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Analyzing Traffic Accidents on Pekanbaru-Dumai Toll Road from Road infrastructure Perspective

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Abstract

The Pekanbaru-Dumai (PERMAI) toll road serves a crucial role as the busiest access route in Riau Province. Due to the high volume of traffic on this toll road, it is suspected that various types of traffic accidents occur. This study analyzed the frequency of traffic accidents, accident rate metrics for black-spot and black-site areas, and the condition of road infrastructure on the Pekanbaru-Dumai toll road. This study employed a qualitative descriptive method and collected data from primary sources through field observations and secondary sources, such as accident reports from the Riau Regional Police Traffic Directorate (Indonesian: *Direktorat Lalu Lintas POLDA Riau*) covering the period from 2020 to 2022 and average daily traffic volume data from the Toll Road Regulatory Agency (Indonesian: *Badan Pengatur Jalan Tol* [BPJT]). The accident rate formula for black spots and black sites was applied to identify accident-prone and high-traffic areas on the Pekanbaru-Dumai toll road. The analysis results revealed a total of 30 incidents over the three years. The highest accident rate for black-spot areas was 0.10 at KM 34 and KM 35, while the highest for black-site areas was 0.10 at KM 35. Most incidents occurred during the night until early morning, specifically from 18:01 to 02:00. Passenger cars were the most frequently involved vehicles, with 16 single-vehicle collisions. These accidents resulted in 28 victims, including 7 fatalities, 9 serious injuries, and 12 minor injuries. In terms of travel direction, Line A (Pekanbaru to Dumai) experienced 11 incidents, while Line B (Dumai to Pekanbaru) had 19 incidents. The primary factor contributing to these accidents was human error, typically due to negligence or carelessness. Based on observations of road equipment and traffic management on the Pekanbaru-Dumai toll road, the study suggests improving safety by adding noise barriers following Indonesia's Minister of Transportation Regulation No. 82/2018, Article 33. Additionally, enhancing overall street lighting is recommended, in alignment with Indonesia's Minister of Public Works Regulation No. 16/PRT/M/2014 concerning Minimum Service Standards.

Keywords: Traffic Accident, Accident Rate, Black Spots, Black Sites, Road Equipment

Introduction

In the transportation sector, particularly in land transportation, freeways play a pivotal role in shaping the economic pace and societal prosperity. The smooth flow of vehicles in and out of an area is critical for ensuring the continuous supply of goods and services. In line with these considerations, toll roads have been developed both within and outside urban areas. Given that toll roads are primarily designed to facilitate unhindered vehicular movement, it is equally essential to address road safety concerns, where traffic accidents serve as the primary indicators of road safety.

This research primarily focuses on analyzing traffic accidents, with case studies conducted on several sections of the Pekanbaru-Dumai toll road. These particular sections of the toll road hold significant influence within Riau Province but have also witnessed a notable frequency of traffic accidents. Over the last three years, for instance, there have been 30 recorded accidents in the Pekanbaru-Dumai toll road sections, and this number appears to be on the rise annually. Consequently, there is a pressing need for further research to shed light on traffic accidents along the Pekanbaru-Dumai toll road sections. This study aims to provide a comprehensive understanding of traffic accidents, with the ultimate goal of preventing and minimizing their occurrence.

Research Objectives

This study aims to achieve the following objectives:

1. To identify the characteristics and factors contributing to accidents on the Pekanbaru-Dumai toll road.
2. To assess the extent of traffic accidents occurring on the Pekanbaru-Dumai toll road.
3. To identify and pinpoint "black spots" (high-accident areas) on the Pekanbaru-Dumai toll road.
4. To formulate strategies for enhancing safety through improvements in road infrastructure and traffic control.

