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ROAD TRAFFIC ACCIDENTS FACTOR ON RURAL ARTERIAL ROADS

Novita Sari[1,2], Siti Malkhamah*[1], Latif Budi Suparma[1]

[1] Faculty of Engineering, Gadjah Mada University, Yogyakarta 55281, Indonesia
[2] Polytechnic of Indonesian Land Transport, Cibitung, Indonesia

** malkhamah@ugm.ac.id*

In Indonesia, traffic accidents occur on 23.55% of national roads and 75.08% of rural roads. The rural roads were identified as accident-prone areas. As a result, unsafe roads hinder population mobility, disrupt daily life, and reduce access to education, employment, and essential services, thereby affecting the well-being and development of rural communities. To identify the dominant factors that influence the frequency of collisions, a more thorough analysis of the multifactorial causes of traffic accidents in accident-prone areas is necessary. This study focused on analyzing the factors that contribute to road traffic accidents. Cross-tabulation was done using chi-square analysis. The chi-square test does not assume a normal distribution of data, which is beneficial when dealing with real-world data that may not follow normal distribution patterns. This flexibility makes it a robust choice for analyzing traffic accident data, which can be highly variable and not normally distributed. The results of the chi-square analysis for significance values below 0.05 indicate that there is a correlation between accident-causing factors (the independent variable) and collision frequency (the dependent variable). The results indicate that human factors, such as carelessness and high speed, as well as road and environmental factors, such as horizontal alignment, road width, clear zone, road signs, road markings, and land use, influence traffic accidents. Infrastructure factors such as horizontal alignment, road width, clear zones, shoulders, signs, and markings influence traffic accidents because they directly impact road user safety. Non-standard road geometry (horizontal alignment, road width, shoulder width, and clear zone) combined with incomplete road safety facilities (signs and markings) have the potential to cause traffic accidents. Therefore, harmonizing road geometry and equipment is necessary to improve arterial road safety, especially in accident-prone areas. Furthermore, speed management across a variety of land uses is required to reduce traffic accidents.

Keywords: arterial road, crosstab analysis, road traffic accident factor

1 INTRODUCTION

According to WHO data [1], the death rate from road traffic accidents increased and peaked in 2016 at 1.35 million. Deaths from traffic accidents were recorded as more than half occurring in vulnerable groups of road users (pedestrians, bicycle, and motorcycle users) [2], [3]. This accident occurred because the traffic system did not provide facilities for vulnerable road users. The lack of facilities for vulnerable road users is often found on arterial roads.

Meanwhile, in Indonesia, 23.55% of traffic accidents occur on national roads, while 75.08% occur on rural roads [4], [5]. The rural roads were identified as accident-prone areas [6]–[10]. Based on data from the Indonesian National Police (KORLANTAS) in 2020, generally, traffic accidents have an increasing trend. Traffic accidents have increased by an average of 6% per year (2017–2019). In 2019, the number of traffic accidents increased by 7%; however, the number of deaths decreased by 13%. The number of seriously injured people decreased by 6%, and the number of light injuries increased to 5% compared to 2018. In terms of the fatality rate, 75% of casualties were light injuries, 9% were serious injuries, and 16% were deaths. These traffic accidents are 61% caused by human factors, 9% by vehicle factors, and 30% by road infrastructure and environmental factors.

One of the primary arterial national roads traverses Ciamis Regency, connecting West Java Province and Central Java Province. Ciamis Regency, located in West Java Province, is one of Indonesia's regencies. According to traffic accident data from the Ciamis Regency Police from 2016–2020, the ten highest traffic accident locations in Ciamis Regency occurred on primary arterial roads, and four of them were accident-prone areas. There were 1,664 traffic accidents during the last five years (2016–2020); 50% of traffic accidents occurred on primary arterial roads. The type of national road that crosses Ciamis Regency is two-lane, two-way undivided, and 36% of collisions are head-on. The frequency of traffic accidents in the last five years (2016–2020) was 19% involving pedestrians and 70% involving motorcycles. The local community's activities influence the traffic characteristics of this road, given its unrestricted access. According to Indonesian road technical standards [11], primary arterial roads are roads designed with a maximum speed of up to 80 km/h. Meanwhile, the Minister of Transportation's regulations determine speed limits for primary arterial roads with unrestricted access based on land use. Residential, commercial, and educational areas dominate the land use along this road. As a result, there is mixed traffic between vulnerable road users and high-speed vehicles that traverse this road [12]–[15].

Studying traffic accidents on rural roads in Indonesia is crucial because these accidents often result in severe injuries or fatalities, significantly impacting public health and economic burdens, especially in areas with limited access to medical services. The associated costs, such as medical expenses and lost productivity, can heavily strain the local economy. Furthermore, unsafe roads hinder residents' mobility, disrupt daily life, and reduce access to education, employment, and essential services, thereby affecting rural communities' well-being and development. Therefore, to improve road safety, it is necessary to identify the factors that cause traffic accidents on rural arterial roads.

