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FACTORS CAUSING TRAFFIC ACCIDENTS BASED ON THE TRIP MAKER PERCEPTION: COMPARISON BETWEEN URBAN AND RURAL ROADS

基於出行者認知的交通事故原因：城鄉道路比較

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Abstract

Traffic accidents can occur due to drivers, vehicles, infrastructure, and the environment. Of the three factors that cause it is necessary to know what attributes have a strong correlation as part of the factors that can cause the accident. This study aims to obtain and compare what factors cause traffic accidents on urban and rural roads. The data used in this study is not based on accident data but trip makers' perception data by conducting interviews. The target respondents are trip makers who have been involved in traffic accidents. The perception data is used to obtain the factors that cause other traffic accidents that are not recorded in conventional accident data. In this research, the causative factors are grouped into two conditions: factors causing accidents on urban roads and rural roads. Identification of these causes is by sorting out which attributes directly affect the likelihood of a traffic accident based on the perception of the trip makers. The analysis uses the Partial Least Square statistical approach to get the intended results. The results show that the dominant cause of accidents based on human factors on urban roads is fatigue, while on rural roads is due to high speed (aggressive). From the vehicle factors, a flat tire is a cause that may cause an accident. Brake failure is one of the causative factors for rural roads not found on urban roads. Side friction such as the buildup of material on the roadside, on-street parking, street vendors, and indiscriminate pedestrians have great potential to cause accidents on urban roads. Sharp curve conditions are the dominant cause on rural roads.

Keywords: Traffic Accidents, Trip Maker Perception, Partial Least Square, Urban Road, Rural Road

摘要 交通事故可能因駕駛員、車輛、基礎設施和環境而發生。在導致事故的三個因素中，有必要知道哪些屬性具有強相關性，作為可能導致事故的因素的一部分。本研究旨在獲取和比較導致城鄉道路交通事故的因素。本研究中使用的數據不是基於事故數據，而是基於出行者通過訪談獲得的感知數據。目標受訪者是曾捲入交通事故的出行者。感知數據用於獲取傳統事故數據中未記錄的導致其他交通事故的因素。在本研究中，成因分為兩種情況：城市道路和農村道路事故的原因。識別這些原因的方法是根據出行者的感知，挑選出哪些屬性直接影響交通事故發生的可能性。該分析使用偏最小二乘統計方法來獲得預期結果。結果表明，城市道路上基於人為因素的事故的主要原因是疲勞，而農村道路上的主要原因是高速（侵略性）。從車輛因素來看，爆胎是可能導致事故的原因。剎車失靈是農村公路在城市道路上找不到的原因之一。側面摩擦，如路邊的材料堆積、路邊停車、街頭小販和不分青紅皂白的行人，很有可能在城市道路上造成事故。急彎條件是農村道路的主要原因。

关键词: 交通事故、出行者感知、偏最小二乘、城市道路、鄉村道路

I. Introduction

The high number of deaths from traffic accidents worldwide in 2016 reached 1.35 million per year. Road traffic injuries are now the leading cause of death for children and young adults aged 5-29 years. Deaths from traffic accidents rank eighth in all age groups after HIV/AIDS, tuberculosis, and diarrheal diseases [1].

Road transport safety is now a global problem that is not only a transportation problem but has become a social problem. Indonesia is reportedly still one of the countries with the highest traffic accident rates in the world, and WHO estimates that state losses due to road accidents can reach 3% of the total Gross Domestic Product. However, the data on deaths and traffic accidents can be higher than the results recorded because many people do not report accidents to the Indonesian National Police for various reasons. Lack of coordination between stakeholders can also be a cause of inaccurate data. In addition, when using conventional accident data, only actual accident data is obtained without knowing other factors that may occur.

Based on these problems, a method through another approach is needed to improve road safety. The approach is to ask the community's opinion as trip makers to participate in providing input on the factors that cause traffic accidents on both urban and rural roads. Therefore, the accident factor based on trip makers' perception was carried out on two road conditions: urban and rural roads.

The use of accident data originating from trip makers will certainly be different from existing conventional accident data. From the perception data, the trip maker will explore hidden factors that have the potential to cause him to have an accident. The data obtained outside the conventional data of this accident need to be known to take appropriate preventive action.