Literature Review

According to Prasetyanto Dwi (2020), traffic accidents are incidents in which motor vehicles collide with objects, causing damage, and in some cases, resulting in injury or even death to humans or animals. Indonesia's Law No. 22/2009 defines a traffic accident as an unexpected and unintentional incident on the road involving a vehicle, with or without other road users, that leads to human casualties and/or property loss. Accidents occur when one or more components of the traffic system do not operate as intended. Several research sources suggest that traffic accidents in Indonesia can be mitigated through improvements in road infrastructure, equipment, and transportation facilities that are not in compliance with road classification standards (Indonesia's Law No. 26/1985). Hobbs (1995) notes that traffic accidents are unpredictable in terms of when and where they occur. These accidents not only result in trauma, injuries, and disabilities but can also lead to fatalities. The difficulty in minimizing accident cases is exacerbated by the increasing traffic volume on roads, driven by a growing human population using vehicles, often with inadequate driving safety education. Indonesian Government Regulation No. 43/1993, as presented in the book "*Traffic Engineering and Management: Theory and Application*," defines a traffic accident as an unexpected event involving vehicles or other road users that leads to human casualties and property loss. To analyze traffic accidents, data on accidents, such as vehicles per kilometer or accidents per

vehicle movement, are employed. These data are processed to determine the frequency of accidents and to identify accident-prone locations, with a more detailed analysis of the underlying causes of these accidents (Malkamah, 1995).

Hobbs (1995) suggests that a comprehensive traffic accident survey should be based on obtaining information in the following ways:

1. Macro Surveys: These surveys provide data on various categories of road users, including their vehicles, and are organized by locations, time, vehicle types, and vehicle movements. They are especially valuable in areas with mixed traffic, such as older settlements and narrow regions.
2. Micro Surveys: These surveys focus on identifying specific hazardous locations within the road system, often referred to as "black spots," and conducting in-depth site studies to evaluate the causes of accidents.

Additionally, Pignataro (1973) emphasizes the importance of observing accidents from several aspects, including the following:

Accident rate per kilometer

The accident rate per kilometer can be calculated using the following formula:

$$R = \frac{A}{L} \tag{1}$$

Where:

R = Total number of traffic accidents per kilometer each year,
A = Number of traffic accidents occurring in a year,
L = Length of the toll road section under consideration (in kilometers).

Accidents based on vehicle miles traveled

In the context of societal impact, they can be expressed as the number of traffic fatalities per 100,000,000 population/trips. This figure provides an overview of the number of traffic accidents. The accidents based on vehicle miles traveled can be calculated using the following formula:

$$R = \frac{C \times 100{,}000{,}000}{V} \tag{2}$$

Where:

R = Number of accidents per 100,000,000 vehicle kilometers traveled per year,
C = Total number of traffic accidents in a year,
V = Vehicle volume kilometers traveled in a year.

Accidents based on the severity index

The accidents based on the severity index can be calculated using the following formula:

$$SI = \frac{F}{A} \times 100\% \tag{3}$$

Where:

SI = Severity Index,
F = Number of fatal accidents per year,
A = Vehicle kilometers traveled in a year.

Accidents related to specific spots on toll roads

The accidents related to specific spots on toll roads can be calculated using the following formula:

$$Rsp = \frac{A \times 1{,}000{,}000}{365 \times L \times V} \quad (4)$$

Where:

Rsp = Accident rate for a specific spot,
A = Number of accidents during the analyzed period,
L = Length of the toll road section (in kilometers),
V = Traffic volume or average daily traffic (ADT),
365 = Observation time in a year.

Apart from that, Hobbs (1995) highlights that the level of traffic accidents is determined by several factors, such as population, registered vehicles, and data on traffic accidents within and outside urban areas.

This level can be quantified using various measures, including the number of vehicles per kilometer, accidents per 10,000 people per year, accidents per 10,000 vehicles, and accidents per 100,000,000 vehicle kilometers of general use. Pignataro (1973) argues that the level of traffic accidents serves as a better measure of risk than the frequency of traffic accidents alone, and it can be calculated using the following standard equation:

$$R = \frac{N \times 10^6}{V} \quad (5)$$

Where:

R = Traffic accidents per million accidents,
N = Number of traffic accidents in the study,
V = Traffic volume.

Identification of Traffic Accidents in Black Spots and Black Sites

The identification of areas prone to traffic accidents comprises two stages. Initially, an analysis of the accident history within the entire study area is conducted to pinpoint several locations susceptible to accidents. Subsequently, the selected locations undergo a detailed examination to determine the measures that have been implemented. Accident-prone areas are categorized into three groups: hazardous sites, hazardous routes, and hazardous areas (Emergency Transportation Education and Training Center, 1998).