2 RESEARCH METHODOLOGY

2.1 Data Collection

Data collection is imperative for identifying traffic accidents, road, and traffic characteristics. For this study, data were sourced from traffic surveys and relevant institutions. The research was conducted from 2020 to 2023. So, the data used is traffic accident data for the last five years (2016-2020), supplied by the Ciamis Regency Police. The Directorate of Road and Bridge Engineering provided road network details, land use information, road geometry, the International Roughness Index (IRI), and roadside specifics.

To procure primary data, various surveys were conducted, including a road inventory survey, a spot speed survey, and a traffic counting survey.

The inventory survey gathered information on road dimensions, hazards, road signs, road markings, accessibility, safety features, and land use. This survey utilized a Hawkeyes 2000 vehicle (an equipment used for traffic monitoring and data collection). A traffic counting survey was employed to capture vehicle volume, while a spot speed survey provided vehicle speed data, with the 85th percentile speed being utilized. A speed gun was used for this survey.

2.2 Method of analysis

This research was conducted on four primary arterial roads which are accident-prone areas in Ciamis Regency (Figure 1). One method to calculate the accident rate is by using the Equivalent Accident Number (EAN) method, which weights the equivalent number of accidents based on traffic accident costs. The EAN calculation entails summing the accident occurrences per kilometer of road length, followed by a weight value based on the severity level. A road segment is considered a high accident area if the EAN value exceeds the Upper Control Limit (UCL). UCL method is a technique used to identify locations with high accident frequencies that exceed acceptable limits based on statistical analysis [16]–[20].

Statistical analysis uses cross tabulation analysis to determine the dominant factors that cause traffic accidents. Cross-tabulation analysis was performed using the Chi-Square test. The Chi-Square test's non-parametric nature, which does not assume a normal distribution of data, is advantageous when handling real-world data that may not adhere to normal distribution patterns. This flexibility renders it a robust choice for analyzing traffic accident data, known for its high variability and lack of normal distribution. Additionally, the Chi-Square test's simplicity in computation and interpretation provides clear results that can signify the presence or absence of significant relationships between variables. Such clarity is valuable for making data-driven decisions in traffic safety analysis.

In this Chi Square test, the level of significance is 95%, or $\alpha = 5\%$. The hypotheses are:

- If the p-value is ≥ 0.05, it explains that there is no correlation between the independent variable and the dependent variable.
- If the p-value is < 0.05, it explains that there is a correlation between the independent variable and the dependent variable.

The output of the chi-square test is the correlation between accident-causing factors (the independent variable) and collision frequency (the dependent variable). The factors contributing to accidents are divided into three main categories: human factors, vehicle factors, and road and environmental factors. These factors, known as independent variables, are identified through a review of the literature from previous studies and adjusted to the data in the study area. In the studied area, data on accident causation were gathered from traffic accident records, geometric analysis of road suitability, and examination of road equipment. According to the traffic accident data, human-related factors, including fatigue, carelessness, sleepiness, undicipline, alcohol influence, and high speed, emerged as significant contributors to traffic accidents. Vehicle-related factors such as brake system failure, tire condition, faulty lights, and engine issues were also identified as potential causes of accidents. Additionally, road and environmental factors, such as horizontal and vertical alignment, road width, clear zones, shoulder width, the International Roughness Index (IRI), road signs and markings, lighting conditions, and land use, were found to influence accident occurrence.