In this study, each group of causative factors (human factor, vehicles, roads, and the environment) will show what conditions must be considered related to the possibility of accidents.

II. Literature Review

A. Partial Least Square (PLS) Approach

The PLS approach has been developed in stages since 1971 by Karl G. Jöreskog and Herman O. A. Wold. This modeling is designed to predict problems with high complexity with limited information. PLS estimates do not restrict the format or data, although it would be better to use many data. Data with no less than 500 will get very accurate results. A high prediction model that produces differences or the impact of small asymmetries for each group is recommended at least an ideal sample size of 150 respondents [2]. Indicators can be derived from quantitative measurements, ordinal ranks, events records, or the high-low level. Therefore, PLS has a free distribution and does not assume any particular distribution in the model. Model evaluations are carried out based on the testing of non-parametric measurements [3], [4]. The PLS model can be applied if the criteria are met. The assessment guidelines for applying the PLS model are shown in Table 1.

Table 1.
PLS application appraisal guidelines [5]-[7]

Criteria	Description
Evaluation of outer model: reflective	
Convergent validity	(a) Value of loading factor > 0.70 indicated as high. (b) Value of Average Variance Extracted (AVE) > 0.50
Reliability	Cronbach's alpha > 0.70; composite reliability > 0.70
Discriminant validity	(a) The value of AVE must be higher than the correlation square value of each other construct. (b) Cross loading: Each indicator's loading value must be higher than the loading value of the construct to be measured.
Evaluation of outer model: formative	
The significance of weight value	Using t-value, P-value, or standard errors. > 1.65 (significance level 10%), > 1.96 (significance level 5%), and > 2.58 (significance level 1%).
Multicollinearity	Value of Variance Inflation Factor (VIF) < 5 / tolerance > 0.20; condition index < 30 to show no multicol. As a rule of thumb, VIF > 10 indicates a fatal collinearity.

B. Factors Influencing Accidents

The travel of vehicles causes traffic because of the need to transport people and/or freight. Motor vehicle accidents involve the interaction of five main factors: the driver, traffic, roads, vehicles, and the environment [8]. The factors that cause the accident are identical to the elements forming traffic. Therefore, accidents can arise if one of these elements does not play a role as it should.

The causes of accidents are categorized into three factors, namely human factors, vehicle factors, and physical and social environmental factors [9]. Of the three factors, human error is the dominant factor that causes accidents seen in research in Monroe County, Indiana; from the existing accident data, 92.6% were due to human factors, environmental factors caused 33.8%, and vehicle factors accounted for 12.6% [10]. In a Florida research, the best model and the highest predictive ability were obtained by dividing the factors causing the accident into four groups related to road, environmental, vehicle, and driver on the severity [11]. In Indonesia, the factors that cause accidents are divided into four factors: humans, vehicles, roads, and the environment. Furthermore, these four factors can be seen in Table 2.

Table 2.
Factors causing road traffic accidents in Indonesia [12]

Causative Factor	Description	Percentage (%)
Human	Careless, sleepy, unskilled, tired, drunk, high speed, not keeping a distance, pedestrian error, animal disturbance.	93.52
Vehicle	Broken tires, damage to the brake system, driver system, axles/lose couplings, and the light system does not work.	2.76
Road	Intersections, narrow roads, access not controlled/ controlled, road markings lacking/unclear, no speed limit signs, and slippery road surfaces.	3.23
Environmental	Mixed traffic between fast and slow vehicles, interaction/mixture of vehicles with pedestrians, supervision, and law enforcement have not been effective; service interruption is not fast, weather, dark, rain, fog, smoke.	0.49

III. Research Method

A. Research Variables

In this research, two variables are used: endogenous and exogenous. Endogenous variables are variables whose value is influenced or determined by other variables in the model. Endogenous variables in this research are the factors that cause traffic accidents (Y). Exogenous variables are human/driver (X_1), vehicle (X_2), and road and environmental (X_3). Determination of exogenous variable indicators (factors that cause accidents) based on the results of an investigative survey of vehicle users and literature. From the investigation, data were then grouped as indicators of each exogenous variable. The total indicators that have been grouped are 22, as shown in Table 3.