A black spot is a location with a high susceptibility to traffic accidents, as evident from accident data over one year. A road section qualifies as a black spot if it exceeds the established accident rate threshold, determined using statistical probability with a specific value (e.g., 0.736). Such a designation indicates a heightened risk of traffic accidents at that specific point on the road section under observation (Kudus, 1995). The Directorate of Traffic and Transportation Development (1999) determines black spots based on the number of accidents

at a location over 3-5 years, with an average number of accidents greater than or equal to 3. However, according to Khisty & Lall (1990), a black spot is identified at a location with an average number of accidents greater than or equal to 10 accidents per year.

A black site is an accident-prone area typically identified on the observed road section. Black sites are frequently located on roads outside urban areas, particularly on specific stretches where accidents occur with higher frequency. Black sites are typically characterized by their distance of more than 300 meters from the point where traffic accidents are prone to happen. The classification of a location as a black site is contingent on the number of accidents per kilometer of road over a 3–5-year period, with the requirement that the number of accidents per kilometer exceeds 2 accidents. A road section qualifies as a black site if it meets the criteria of an accident rate figure falling below a specific threshold, which indicates the level of accident vulnerability, as determined by the accident rate of 0.003 (Kudus, 1995).

$$Rsp = \frac{A \times 1{,}000{,}000}{V \times 365} \tag{6}$$

Where:

Rsp = Number of accidents at the spot (in accidents per million vehicles entering the spot),
A = Average number of accidents per year,
V = Traffic volume or average daily traffic (ADT),
365 = Number of days in a year.

$$Rsp = \frac{A \times 1{,}000{,}000}{V \times T \times 365} \tag{7}$$

Where:

Rsc = Number of accidents on a section of highway (in accidents per million vehicles),
A = Average number of accidents per year.
V = Traffic volume or average daily traffic (ADT),
T = Number of hours in a day during which the traffic volume is observed
365 = Number of days in a year.

Research Methods

To obtain the necessary data and information, various data collection methods were employed, including, as following:

Primary Data

Primary data were gathered through direct field observations. This involved visual inspections, measurements, and documentation of infrastructure along the Pekanbaru-Dumai toll road, which is pertinent to the research.

Secondary Data

This research utilized secondary data derived from traffic accident reports spanning from 2020 to 2022 on the Pekanbaru-Dumai toll road. These reports were sourced from the Riau Regional Police Traffic Directorate (Indonesian: *Direktorat Lalu Lintas POLDA Riau*). Additionally, data on the average daily traffic volume (ADT) of the Pekanbaru-Dumai toll road per KM sections were obtained from the Toll Road Regulatory Agency (Indonesian: *Badan Pengatur Jalan Tol* [BPJT]).

Literature Studies

Extensive literature studies were undertaken to gain insights into key concepts related to the research. This involved reviewing journals, books, online resources, lecture materials, and relevant documents. The purpose was to elucidate the issues under investigation and to draw upon information from prior research for reference and comparison.

Field Observations

Preliminary field observations and direct monitoring were conducted to acquire real-time data through on-site inspections at the research location.

Challenges in Research

The research process encountered several challenges, notably in data acquisition from relevant authorities and field surveys on the Pekanbaru-Dumai toll road. These challenges were attributed to internal regulations within the toll road management company. In addition, these challenges included the researchers' limited knowledge regarding traffic accidents, reluctance from relevant agencies to grant access to data, data incompleteness, and data validity issues. This section encompasses aspects of research design, data collection instruments, participant/sample selection, data collection procedures, and data analysis.

Research Location

This study was conducted on Section KM 31 until Section 37 of the Pekanbaru-Dumai toll road, situated between 1°06'53" North Latitude and 101°15'35" East Latitude. These sections extend from the Pekanbaru toll gate to the Dumai gate exit, encompassing the Muara Fajar gate and the Bagan Besar gate in Dumai City, Riau Province. These road sections fall under the category of a national road and a toll road under the supervision of the Toll Road Regulatory Agency (Indonesian: *Badan Pengatur Jalan Tol* [BPJT]) within the Directorate General of Highways, Ministry of Public Works and Public Housing of the Republic of Indonesia.