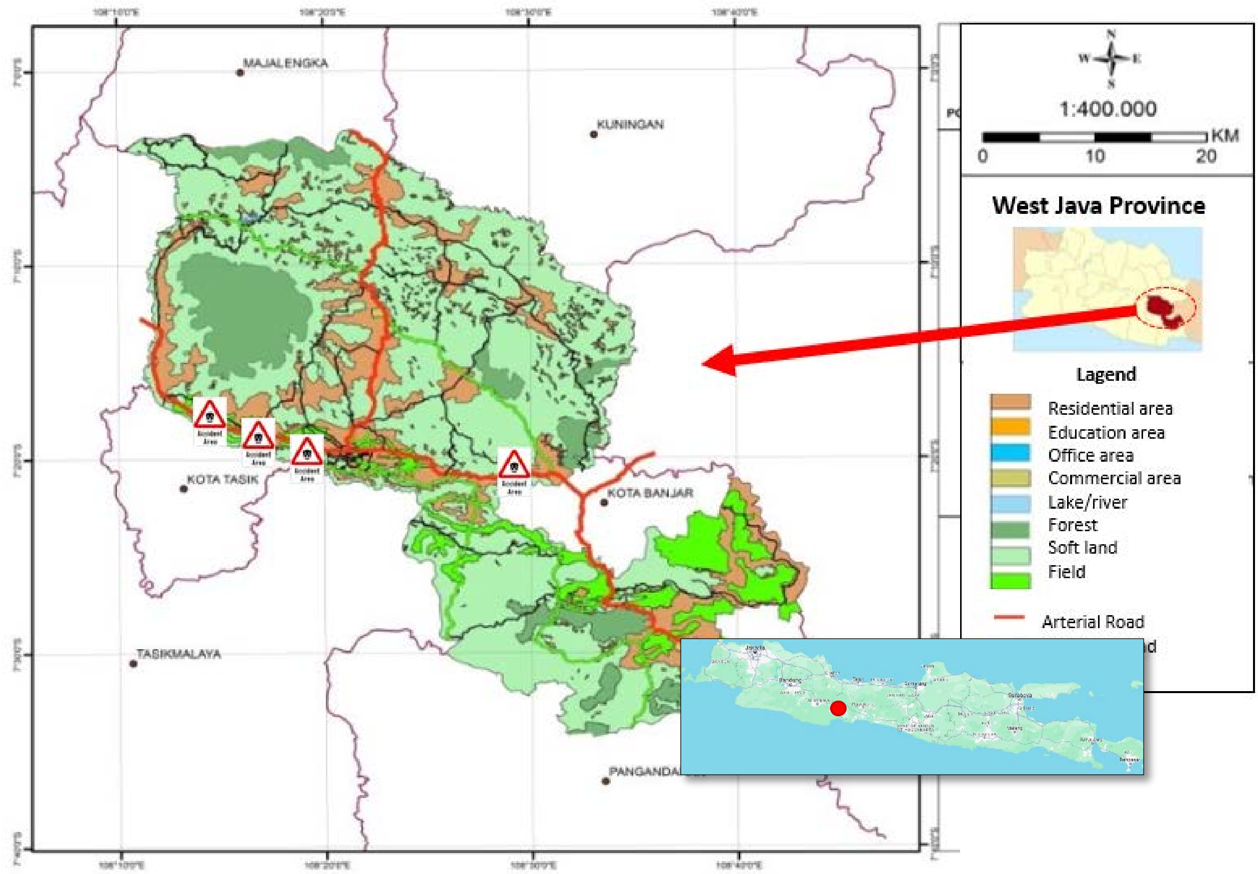

Fig. 1. The location of research

3 DATA ANALYSIS

3.1 Determination of accident-prone areas

Determination of accident-prone locations using quality control statistics as a UCL control-chart [16]. Road segments with accident rates above the UCL line are defined as accident-prone locations. UCL is calculated by the formula (1):

$$UCL = \lambda + [2.576 \sqrt{(\lambda/m)}] + [0,829/m] + [1/2m] \quad (1)$$

Where:

UCL: upper limit control line

λ: average accident rate in accident units per exposure

m: exposure unit, km

Coefficient number based on guidelines for accident-prone areas: 12 (fatality), 3 (major and minor injury). Thus, EAN is calculated by the formula (2):

$$EAN = 12MD + 3LB + 3LR \quad (2)$$

Where:

MD: fatality

LB: major injury

LR: minor injury

The results of the analysis showed that four areas prone to traffic accidents in Ciamis Regency are Jalan Jendral Sudirman, Jalan Raya Imbanagara, Jalan Ciamis-Banjar, and Jalan Raya Cikoneng (Figure 1). Table 1 shows the results of the accident-prone area analysis.

Table 1. Result of accident-prone area analysis

No	Location	Road status	Road Funtion	Total accident	Total accident based on fatalities			(coefficient) x (total accident victims based on fatalities)			EAN	UCL	Result
					fatalitiy	major injuriy	minor injury	12	3	3			
1	imbanagara (Jl. Raya Imbanagara)	national	arterial	44	14	31	22	168	93	66	327	258.31	accident-prone areas
2	sindangrasa (Jl. Jenderal Sudirman)	national	arterial	56	19	29	27	228	87	81	396	261.60	accident-prone areas
3	bojongmengger (Jl. Ciamis - Banjar)	national	arterial	31	5	25	13	60	75	39	174	249.51	-
4	karangkamulyan (Jl. Ciamis - Banjar)	national	arterial	30	14	20	15	168	60	45	273	255.49	accident-prone areas
5	mekarmukti (Jl. Ciamis - Banjar)	national	arterial	28	11	20	9	132	60	27	219	252.38	-
6	margaluyu (jl. Raya Cikoneng)	national	arterial	24	16	13	9	192	39	27	258	254.66	accident-prone areas
7	kota kulon (Jl. Jenderal Sudirman)	national	arterial	23	7	12	12	84	36	36	156	248.26	-
8	kertahayu (Jl. Raya Banjar - Pangandaran)	national	arterial	20	13	9	13	156	27	39	222	252.56	-
9	karangpawitan (Jl. Raya Kawali)	national	arterial	11	5	7	5	60	21	15	96	243.58	-
10	kaler (jl. Nasional III)	national	arterial	17	6	9	11	72	27	33	132	246.50	-

3.2 Road characteristics

The results of the road inventory survey obtained were road width, road length, road pavement type, and land use. Based on the results of the inventory survey, it was found that the type of national road that crosses Ciamis Regency is two-lane, two-way undivided. The type of pavement is flexible pavement. Land use along this road is dominated by residential, commercial, and educational areas. Table 2 is a recapitulation of road characteristics.