Table 3.
Variables, indicators, and statement information

Variable/Indicator	Operational Definition
Human (trip makers) factor (X1):	
1. Internal concentration (X1.1)	Drivers do other activities or are not focused due to internal driving factors, such as being careless, upset, thoughts, and work pressure.
2. External concentration (X1.2)	Drivers do other activities or are not focused due to external factors, such as driving while using a cell phone, listening to music, driving while smoking, too busy chatting, driving while eating and drinking, and paying attention to other objects.
3. Discipline (X1.3)	Drivers do not obey the rules of traffic rules that apply, such as being inconsiderate, violating traffic signs, and driving while intoxicated.
4. Driving skills (X1.4)	Drivers cannot predict the danger that might occur due to the expertise and skills of driving a vehicle.
5. Aggressiveness (X1.5)	Driving with excessive speed (exceeds speed limit) or improper speed (driving too fast for current conditions but not exceeding the speed limit).
6. Fatigue (X1.6)	A body condition that results in decreased work capacity and endurance.
Vehicle factor (X2):	
1. Tire condition (X2.1)	A vehicle whose tire condition is not functioning properly due to rupture.
2. Oversizing and overloading (OSOL) (X2.2)	The use of vehicles whose size and load does not comply with the rules (overloaded), including the result of non-standard size (modification) or the use of vehicles not under the class of road.
3. Steering system condition (X2.3)	The steering system does not function to regulate the vehicle's direction by turning the front wheels.
4. Vehicle parts that are not maintained (X2.4)	Lack of maintenance and replacement of parts that regularly deteriorate in performance at intervals, such as a thin clutch web, flimsy gas pedals, rearview mirrors, and engine.
5. Lighting conditions (vehicle lights) (X2.5)	The vehicle's headlights, indicator lights, and turn signal (not lit) malfunctioned.
6. Brake system condition (X2.6)	The state of brake pedal does not work even though it has been stepped on so that the vehicle cannot stop.
Road and environmental factor (X3):	
1. Road geometric /road slope (X3.1)	Road construction on the shape/size of the highway involves cross-sections, lengths, and other aspects related to the physical shape of the road that is not under planning standards, such as intersections, narrowed roads, and steep or winding roads.
2. Road Pavement Conditions (X3.2)	Conditions where the road surface is not good, such as cracking, distortion, disintegration, or bleeding.
3. Road Equipment (X3.3)	The situation is not installed means for safety, security, order, smooth traffic, and ease of trip makers, such as road markings, road lighting, and traffic signs.
4. Road slippage condition (X3.4)	A slippery road condition is either due to water (rain/drainage) or other liquid spills.
5. Curve condition (X3.5)	Road curve conditions are too sharp, and the slope of the curves is made without the technical calculation process and the standard road curve planning.
6. Side Friction (X4.1)	The environmental conditions of the side activities of road segments include the accumulation of materials along the roadside, on-street parking, street vendors, and pedestrians (crosswalks).
7. Weather/climate (X4.2)	Environmental conditions, such as rain, fog, or thick smoke, limit drivers' visibility.
8. Environmental density (X4.3)	Environmental conditions that restrict many human activities
9. Traffic Density (X4.4)	Environmental conditions that many motorized vehicle activities
10. Animals (X4.5)	Environmental conditions are many activities of farm or wild animals.

B. Data Collection Techniques

Data collection is done by survey technique using a questionnaire. The research instrument used a Likert Scale of 1-5. The statements in the questionnaire were made to describe the 22 indicators used for each variable. The weighting results with a Likert scale are value 1 (strongly disagree), value 2 (disagree), value 3 (neutral), value 4 (agree), and value 5 (strongly agree). Respondents must complete the entire list of questions on the questionnaire distributed directly and then return it to the researcher.

The number of respondents used was 300 respondents with a sample distribution of 150 people to provide a perception of the causes of accidents on urban roads and 150 people for rural roads.

IV. RESULTS

The SO-CFA path diagram model for obtaining the accident factors influencing is described in Figure 1.