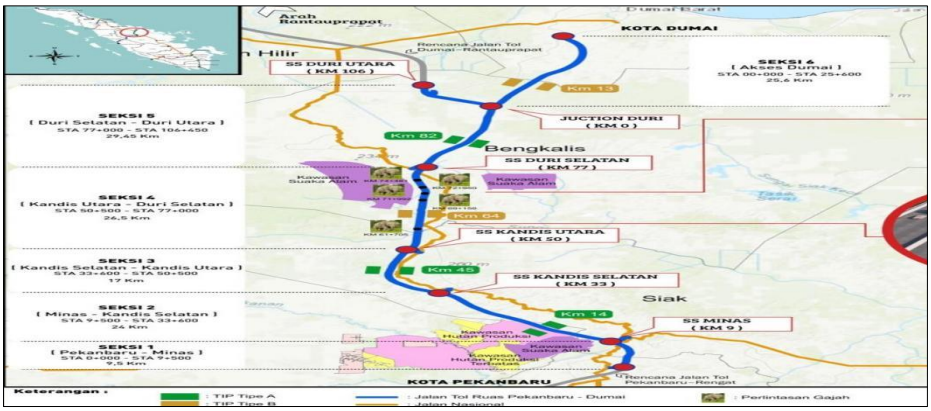

Figure 1. Research Location

Results and Discussion

Number of Traffic Accidents

Traffic accidents refer to incidents involving a vehicle, with or without other road users, that lead to human casualties and/or property loss. The following table presents the number of traffic accidents on the Pekanbaru-Dumai Toll Road in Riau Province for the years 2020-2022.

Table 1. Number of Traffic Accidents on the Pekanbaru-Dumai Toll Road, Riau Province (2020-2022)

No.	KM	Years			Total Accidents
		2020	2021	2022	
1.	KM 31	1	1	0	2
2.	KM 32	1	2	0	3
3.	**KM 34**	**4**	**4**	**0**	**8**
4.	**KM 35**	**7**	**0**	**1**	**8**
5.	KM 36	1	3	0	4
6.	KM 37	0	2	3	5
Total		**14**	**12**	**4**	**30**

Source: Calculation Results

Based on Table 1, the highest number of accidents on the Pekanbaru-Dumai toll road section during the three years (2020-2022) occurred at KM 34 and KM 35, with a total of 8 accidents. KM 37 followed with 5 accidents, and KM 36 had 4 accidents. These figures illustrate that the level of traffic accidents on the Pekanbaru-Dumai toll road in Riau Province remained relatively high over the specified period.

Traffic Accidents Based on Time of Occurrence

Understanding the timing of incidents is crucial for assessing the frequency of traffic accidents on the Pekanbaru-Dumai toll road in Riau Province. The distribution of traffic accidents on this toll road over three years is categorized based on the time of occurrence, specifically within the 24-hour cycle. By examining the times when accidents take place, drivers can anticipate accident patterns on this road section, gaining a comprehensive understanding of traffic accident incidents. This research delves into the calculation of traffic accidents based on the temporal classification of accidents. The time variations are presented in the following table.

Table 2. Time Data for Traffic Accidents on the Pekanbaru-Dumai Toll Road (2020-2022)

No	Time Range	Total Accidents
1.	06:01-10:00 (Morning)	5
2.	10:01-14:00 (Afternoon)	4
3.	14:01-18:00 (Evening)	4

4.	**18:01-22:00 (Night)**	**6**
5.	**22:01-02:00 (Early Morning)**	**6**
6.	02:01-06:00 (Dawn)	5
	Total	**30**

Source: Calculation Results

Based on Table 2, it is evident that the highest number of traffic accidents occurred during the night (18:01-22:00) and early morning (22:01-02:00), with 6 cases of traffic accidents. This was followed by the dawn hours (02:01-06:00) with 5 cases of traffic accidents, and the morning hours (06:01-10:00) with 5 cases of traffic accidents. The higher number of accidents during the night and early morning hours can be attributed to increased vehicular activity on the Pekanbaru-Dumai toll road during this time frame from 2020 to 2022.

Table 3. Number of Traffic Accident Victims on the Pekanbaru-Dumai Toll Road (2020-2022)

No.	Years	Fatalities	Serious Injuries	Minor Injuries
1.	2020	1	3	3
2.	2021	5	5	7
3.	2022	1	1	2
Total		**7**	**9**	**12**

Source: Calculation Results

In the category of fatalities, there were 1 victim in 2020, 5 victims in 2021, and 1 victim in 2022. For serious injuries, there were 3 victims in 2020, 5 victims in 2021, and 1 victim in 2022. In the category of minor injuries, there were 3 victims in 2020, 7 victims in 2021, and 2 victims in 2022.