Table 2. Road Characteristics

No	Location	Road Statue	Road Funcion	Road Type	Length (KM)	Width (m)	Lane Width (m)		Shoulder Width (m)		Foorpath width (m)	Pavement type
							Right	Left	Right	Left		
1	Jl. Jendral Sudirman (Sindang Rasa)	National	Arterial	2/2UD	3	10	5	5	0	0	2	Flexible Pavement
2	Jl.Raya Imbanagara (Imbanagara)	National	Arterial	2/2UD	1	6.6	3.3	3.3	0	0	2	Flexible Pavement
3	Jl. Ciamis-Banjar (Karangkamulyan)	National	Arterial	2/2UD	4.8	7	3.5	3.5	2.5	2.5	0	Flexible Pavement
4	Jl. Raya Cikoneng (Margaluyu)	National	Arterial	2/2UD	1.5	7	3.5	3.5	2	2	0	Flexible Pavement

3.3 Traffic characteristics

Data from traffic surveys is analyzed to find the road volume, road capacity, and volume per capacity (V/C) ratio. Traffic volume shows the number of vehicles passing through one observation point during one unit of time (vehicles per day, vehicles per hour). Traffic volume for the purposes of road geometric capacity design needs to be expressed in passenger car units (PCU). The PCU value is based on each type of vehicle. Traffic volume is calculated by the formula (3):

$$V = D.S \tag{3}$$

Where:
V: Traffic volume (pcu/hour)
D: Density (pcu/km)
S: Speed (km/h)

According to the Indonesian road capacity guidelines [21], road capacity is the maximum flow through one point on the road that can be maintained per hour under certain conditions. For two-lane two-way roads, capacity is determined for two-way flow. The basic equation for determining capacity is calculated by formula (4):

$$C = Co \ x \ FCw \ x \ FCsp \ x \ FCsf \ x \ FCcs \quad (4)$$

Where:

C: Capacity (pcu/hour).

CO: Basic capacity (pcu/hour).

FCw: Road width adjustment factor.

FCsp: Directional separation adjustment factor (only for undivided roads)

FCsf: Adjustment factors for side resistance and shoulder width or obstacle kreb distance

FCcs: Speed adjustment factor

The V/C ratio is one of the levels of service (LoS) indicators of a road section. LoS is a qualitative measure used to describe the operational conditions of a roadway. Several factors, including speed, traffic volume, density, flow rate, and travel time, typically determine LoS. These factors help assess how well a road is performing in terms of providing a smooth and efficient travel experience for users.

The V/C ratio is a comparison of traffic volume divided by road capacity. Tabel 3 describes a recapitulation of traffic characteristics.

Table 3. Traffic characteristics of accicent-prone area

No	Location	Width (M)	Length (KM)	Road Type	Volume (pcu/our)	Capasity (pcu)	V/C
1	Jl. Jendral Sudirman (Sindang Rasa)	10	3	2/2UD	1436.38	2917.98	0.49
2	Jl.Raya Imbanagara (Imbanagara)	6.6	1	2/2UD	1616.50	2270.70	0.71
3	Jl. Ciamis-Banjar (Karangkamulyan)	7	4.8	2/2UD	2038.5	2396.85	0.85
4	Jl. Raya Cikoneng (Margaluyu)	6	1.5	2/2UD	1962.3	2842	0.69

3.4 Traffic accidents characteristics

Based on accident data from the Ciamis Regency Police, there have been 153 traffic accidents in the research location over the past five years. Figure 2 describes the trend of traffic accidents for five years (2016–2020).

