infrastructure development in surrounding areas, ensuring that the rise in tourist traffic is effectively managed.
- With increased traffic flow and reduced travel time on toll roads, this study supports economic models that estimate the long-term benefits of toll road projects. These insights can assist policymakers and investors in making informed decisions regarding infrastructure development in emerging economies.

The recommendation is that this study provides practical insights into toll road management and broader implications for sustainable infrastructure development in rapidly growing regions, particularly concerning tourism and regional connectivity.

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