Travel Performance

Travel performance is represented by the number of travel requests, defined by the number of vehicles and road length in kilometers on a road section. An overview of travel performance on the Pekanbaru-Dumai toll road per KM sections was obtained from survey data on vehicles entering and exiting the Pekanbaru-Dumai toll gate, managed by the Pekanbaru-Dumai Toll Road Management Agency. The following table presents the average annual traffic volume (AATV) over three years.

Table 4. The Average Annual Traffic Volume (AATV) on the Pekanbaru-Dumai Toll Road, Riau Province

No.	Years	AATV (in Passenger Car Unit [PCU] per day)
1.	2020	24,236
2.	2021	154,959
3.	2022	30,826
Total		210,021

Average	70,007

Source: Calculation Results

Identification of Black Spots Based on Accident Rate

To calculate the accident rate for the black-spot areas, we use the parameters in the following table.

Table 5. Accident Rate Calculation Results for Black Spots on the Pekanbaru-Dumai Toll Road

No.	KM	Total Accidents		AATV (PCU/day)	Accident Rate
		Total	Average		
1.	KM 31	2	0.67	70,007	0.03
2.	KM 32	3	1.00	70,007	0.04
3.	**KM 34**	**8**	**2.67**	70,007	**0.10**
4.	**KM 35**	**8**	**2.67**	70,007	**0.10**
5.	KM 36	4	1.33	70,007	0.05
6.	KM 37	5	1.67	70,007	0.07

Source: Analysis Results

Based on Table 5, the highest accident rate values for black spots are found at KM 34 and KM 35, both at 0.10, followed by KM 37 at 0.07, KM 36 at 0.05, KM 32 at 0.04, and KM 31 at 0.03. According to Abdul Kudus' theory, as cited in the thesis of Zulendra Fadillah (2020), black spots are characterized by an accident rate criterion of 0.736 or higher. Therefore, none of the section points in the table above meet the criteria to be classified as black spots on the Pekanbaru-Dumai toll road.

Identification of Black Sites Based on Accident Rate

Here are the Accident Rate calculation results for black sites on the Pekanbaru-Dumai toll road from September 2020 to February 2022:

Table 6. Accident Rate Calculation Results for Black Sites on the Pekanbaru-Dumai Toll Road

No.	KM	Total Accidents		AATV (PCU/day)	Road Length	Travel Performance	Accident Rate
		Total	Average				
1.	KM 31	2	0.67	70,007	1	70,007	0.03
2.	KM 32	3	1.00	70,007	1	70,007	0.04
3.	**KM 34**	**8**	**2.67**	**70,007**	**2**	**140,014**	**0.05**
4.	**KM 35**	**8**	**2.67**	**70,007**	**1**	**70,007**	**0.10**

5.	KM 36	4	1.33	70,007	1	70,007	0.05
6.	KM 37	5	1.67	70,007	1	70,007	0.07

Source: Analysis Results

Based on Table 6, it is evident that the locations with the highest accident rate values for black sites are as follows: KM 35 with an accident rate of 0.10, followed by KM 37 at 0.07, and KM 34 and KM 36 both with an accident rate of 0.05, KM 32 with an accident rate of 0.04, and KM 31 with an accident rate of 0.03. According to Abdul Kudus's theory, as quoted in Muhammad Alqodri's research, black sites are characterized by an accident rate figure of less than 1. In practical terms, this means that the level of accident vulnerability in these specific accident-prone areas is relatively low, with an observed accident rate of 0.003.

Based on the results of field observations and discussions arising from an analysis of the locations most susceptible to traffic accidents conducted by our research team, the KM sections of the Pekanbaru-Dumai toll road with the highest frequency of traffic accidents are as follows:

Section KM 31 of the Pekanbaru-Dumai Toll Road

Section KM 31 of the Pekanbaru-Dumai toll road features an elevated bend stretching approximately 120 meters in length. It includes a lane width of 3.6 meters, an outer shoulder width of 3 meters, an inner shoulder width of 1.5 meters, and a median width of 3.8 meters, with a height of 1,000 meters. The road design complies with specified requirements and utilizes flexible pavement, as illustrated in Figure 2 and Figure 3 below.