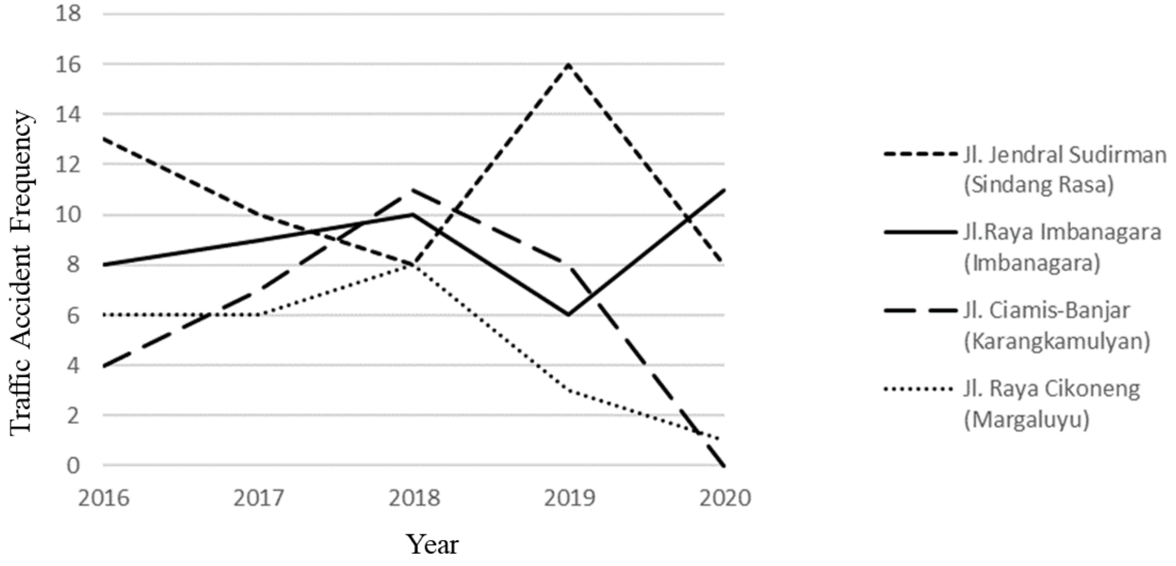

Fig. 2. Trend of traffic accidents for five years (2016-2020)

The incidence of traffic accidents showed a steady increase, averaging 9% annually, from 2016 to 2018. Despite an 11% decrease in 2019, there was a significant 39% decrease in 2020. This decline was attributed to the government's efforts to curb the spread of the COVID-19 virus by implementing extensive social restrictions. Consequently, schools shifted to online learning, and non-essential offices largely adopted the Work From Home (WFH) system. In contrast, along jalan Imbanagara, there has been a consistent rise in traffic accidents, averaging 12% annually over the past three years and projecting an 83% increase in 2020. The commercial land use surrounding jalan Imbanagara includes the largest store selling essential goods in Ciamis Regency. Consequently, during the COVID-19 pandemic, there were no significant differences in traffic characteristics before and after the COVID pandemic.

4 RESULT

4.1 Cause of traffic accidents due to human factors

Basically, the fundamental elements of road traffic encompass: road users, vehicles, and road and environmental conditions [22]–[24]. Each of these elements exhibits distinct characteristics at various sections of the road, which can play a role in road traffic accidents [25]–[27].

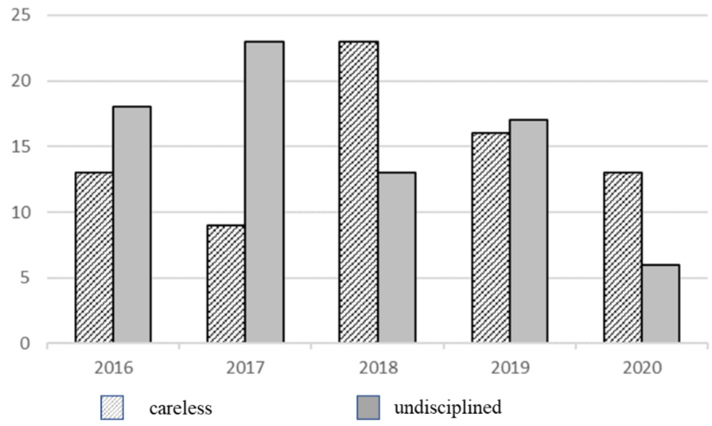

Fig. 3. Proportion of cause traffic accidents based on human factor

Based on the percentage of accident frequency over the past five years (2016–2020), 44% of accidents were caused by undisciplined drivers, and 56% were caused by careless drivers.

Results of a spot speed survey, it was obtained for the 85th percentile speed of motorcycle of 66.9 KM/hour, light vehicles of 65.8 KM/hour and heavy vehicles of 59 KM/hour. From the results of the analysis, it was found that 85% of vehicles exceeded the speed limit.

4.2 Cause traffic accidents due to vehicle factors

Vehicles are one of the traffic components that contribute to accidents. The vehicle types are divided into motorized vehicles and non-motorized vehicles. Based on accident data from the Ciamis Regency Police for five years (2016–2020), the highest proportion of vehicles involved in accidents, at 65%, were motorbikes. However, the vehicle's technical condition did not cause any traffic accidents in Ciamis Regency's accident-prone areas.

4.3 Cause traffic accidents due to road and environment factors

By analyzing data from the survey results (Hawkeyes 2000 vehicle) and direct field observations, the causes of traffic accidents were determined based on road and environmental factors. Road and environmental factors observed include horizontal alignment, vertical alignment, road width, shoulder width, clear zone, IRI, signs, markings, public street lighting, and land use where the accident occurred. Furthermore, the road and environmental data obtained are compared with applicable technical standards. Vertical alignment, horizontal alignment, IRI, road width, road shoulder width, and clear zone are compared with Road Geometric Design Guidelines [28] and Road Technical Requirements [11]. The observed results from the road and environmental elements are as follows:

