***Ambon City is the capital of Maluku Province. The rapid growth of transportation facilities in Ambon City has resulted in traffic problems such as traffic accidents. This study aims to model the probability of four-wheeled vehicle accidents. Factors reviewed in this study include socioeconomic and travel patterns, driving equipment and preparation, driving habits, and driving behavior. The survey was conducted using interview and questionnaire survey methods with a total of 127 respondents who had experienced an accident. The research method used is data analysis using Structural Equation Modeling (SEM) using SmartPLS software. Result of accident modeling Y=–0.203X1+(–0.179X2)++0.214X3+0.536X4. The first biggest influence on the chance of an accident is driving behavior characteristics (X4) is driving under the influence of alcohol (X4.7). The more often you drive under the influence of alcohol, the higher the chance of an accident. Thus, when a driver drives its vehicle under the influence of alcohol, the higher the chance that the driver will have a traffic accident. So that there is a need for cooperation between the police and related parties in dealing with accidents and reducing the risk of traffic accidents such as providing socialization or information, through newspapers or electronic media to the people in Ambon City regarding the importance of increasing awareness of driving safety***

***Keywords: traffic accidents, driver behavior, Structural Equation Modeling (SEM), SmartPLS***

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# ANALYSIS OF FOUR-WHEEL ACCIDENT MODEL USING STRUCTURAL EQUATION MODELING METHOD

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## 1. Introduction

Road traffic crashes are among the eight-leading causes of death globally. Strategies and policies have been put in place by many countries to reduce Road traffic crashes and to prevent Road traffic crashes and related injuries/deaths [1]. Road traffic crashes can result in property damage, injury, or loss of life. A road traffic injury (RTI) is defined by the World Health Organization (WHO) as «a fatal or nonfatal injury incurred as a result of a collision on a public road involving at least one moving vehicle». The WHO reports that about 1.24 million people die on the roads annually, with 20–50 million sustaining non-fatal injuries [2]. The number of motorized vehicles increases exposure to risk factors such as speed and alcohol, and is exacerbated by inadequate enforcement of traffic and community safety regulations health infrastructure [3]. For example, the rapid growth of transportation facilities in Ambon City has resulted in traffic problems such as congestion and traffic accidents. Traffic accidents are a problem in the transportation sector that needs to be taken seriously. In 2015 and 2021, the number of traffic accidents that occurred in Ambon City was 1101 cases of traffic accidents, of which 377 died, 953 were seriously injured and 605 were slightly injured according to Ambon City Police in 2022 [4].

A traffic accident is a series of events, which in the end, shortly before the accident occurs, is preceded by the failure of road users to anticipate their surroundings, including themselves and traffic accidents resulting in casualties or loss of property. Humans are the factor that has the most role in causing traffic accidents, and three factors that greatly affect aspects of driving safety are human characteristics as drivers, human habits while driving, and human behavior while driving [5]. Analysis by [6] revealed that driving behavior increases the risk of having an accident by 50 %. According to the National Police, the highest number of accidents in Indonesia occurred in 2019, with 116,441 fatalities. Several previous studies have found that the human factor is the main cause of accidents [6, 7]. This study examines in depth the driver factors of several variables, namely socio-economic and travel patterns, completeness and preparation for driving, driving habits, driving behavior, and the chance of an accident.

Therefore, research aimed at modeling the probability of a four-wheeled vehicle accident has scientific relevance and needs to be carried out to minimize the occurrence of accidents. The driver factors reviewed in this study include: socioeconomic and travel patterns, completeness and preparation for driving, driving habits, driving behavior, and accident characteristics. This research was conducted using the SEM-PLS method. SEM-PLS is a modeling approach that aims to maximize the variance of the criterion latent variable that can be explained (explained variance) by the predictor latent variable [7].

The increasing number of road traffic accidents is partly due to the behavior of drivers who violate laws and regulations, such as high vehicle speeds, violation of traffic signs and road markings. Traffic accidents are the leading cause of death

worldwide and are expected to be the fifth in 2020 [8]. This is a problem because 91 % of deaths occur on the road [9].

## 2. Literature review and problem statement

This paper is for safe transportation is an action aimed at reducing the possibility or risk of road users being involved in accidents or incidents that can cause property damage, serious injury, and even death. Transportation is important in supporting human life, for mobility and for moving from place of origin to destination. However, there are problems that have not been resolved in transportation, namely accidents. Accidents are dangerous for road users. Because accidents can result in physical and material losses. Accidents are still a major problem that must be prevented to meet safe transportation. Motorcycle riders are the most common road users and are very vulnerable to traffic accidents. However, driving behavior is a one of the causes of traffic accidents that must be considered [10].