Figure 2. Condition of Section KM 31 A of the Pekanbaru-Dumai Toll Road

Figure 3. Condition of Section KM 31 B of the Pekanbaru-Dumai Toll Road

The Description of the Audit of the Accident-Prone Areas on Section KM 31

Upon conducting a direct field assessment at the KM 31 location, our observations revealed a bend spanning approximately 120 meters. Road equipment facilities were identified, including directional signs indicating a leftward bend for lane A and a rightward bend for lane B, as depicted in Figures 2 and 3. Additionally, speed limit warning signs, guardrails, kilometer markers, road markings, and well-maintained road medians were present and still in good condition. However, one significant omission was the absence of road lighting in Section KM 31. According to Regulation No. 16/PRT/M/2014 issued by Indonesia's Minister of Public Works, which outlines the Minimum Service Standards for Toll Roads, road lighting is a mandatory facility to be provided by toll road operators. This regulation stipulates the requirement for road lighting installations on all segments of the Pekanbaru-Dumai toll road. Another noteworthy observation was the absence of noise tape before the bend. Following Indonesia's Minister of Transportation Regulation No. 82/2018, as outlined in Article 33, noise tape serves as an additional road feature designed to reduce vehicle speed, alert drivers to objects ahead that require caution, and signal accident-prone areas. From the analysis, it is evident that the equipment condition on the Pekanbaru-Dumai toll road, specifically on Section KM 31, presents several issues—namely, the absence of noise tape and public road lighting. These omissions can potentially lead to accidents, primarily due to the geometric characteristics of the curved road.

Based on data obtained from the Riau Regional Police Traffic Directorate (Indonesian: *Direktorat Lalu Lintas POLDA Riau*), regarding Section KM 31 over three years (2020-2022), there were two cases of traffic accidents. These accidents were caused by the following factors.

Accident #1. A single collision accident with accident type code: Rum 020 (driver lost control due to negligence).

Accident #2. A double front-rear collision accident with accident type code: Rum 063 (driver hit the vehicle front-rear due to negligence).

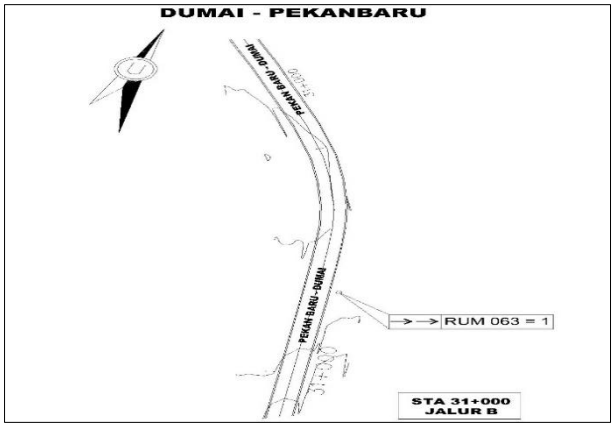

Figure 4. Map of the Pekanbaru-Dumai Toll Road

Section KM 32 of the Pekanbaru-Dumai Toll Road

Moving on to Section KM 32 of the Pekanbaru-Dumai toll road, it features an elevated bend with a length of approximately 80 meters. The lane width is 3.6 meters, the outer shoulder is 3 meters wide, the inner shoulder is 1.5 meters wide, and it has a median width of 3.8 meters, with a height of 1,000 meters. The road surface complies with the required standards and utilizes flexible pavement, as depicted in Figure 5 below.

Figure 5. Condition of Section KM 32 A of the Pekanbaru-Dumai Toll Road

Section KM 36 of the Pekanbaru-Dumai Toll Road

Section 36 of the Pekanbaru-Dumai toll road presents an elevated bend spanning approximately 150 meters. It has a lane width of 3.6 meters, an outer shoulder width of 3 meters, an inner shoulder width of 1.5 meters, and a median width of 3.8 meters, including the inner shoulders. The road surface meets the necessary standards and employs a flexible pavement, as shown in Figure 6 below.