- The descriptive analysis of road accident causes, and environmental factors revealed that 11% of traffic accidents occurred on curves, while 89% occurred on straight roads in the studied area.
- The results of the vertical alignment analysis show that all road sections have flat topography with an average slope of 3%. According to the Geometric Road Design Guidelines [28], roads with flat terrain have a maximum allowable slope of 5%. Therefore, it can be concluded that all roads meet the slope standards.
- The curvature radius is the visible part of the horizontal alignment. The road inventory survey results identified two curved road sections: the Jl. Ciamis-Banjar and the Jl.Raya Cikoneng. According to the Ciamis District Police's data, there were 17 traffic accidents in the curve areas. Out of the 17 traffic accidents, 47% of them occurred in curve areas with curvature radius below the required minimum radius.
- Road width is the total width of the traffic lanes plus the road shoulders. According to the Technical Requirements for Roads and Road Technical Planning Criteria [11], the standard road width for primary arterial roads with flat terrain type and a traffic volume of ≤22,000 SMP/day is a minimum of 11 meters. According to road inventory data, 84% of road widths do not meet standards.
- Regulations measure the width of a road clear zone from the outermost traffic lane limit outward to a specific width, ensuring it does not surpass the road space limit. Road clear zone analysis found that 82% of accident locations had road clear zones that did not meet the standards of the Road Geometric Design Guidelines [28].

- According to the results of the IRI analysis [29], there are 37% of roads with good conditions, 61% of roads with moderate conditions, and 2% of roads with slightly damaged conditions. 90% of road stability falls under the stable category.
- In this study, road safety facilities were considered variables, including signs, markings, and street lighting. The parameters for road signs meeting the standards in this study include technical specifications, placement, and nighttime reflectivity [30], [31].Similarly, the observed road markings focused on their color and suitability [32]. A total of 22% of accident locations do not have traffic signs, while 78% have traffic signs. Out of the 78% of signs, 68% meet the standards, and 32% do not meet the standards. A total of 54% of locations do not have standard traffic signs.
- According to the road marking analysis results, 6% of accident locations do not yet have road markings. Out of the 94% of accident locations that have markings, 37% do not meet the standards. A total of 43% of locations do not have standard road markings.
- Street lighting is an essential component of road infrastructure aimed at enhancing traffic safety, particularly during nighttime hours. According to Ciamis Regency Police data, 38% of traffic accidents occur at night when the lighting conditions are minimal, which can affect the safety of road users. In accident-prone areas, 17% do not have streetlights, whereas 83% do.
- The traffic accident chronology analysis revealed that residential areas had the highest number of accidents (43%). 39% of traffic accidents occurred in commercial areas (shops and offices), and 18% occurred in educational areas.

Table 4 describes the results of the analysis of road and environmental factors that cause traffic accidents.

Table 4. Proportion of road and environmental factors

No	Condition	Road and environment factors								
		Vertical aligment	Horizontal aligment	Road width	Shoulder width	IRI	Clearzone	Road Signs	Road Markings	Public street light
1	Standard (%)	100	53	16	53	100	18	46	57	85
2	Non-standard (%)	0	47	84	47	0	83	54	43	17

4.4 Crosstab analysis

To determine the correlation between the independent and dependent variables, a univariate analysis was conducted. Univariate analysis is used to observe the frequencies and percentages within each dataset. In this research, SPSS 22 software was utilized for the Chi-square statistical test. The confidence level for the chi-square test is set at 95%, or α = 5%. The hypothesis used to ascertain the relationship between the frequency of traffic accidents and the causal factors of traffic accidents is outlined as follows:

1) If the p-value test results are less than 0.05, it rejects the hypothesis that there is no correlation between accident-causing factors (the independent variable) and collision frequency (the dependent variable).
2) If the p-value test results are less than 0.05, it indicates a correlation between accident-causing factors (the independent variable) and collision frequency (the dependent variable).

Human error is the most dominant cause of traffic accidents [6], [18], [33]–[36]. Table 5 describes the chi-square test results for each human factor causing traffic accidents.

Table 5. Cross-tabulation of causes of traffic accidents based on human factors

Causes of traffic accidents by human factors		Collision frequency				Total	p-value
		Jend Sud	Imba	K Mul	Cikoneng		
Fatigue	No	55	44	30	24	153	-
		36%	29%	20%	16%	100%	
	Yes	0	0	0	0	0	
		0%	0%	0%	0%	0%	
carelessness	No	27	16	20	16	79	0.028
		49.1%	36.4%	66.7%	66.7%	51.6%	
	Yes	28	28	10	8	74	
		50.9%	63.6%	33.3%	33.3%	48.4%	
sleepness	No	55	44	30	24	153	-
		36%	29%	20%	16%	100%	
	Yes	0	0	0	0	0	
		0%	0%	0%	0%	0%	