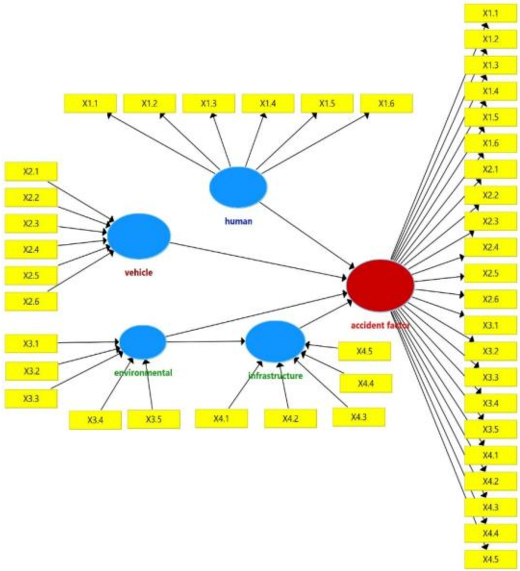

Figure 1. Initial model SO-CFA path diagram for accident factors

In selecting this indicator, the initial analysis process is to correct the loading factor value of each indicator in the reflective model (human factor) and the magnitude of the P-value in the formative model (vehicle factor and road-environmental factor). The loading factor and P-value are obtained from the path diagram model (Figure 1) using the preference data for each approach condition. In this case, the "human" indicator with a load factor value ≤ 0.70 and the cross-loading indicator < "construct" are reduced one by one until the specified conditions are met. In addition, "vehicle condition" and "road and environment" indicators with a P-value > 0.05 one by one are also reduced from the model as a requirement of the PLS Fit Model Goodness.

The final results of reducing indicators for factors that cause accidents on urban roads are shown in Figures 2 and 3.

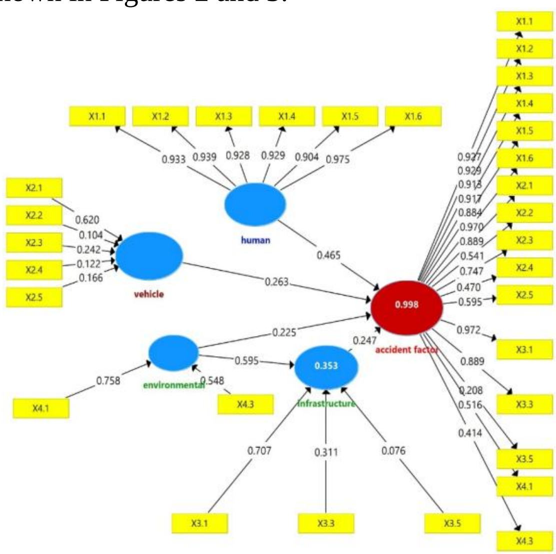

Figure 2. Loading factor on SO-CFA final process of urban road

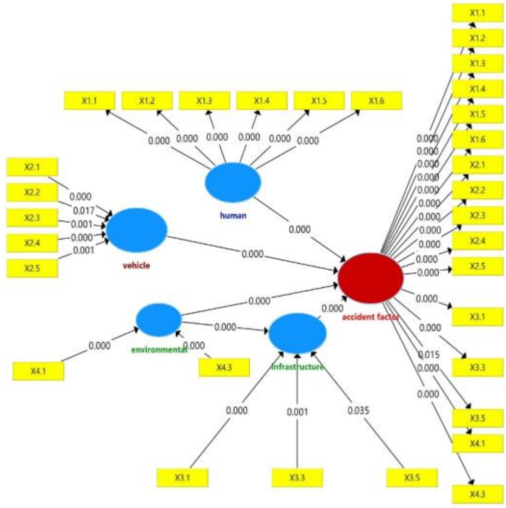

Figure 3. P-value on SO-CFA final process of urban road

The final process of reducing indicators for the causes of accidents on rural roads is shown in Figures 4 and 5.