Figure 6. Condition of Section KM 36 A of the Pekanbaru-Dumai Toll Road

The Description of the Audit of the Accident-Prone Areas on Section KM 36

Upon conducting field observations at the KM 36 location, researchers identified a bend with a length of approximately 150 meters. Road infrastructure features included a sign indicating a right bend from lane A, as well as a sign directing a left bend from lane B, as shown in Figure 6. Additionally, there were warning signs for speed limits, guardrails, kilometer markers, road markings, and road medians. All these facilities were in good condition. However, it is noteworthy that road lighting has not been installed on Section KM 36, even though Regulation No. 16/PRT/M/2014 issued by Indonesia's Minister of Public Works, outlining Minimum Service Standards for Toll Roads, mandates the provision of road lighting facilities, in this case on all sections of the Pekanbaru-Dumai toll road. Furthermore, it is essential to mention that there was a lack of noise tape before the bend. According to Indonesia's Minister of Transportation Regulation No. 82/2018, as outlined in Article 33, noise tape is additional road equipment designed to reduce vehicle speed, alert drivers to objects ahead that require attention, and signal accident-prone areas. Based on the observations, the equipment on the Pekanbaru-Dumai toll road, specifically at Section KM 36 has two issues, as it lacks noise tape and public road lighting. These shortcomings can contribute to potential accidents due to the geometry of the curved road.

Analyzing Traffic Accidents on Pekanbaru-Dumai Toll Road from Road infrastructure Perspective

Based on data obtained from the Riau Regional Police Traffic Directorate regarding Section KM 36 over three years (2020-2022), there were four cases of traffic accidents. These accidents were attributed to the following factors.

Accident #1. A multiple front-rear collision accident with accident type code: Rum 063 (resulting from a drowsy driver causing a front-rear collision of the vehicle).

Accident #2. A single-vehicle collision, self-accident, with accident type code: Rum 020 (driver lost control due to a tire blowout).

Accident #3. A single-vehicle collision, self-accident, with accident type code: Rum 020 (driver lost control due to a tire blowout).

Accident #4. A multiple front-rear collision accident with accident type code: Rum 063 (resulting from a drowsy driver causing a front-rear collision of the vehicle).

Section KM 37 of the Pekanbaru-Dumai Toll Road

Section KM 37 of the Pekanbaru-Dumai toll road features an uphill and downhill flyover spanning approximately 150 meters in length. This section has a lane width of 3.6 meters, an outer shoulder width of 3 meters, an inner shoulder width of 1.5 meters, and a median width of 3.8 meters. It meets all required specifications and utilizes a flexible type of pavement, as shown in Figure 7.

Figure 7. Condition of Section KM 37 A of the Pekanbaru-Dumai Toll Road

The Description of the Audit of the Accident-Prone Areas on Section KM 37

Based on direct field observations at the KM 37 location, this section features an elevated and descending curve, as shown in Figure 7, spanning approximately 150 meters. Road equipment facilities include signs directing a right bend from lane A and a sign directing a left bend from lane B. The section is also equipped with speed limit warning signs, incline and descent warning signs, guardrails, kilometer markers, road markings, and road medians, all of which are in good condition. However, it is important to note that road lighting on Section KM 37 has not been installed. According to Indonesia's Minister of Public Works Regulation No. 16/PRT/M/2014, which outlines Minimum Service Standards for Toll Roads, toll road providers–including those responsible for the Pekanbaru-Dumai toll road–are required to provide road lighting facilities. In addition, there is no noise tape before the curve. The guidelines set by Indonesia's Minister of Transportation Regulation No. 82/2018, Article 33, mention that noise tape serves as additional equipment on the road to reduce vehicle speed,

alert drivers to objects ahead that require caution, and remind them of accident-prone areas. In summary, the equipment on Section KM 37 of the Pekanbaru-Dumai toll road has certain deficiencies, specifically the absence of noise tape and road lighting, which could potentially lead to accidents due to the geometric conditions of the curved road.

Based on data collected by researchers from the Riau Regional Police Traffic Directorate regarding Section KM 36 over three years (2020-2022), there were five cases of traffic accidents. These accidents were caused by the following factors.

Accident #1. A single collision accident with accident type code: Rum 020 (driver lost control of the vehicle due to a burst tire).

Accident #2. A single collision accident with accident type code: Rum 020 (driver lost control due to drowsiness).

Accident #3. A single collision accident, self-accident, with accident type code: Rum 020 (driver lost control due to a tire blowout).