Causes of traffic accidents by human factors		Collision frequency				Total	p-value
		Jend Sud	Imba	K Mul	Cikoneng		
Undiciplined	No	28	28	12	9	77	0.112
		50.9%	63.6%	40.0%	37.5%	50.3%	
	Yes	27	16	18	15	76	
		49.1%	36.4%	60.0%	62.5%	49.7%	
Alcohol influence	No	55	44	30	24	153	-
		36%	29%	20%	16%	100%	
	Yes	0	0	0	0	0	
		0%	0%	0%	0%	0%	
High speed	No	8	2	13	0	23	0.000
		5%	1%	8%	0%	15%	
	Yes	47	42	17	24	130	
		31%	27%	11%	16%	85%	

The results of the Chi-Square analysis found that the significance value for carelessness and high-speed factors was below 0.05, which means that there is a correlation between carelessness, high speed factors, and the frequency of traffic accidents. However, the undisciplined factor has a significant value above 0.5, indicating that it has no relationship with traffic accidents. Furthermore, the absence of these causal factors in the traffic accident data renders the factors of fatigue, sleepiness, distraction, psychological pressure, and alcohol influence as non-significant.

Table 6 describes the chi-square test results for each factor causing traffic accidents on the road and in the environment.

Table 6. Cross-tabulation of causes of accidents based on road and environmental factors

Causes of traffic accidents by human factors		Collision frequency				Total	*p-value*
		Jend Sud	Imba	K Mul	Cikoneng		
Vertical aligment	No	55	44	30	24	153	-
		36%	29%	20%	16%	100%	
	Yes	55	44	30	24	153	
		36%	29%	20%	16%	100%	
Horizontal aligment	No	55	44	18	19	136	0.000
		36%	29%	12%	12%	89%	
	Yes	0	0	12	5	17	
		0%	0%	8%	3%	11%	
Road width	No	0	25	0	0	25	0.000
		0%	16%	0%	0%	16%	
	Yes	55	19	30	24	128	
		36%	12%	20%	16%	84%	
Shoulder width	No	0	27	30	24	81	0.000
		0%	18%	20%	16%	53%	
	Yes	55	17	0	0	72	
		36%	11%	0%	0%	47%	
Clearzone	No	0	10	20	7	37	0.000
		0%	7%	13%	5%	24%	
	Yes	55	34	9	17	115	
		36%	22%	6%	11%	75%	
IRI	No	55	44	30	24	153	-
		36%	29%	20%	16%	100%	
	Yes	0	0	0	0	0	
		0%	0%	0%	0%	0%	
Road Signs	No	18	26	17	9	70	0.029
		12%	17%	11%	6%	46%	
	Yes	37	18	13	15	83	
		24%	12%	8%	10%	54%	
Road Markings	No	31	16	25	18	90	0.000
		20%	10%	16%	12%	59%	
	Yes	24	28	5	6	63	
		16%	18%	3%	4%	41%	

Causes of traffic accidents by human factors		Collision frequency				Total	*p-value*
		Jend Sud	Imba	K Mul	Cikoneng		
Public street light	No	47	30	26	21	124	0.060
		31%	20%	17%	14%	81%	
	Yes	8	14	4	3	29	
		5%	9%	3%	2%	19%	
Land use	Educational	18	5	4	0	27	0.000
		12%	3%	3%	0%	18%	
	Residential	22	20	11	14	67	
		14%	13%	7%	9%	44%	
	Commercial	15	19	15	10	59	
		10%	12%	10%	7%	39%	

Table 6 demonstrates that factors such as horizontal alignment, road width, shoulder width, clear zone, signs, markings, public streetlights, and land use have a p-value below 0.05. This shows that these factors have a correlation with the frequency of traffic accidents.

5 DISCUSSION

5.1 The role of human behavior in traffic accidents

Several studies have found that human error is the most dominant cause of traffic accidents [6], [18], [19], [37]–[40]. Humans, as road users, can be drivers or pedestrians. Some variables that cause accidents due to human factors include fatigue, carelessness, sleepiness, illness, undisciplined, psychological pressure, the influence of drugs and alcohol, and driving beyond the speed limit.

Nurdjanah [38] reports that vehicle conditions account for 31% of the dominant factors influencing the concentration of intercity bus drivers. Meanwhile, for pedestrians, lack of caution is the primary cause of traffic accidents [41]. Factors such as lack of experience [24], [42], lack skills, and risky behavior contribute to accidents among young drivers. Conversely, vision, cognitive, and mobility impairments have been associated with crashes involving older drivers [43]. As a result, age factors influence the fatality rate of drivers involved in accidents [26], [44].

Bucsuházy et al. [33] and P. Wu et al. [34] analyzed human behavior or conditions that can cause accidents or influence accident causation. Driver inattention, a result of various factors such as distractions, excessive attention, and monotony while driving, is the most common factor contributing to traffic accidents [35], [36], [45]. The analysis results show that age, gender, terrain mastery, tendency for risky behavior, and driving habits contribute to the occurrence of accidents. Meanwhile, according to Fernandez et al. [46], the factors contributing to road accidents include a lack of knowledge about traffic signs, while the least prioritized factor is poor driving behavior.