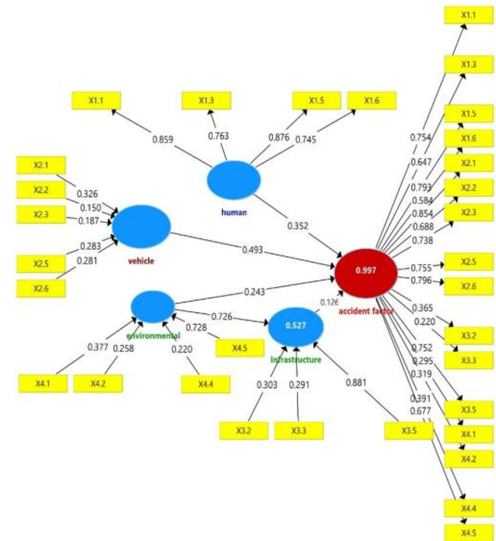

Figure 4. Loading factor on SO-CFA final process of rural road

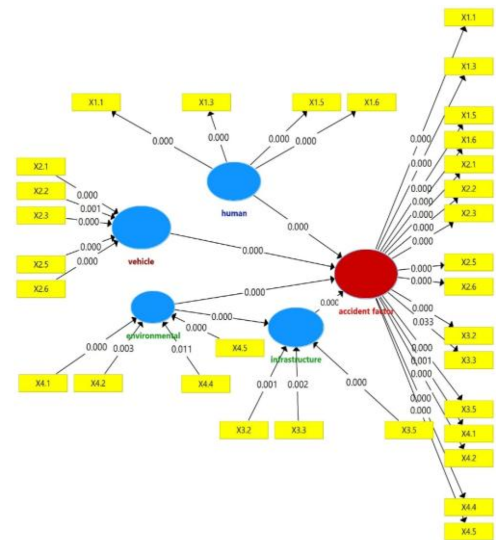

Figure 5. P-value on SO-CFA final process of rural road

The full results of the model test of the causes of accidents on urban and rural roads are described in Table 4.

Table 4.
The goodness of fit model SO-CFA

Criteria	Description	Urban Road		Rural Road	
		Indicator/Model	**Value**	**Indicator/Model**	**Value**
Reflective Model (human factor)					
Convergent validity	Loading factor > 0.70	X1.1 Int. concentration	0.933	X1.1 Int. concentration	0.859
		X1.2 Ext. concentration	0.939	X1.3 Discipline	0.763
		X1.3 Discipline	0.928	X1.5 Aggressiveness	0.876
		X1.4 Driving skills	0.929	X1.6 Fatigue	0.745
		X1.5 Aggressiveness	0.904		
		X1.6 Fatigue	0.975		
	AVE > 0.50	Model	0.874	Model	0.661
Reliability	Cronbach's alpha > 0.70	Model	0.971	Model	0.828
	Composite reliability > 0.70	Model	0.977	Model	0.886
Discriminant validity	Cross loading, loading factor indicator > its respective latent variable	X1.1 Int. concentration	0.933 > 0.927	X1.1 Int. concentration	0.859 > 0.754
		X1.2 Ext. concentration	0.939 > 0.929	X1.3 Discipline	0.763 > 0.647
		X1.3 Discipline	0.928 > 0.913	X1.5 Aggressiveness	0.876 > 0.793
		X1.4 Driving skills	0.929 > 0.917	X1.6 Fatigue	0.745 > 0.584
		X1.5 Aggressiveness	0.904 > 0.884		
		X1.6 Fatigue	0.975 > 0.970		
Formative model (vehicle factor and road-environmental factor)					
Significance of weight	*p*-value < 0.05	X2.1 Tire	0.000	X2.1 Tire	0.000
		X2.2 OSOL	0.017	X2.2 OSOL	0.001
		X2.3 Steering system	0.001	X2.3 Steering system	0.000
		X2.4 Spare part	0.000	X2.5 Lighting	0.000
		X2.5 Lighting	0.001	X2.6 Brake System	0.000
		X3.1 Road geometric	0.000	X3.2 Road pavement	0.001
		X3.3 Road equipment	0.001	X3.3 Road equipment	0.002
		X3.5 Curve	0.035	X3.5 Curve	0.000
		X4.1 Side friction	0.000	X4.1 Side friction	0.000
		X4.3 Environmental density	0.000	X4.2 Weather/climate	0.003
				X4.4 Traffic density	0.011
				X4.5 Animals	0.000
Multicollinearity	VIF < 5	X2.1 Tire	2.108	X2.1 Tire	2.647
		X2.2 OSOL	1.338	X2.2 OSOL	2.008
		X2.3 Steering system	1.996	X2.3 Steering system	2.159
		X2.4 Spare part	1.357	X2.5 Lighting	1.760
		X2.5 Lighting	1.374	X2.6 Brake System	2.086
		X3.1 Road geometric	3.500	X3.2 Road pavement	1.005
		X3.3 Road equipment	3.471	X3.3 Road equipment	1.003
		X3.5 Curve	1.035	X3.5 Curve	1.006
		X4.1 Side friction	1.023	X4.1 Side friction	1.130
		X4.3 Environmental density	1.023	X4.2 Weather/climate	1.048
				X4.4 Traffic density	1.288
				X4.5 Animals	1.221