Accident #4. A double front-side collision accident with accident type code: Rum 067 (driver lost control due to a tire blowout)

Accident #5. A single collision accident, self-accident, with accident type code: Rum 020 (driver lost control due to a tire blowout).

Strategies for Preventing and Managing Traffic Accidents

Based on the research findings and discussions, it is evident that several factors contribute to traffic accidents. According to the theory by Harsono, as cited by Heru Aditriansyah (2018), it is possible to prevent and mitigate traffic accidents in Indonesia by focusing on road infrastructure, equipment engineering, and adherence to road function and classification. Therefore, the researchers propose several measures to address traffic accidents, ultimately reducing their occurrence on the Pekanbaru-Dumai toll road. These measures include:

Traffic Engineering

1. Installation of Noise Tape: Place noise tapes before corners to signal accident-prone areas, encouraging drivers to reduce their vehicle speed.
2. Road Lighting: Implement road lighting on sections without it to improve nighttime visibility for toll road users.
3. Warning Signs: Add new warning signs in accident-prone areas.
4. Vehicle Quarantine: Establish regulations requiring road users to quarantine their vehicles and drivers at a designated toll gate before continuing their journey to minimize accidents caused by vehicles and drivers.

Education

1. Public Outreach: Educate toll road users on safe traffic practices through various means, such as public education billboards promoting traffic safety.
2. Collaboration: Partner with relevant agencies to conduct ongoing anti-accident programs that reinforce traffic safety rules on the Pekanbaru-Dumai toll road.

Role of Traffic Police and Highway Safety Officers

Safety officers and toll road police under the jurisdiction of the Riau Regional Police Traffic Directorate should consistently educate and monitor traffic activities in the field. They

should also enforce penalties for road users who violate traffic laws to maintain orderly, controlled, and safe traffic conditions.

Conclusions

The analysis results reveal that the prevalent traffic accidents on the Pekanbaru-Dumai toll road from Section KM 31 to Section KM 37 are single collision accidents (type 020), primarily caused by human factors. These single collision accidents, stemming from drivers' inattentiveness, account for 16 cases of traffic accidents over the three years (2020-2022).

The analysis of the Pekanbaru-Dumai toll road from Section KM 31 to Section KM 37 in Riau Province indicates that there are no designated accident-prone areas (black spots). These areas are not black spots as they do not meet the standard criteria set by probability statistics, i.e., a value of ≥ 0.736 (as outlined in Kudus, 1995). The highest accident rate, calculated from our analysis, occurs at Sections KM 34 and KM 35, with a value of 0.10. We conclude that the Pekanbaru-Dumai toll road, specifically from Section KM 31 to Section KM 37, primarily faces traffic accidents due to human negligence while driving.

Based on our field observations, we recommend enhancing the condition of road equipment and traffic infrastructure on the Pekanbaru-Dumai toll road to address traffic accidents. This can be achieved by adding noise barriers, which comply with Indonesia's Minister of Transportation Regulation No. 82/2018, Article 33. Noise barriers are additional road safety features that help reduce vehicle speed, alert drivers to objects ahead, and remind them of accident-prone areas. Furthermore, we suggest adding comprehensive road lighting in line with Indonesia's Minister of Public Works Regulation No. 16/PRT/M/2014, which outlines Minimum Service Standards for Toll Roads. In addition, public road lighting facilities should be installed along all sections of the toll road to improve visibility and enhance safety.

Suggestions

1. Toll road management companies should prioritize addressing physical deficiencies in toll road infrastructure and facilities to enhance safety for all road users. This includes evaluating and updating road facilities and infrastructure. Measures, such as adding noise barriers at bends and accident-prone areas, along with installing signs and public road lighting, should be considered and implemented on the Pekanbaru-Dumai toll road to improve overall traffic safety.
2. Enhanced supervision and enforcement by the Riau Regional Police Traffic Directorate are necessary to curb traffic violations and reduce hazards to other toll road users. Vigilant monitoring of traffic violations is crucial for maintaining a safe environment.
3. Increased efforts in educating the public about traffic accidents are essential, given that human factors are the primary causes of accidents. Tightening regulations related to driver permits and promoting awareness of traffic discipline on toll roads should be undertaken to mitigate accidents.
4. This study can serve as a valuable reference for future research on traffic accidents on toll roads, offering insights into accident causes and potential safety improvements.

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