One of the human behaviors that most often contributes to traffic accidents is carelessness [33]–[36]. Age, gender, and knowledge of road conditions can influence carelessness. Furthermore, a lack of knowledge about traffic signs contributes to traffic accidents [46]. Speed affects the possibility of a collision and increases fatality [47]–[49]. Human factors, such as violating speed limits, have the biggest influence on traffic accidents [14], [50], [51]. Therefore, reducing vehicle speed is one of the main factors contributing to improving road safety [52]–[54].

5.2 The role of road and environment in traffic accidents

Every element of road infrastructure that meets safety standards adheres to planning requirements and considers all safety aspects [55]. According to Perdana et al. [56] and Turner et al. [57], high speed is a major factor causing accidents, making speed management the most effective way to reduce traffic accidents. To improve road safety, Shehera et al. [58] propose implementing speed management, characterized by speed limit signs placed at intervals that align with driver visibility. Zheng et al. [59] suggest that installing more traffic signs at reasonable densities can decrease the frequency of collisions. Additionally, the harmony between road geometry and road equipment is a crucial aspect to consider. The placement of traffic signs on roads, in relation to the geometric (vertical and horizontal alignment) and functional characteristics of the road (road and shoulder width), is an integral part of road design and one of the fundamental tools for enhancing road safety [6], [56].

To reduce the severity of driver injuries, Lee & Li [26] suggest increasing the road width to lower the severity of injuries related to collisions. Furthermore, shoulder width, guardrails, and road geometry (vertical and horizontal alignment) influence vehicle speed, indicating that shoulder width has a significant impact on actual speed, lane position, and perceived safe driving speed. However, the benefits and effects of shoulder width on driving behavior significantly diminish in the absence of guardrails [60].

In curving areas, a wider shoulder provides a larger clear zone, which can reduce the risk of collisions [59], [60]. Non-compliance with technical standards for curve radius can be a geometric factor contributing to accidents [37]. To reduce fatality rates, C. Lee & Li [26] propose widening roads in curving areas. Expanding the clear zone in curves can lower the risk of accidents [59]. A curve radius that does not meet standards or is less than the specified minimum radius can potentially cause vehicle collisions [37], [61]–[63]. Vehicles passing through curves at the recommended speed are expected to navigate the curve while remaining within their lane throughout the curved segment [64], [65]. Addressing accident-prone areas with a high rate of nighttime accidents and side collision types can be mitigated by installing medians, road markings, lighting, and improving road pavement (IRI) [19]. To enhance pedestrian safety as road users, it is necessary to improve pedestrian facilities, including sidewalks, crossing facilities, traffic signs, and lighting conditions [15], [66], [67].

Based on IRI and the road shoulder width, it also has asignificant effect on the potential for the number of accident events [61]. Therefore, roads with non-standard conditions, insufficient road width, and lack of road equipment, especially traffic signs, have a significant effect on the crash frequency [39], [56], [68]–[71].

Commercial, residential, and recreational land use positively influences traffic accidents. Because road access remains unrestricted, frequent merging and diverging maneuvers increase the likelihood of collisions. This blend of varying traffic volumes, diverse road users, and uncontrolled interactions disrupts smooth traffic flow, contributing to higher accident rates. Consequently, effective traffic management and planning are crucial to mitigating these risks and enhancing road safety in these mixed-use areas.

6 CONCLUSIONS

According to Chi-Square analysis, carelessness and high speed are the human factors that cause traffic accidents on arterial roads. However, based on the results of interviews with the Ciamis District Police, one example of undisciplined driver behavior is not obeying traffic signs and driving a vehicle at high speed. Therefore, it is crucial to understand that a lack of discipline can also contribute to the occurrence of traffic accidents. According to road and environmental factors, traffic accidents on arterial roads are caused by horizontal alignment, road width, clear zone, signs, markings, and land use.

It can be concluded that the causes of traffic accidents are related to human interactions with the road and the environment. Non-standard geometric conditions on roads, carelessness, and undisciplined drivers combined with a lack of road equipment (road signs and markings) have a significant effect on the frequency of traffic accidents.

To improve arterial road safety, especially in accident-prone areas, potential technical policy recommendations could focus on optimizing horizontal alignment, road width, shoulder width, clear zones, traffic signs, and road markings. The recommendations to improve road safety are as follows:

- Improving horizontal alignment involves minimizing sharp curves and ensuring smoother road surfaces, which can reduce the risk of accidents.
- Adjusting road and shoulder widths based on traffic volumes aims to alleviate congestion and enhance driver comfort.
- Expanding clear zones along roads provides additional safety margins for drivers during emergencies.
- Updating and installing clear, visible traffic signs and road markings, including hazard warnings, can enhance driver awareness and reduce the likelihood of accidents.
- It is necessary to harmonize road geometry and equipment.
- To reduce traffic accidents, speed management on a variety of land uses is also necessary.

These measures collectively contribute to creating safer road environments for all users.

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