From the results of the model tests in Table 4, it can be explained that of the 22 indicators of all exogenous variables tested, only 16 relevant indicators caused accidents on urban roads and 16 indicators on rural roads.

V. DISCUSSION

Based on outer weights/loadings values, factors that cause accidents can be arranged based on user perceptions sorted from biggest to smallest influences, as shown in Table 5.

Table 5.
Accident factors based on the perception of trip makers

Urban Road	Rural Road
Human factor	
1. Fatigue due to decreased endurance or drowsiness.	1. Drive at high speed (aggressive).
2. Decreased	2. Decreased concentration due to

Urban Road	Rural Road
concentration due to other activities such as using a cellphone, listening to music, smoking, chatting, driving while eating and drinking, or paying too much attention to other objects. 3. Decreased concentration due to carelessness, confusion, many thoughts, or work pressure. 4. Not skilled at driving. 5. Do not discipline the rules and traffic signs, including reckless and drunken behavior. 6. Drive at high speed (aggressive).	other activities such as using a cellphone, listening to music, smoking, chatting, driving while eating and drinking, or paying too much attention to other objects. 3. Do not discipline the rules and traffic signs, including reckless and drunken behavior. 4. Fatigue due to decreased endurance or drowsiness.
Vehicle factor	
1. Flat tire. 2. Damage to the steering system. 3. Not functioning vehicle lights. 4. Malfunction of the clutch, gas pedal, rearview mirror, and engine. 5. Oversizing and overloading.	1. Flat tire. 2. Not functioning vehicle lights. 3. Failure of the brake function. 4. Damage to the steering system. 5. Oversizing and overloading.
Road (infrastructure) and environmental factors	
1. Side frictions include the accumulation of material along the roadside, on-street parking, street vendors, and pedestrians (crosswalks). 2. Road geometric include unregulated intersections, narrow, steep, or winding roads. 3. Environmental density (many human activities). 4. Road equipment such as road markings, lighting, and traffic signs are not provided. 5. Sharp curve	1. Sharp curve. 2. Disturbances from animal (farm/wild) activities. 3. Side frictions include the accumulation of material along the roadside, on-street parking, street vendors, and pedestrians (crosswalks). 4. Road pavement damage such as cracking, distortion, disintegration, or bleeding. 5. Road equipment such as road markings, lighting, and traffic signs are not provided. 6. Weather/climat e interferes with the driver's visibility, such as rain, fog, or thick smoke. 7. High traffic density.

There is a difference for each factor causing an accident between an urban road and a rural road. The human factor most affecting urban roads is fatigue, while it is high speed or aggressive driving on rural roads. According to research in Finland, fatigue is a major factor causing accidents, with 90.4% committing fatigue-related traffic violations [13]. Aggressive driving behavior greatly influences the risk of accidents in driving later [14]. This aggressiveness is strongly correlated with age [15]; young age tends to have more aggressiveness than parents. Driving at high speeds above the allowable limit is one factor that significantly increases the risk of fatal injuries in accidents [11], [16]. Other human factors that have the potential to cause accidents both on urban roads and rural roads are a decrease in concentration due to other activities and undisciplined behavior towards traffic rules and signs. The existence of violation behavior towards this rule leads to risk and closely related accidents [17], [18], [19].

As for the vehicle factor, broken tires show the greatest potential for accidents on urban and rural roads. Other indicators of the same cause are non-functioning vehicle lights, steering system failures, and oversizing and overloading of vehicles. In general, accidents due to vehicle factors tend to be due to poor maintenance of the vehicle or design changes resulting in malfunctioning one of its components. Vehicle design is important in road safety, so many factors are incorporated into vehicles to avoid accidents [20].

Side friction such as the buildup of material on the roadside, on-street parking, street vendors, and pedestrians (crosswalks) can cause accidents on urban roads. While on the rural road, that has great potential is a sharp curve condition. Research that correlates sharp curves with accident rates shows a significant relationship; the sharper the horizontal curve angles, the greater the accident rate [21]. Potentially the same conditions for both types of roads are road equipment such as road markings, road lighting, and traffic signs that are not provided.

Road and environmental factors other than above, which have the potential for urban roads, are the geometric conditions of the road and disruption by human activities. Road geometric conditions here include those of intersections that are not well regulated. Unsignalized intersections contribute significantly to causing accidents [22], as well as the existence of class/road curves [11] and road shoulders [19]. From the research using accident data in the same area, it was found that geometric constriction, availability of traffic markings and signs, environmental density, availability of road lighting, and protected curves have a very strong correlation to accident rates on urban roads [23]. On rural roads, the cause of the accident is also contributed by interference from farm/wild animals, road conditions that are not good pavement, weather/climate that disturbs drivers' visibility, and high traffic density. Based on accident data, this pavement's condition strongly correlates with the accident rate in the same road area [24].

VI. CONCLUSION

From the analysis of the factors that cause accidents based on the perception of trip makers, there are 16 causes for both urban and rural roads. However, the factors obtained are not always the same as those on urban and rural roads, as shown in Table 5.

The difference in the dominant factor that causes accidents due to human factors on urban roads is fatigue, while on rural roads is high speed (aggressive) that is the same as the tendency of drivers to drive their vehicles faster on rural roads than on urban roads. Additional factors that cause accidents that need attention on urban roads are decreased concentration due to interference from within themselves (carelessness, confusion, many thoughts, or work pressure) and not being skilled at driving. In this study area, these two additional factors are closely related to the age of the trip makers, who are still young and do not have a driver's license.

Broken tires caused accidents due to the dominant vehicle factor, damage to the steering system, vehicle lights not functioning, and over-dimensional and over-loaded. Brake failure is one of the causes on rural roads that is strongly correlated with accidents caused by human factors, namely driving at high speeds. Especially for urban roads, the clutch, gas pedal, rearview mirror, and engine malfunction become an additional factor. Compared to the factors that cause accidents issued by the Directorate General of Land Transportation of Indonesia, the factors that cause accidents that are obtained emphasize and specify the vehicle's condition, which must be considered.

Based on trip makers' perceptions of accidents due to the road and environmental factors, it was found that geometric, hierarchical, and road pavement conditions that were not under the design standards were factors causing accidents. The difference in the dominant factor causing accidents on urban roads is high side frictions, while on rural roads is sharp curves. The high side frictions are the accumulation of material along the roadside, on-street parking, street vendors, and pedestrians (crosswalks); in other words, the road is not functioning properly. Therefore, preservation of function and road hierarchy needs to be done as a preventive measure to reduce the potential for accidents.

The factors that cause accidents result from the perception of trip makers; therefore, they must be aware of the things that can lead to traffic accidents; that is very beneficial for the Government to promote zero-accident. The factors causing traffic accidents obtained with this approach are more effective than those based on conventional accident data or existing references because several traffic accident factors are selected according to their influence level. These factors show conditions that must be considered from several random and possible causal factors. Therefore, handling accident prevention will be more focused and measurable for each group of causative factors (human, vehicles, roads, and environmental) in the study area. Factors causing traffic accidents are also distinguished between urban roads and rural roads because they produce factors with different levels of influence for both roads that will also assist the Government in determining the appropriate form of preventive action for both roads.

The weakness of this study is that it cannot quantitatively show the influence of each causal factor on the level of accidents that occur. Therefore, supporting data or further studies that can provide information on the influence or sensitivity of each factor on the accident rate are needed.

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