Several previous studies on traffic accidents found that the main cause of traffic accidents is driver factors or driver behavior factors, as in the study [11] it was found that the most dominant cause of accidents was due to human error or driver factors as many as 2844 incidents or 91.56 %. As for research [12], it was found that the most important factor causing accidents on Jalan Raya Cilegon was the human factor as much as 96 % of the total accident cases. In research [13] using the *k*-means clustering method in Semarang City, it was found that the main factor causing accidents was the driver with an average percentage of 96.57 % who was identified as the highest cause of traffic accidents in all clusters. The factors that cause accidents are vehicle drivers who are not careful in controlling their vehicles, careless drivers in driving vehicles and physical health of drivers who are less than optimal when driving on the highway which results in 183 accidents or 79.91 % [14], as well as in research [15] found that the driver factor was the main cause of accidents, namely 196 incidents (66.89 %) with the driver's lack of anticipation being the biggest cause of accidents, namely 142 incidents (72.45 %). From previous research, it still uses the usual regression analysis method and the discussion of human factors as the main cause of traffic accidents is still less specific.

According to [16] in Indonesia the main cause of the large number of accidents is the human factor, either due to negligence, negligence or negligence of vehicle drivers and other road users in traffic or intentionally or unintentionally ignoring manners and traffic rules in public road. The high number of traffic accidents and the large cost of losses caused by the many problems faced in improving traffic safety and road transportation really need serious safeguards.

The results of research from [17], it is known that driver behavior is classified into three main categories namely: making unintentional mistakes, driving fast, and driving aggressively. This behavior turns out to be influenced by personal attitudes towards traffic safety in very different ways. A positive attitude towards traffic safety significantly reduces the likelihood of fast and aggressive driving behavior. Fast driving behavior is reported to contribute the most to accidents, followed by aggressive driving behavior. Meanwhile, the socio-economic and demographic variables do not show a significant impact on accident involvement.

Previous studies have also found that not only driving behavior factors but also socioeconomic status such as an individual's educational level, gender, age, and occupation influence the number of deaths from road traffic accidents [18].

Research conducted by [19, 20] showed that the age factor also determined the element causing the accident, but this study did not explain how the relationship between the age factor and the impact on the occurrence of accidents. However, the study used a random sample, where respondents were drawn from those who had or had never had an accident.

Accidents can still happen at any time; therefore, the parties involved need to be responsible and make maximum efforts to overcome these problems. In this regard, research conducted by [21] has investigated the factors that cause accidents, namely driver behavior and socio-economic factors. However, this study uses an analysis method that is not renewable and cannot describe the causes of accidents and their relationship to human factors in detail. The discussion of the causes of accidents involves only one or two elements. Meanwhile, the current research conducted by the author relates the four factors that cause accidents based on a combination of factors that do not yet exist. Therefore, it is necessary to research the causes of accidents caused by many factors.

All this allows to assert that it is expedient to conduct a study on to determine the factors that cause accidents, especially in driving behavior, to create safe and secure transportation with SEM (Structural Equation Modeling). Previously, research used the first generation SEM with Lisrel software [18], this software is the first generation SEM software, which allows more complicated assumptions. The author uses the second generation of SEM, namely Smart PLS which is easier to use, does not require a lot of data, and automatic data normality makes data analysis easier. However, vehicles have an unresolved and challenging problem, namely accidents. Accidents are very dangerous for road users because accidents can result in physical and material losses. Accidents are still a significant problem that must be prevented for safe transportation.

## 3. The aim and objectives of the study

The aim of this study is to determine the characteristics of driving behavior towards the characteristics of accidents and create a model of accident probability.

To achieve this aim, the following objectives are accomplished:

– to determining the most critical factor among the parameters that influence accidents: Socioeconomic Characteristics, and Travel Patterns ($X1$), Driving Equipment and Preparation ($X2$), Driving Habits ($X3$), Driving Behavior ($X4$) to Accident Characteristics ($Y$);

– to produce a probability model of four-wheeled vehicle accidents in Ambon City.

## 4. Materials and methods

This research was conducted in Ambon City, on all roads in Ambon City. The sampling technique was carried out using the Isaac and Michael formula [8] with 127 samples. The questionnaire is only addressed to drivers of four-wheeled vehicles with accidental or purposive samples. So that the modeling results will be significant and valid. The research method used is interview techniques and questionnaires using SmartPLS SEM (Structural Equation Modeling) software.

The sample in this study used purposive sampling, where respondents were selected only who had experienced an accident so that the results of the analysis could be accurately detected regarding the factors causing the accident.

Based on previous studies, discussions on the causes of accidents only involve one or two factors. Meanwhile, the research conducted by the author currently links four factors that cause accidents based on a combination of factors that do not yet exist. Therefore, it is necessary to do research on the causes of accidents caused by many factors this study complements previous research, namely analyzing Socio-Economic Characteristics and Travel Patterns, Driving Equipment and Preparation, Driving Habits, Driving Behavior towards Accident Chances; from the high number of accidents on Ambon City roads with SmartPLS SEM (Structural Equation Modeling) software.

The SEM method is a relevant method in this study because SEM can analyze the relationship between many variables. Sewal Wright developed this concept in 1934, at first this technique was known as path analysis and then narrowed down in the form of Structural Equation Modeling analysis [22]. SEM (Structural Equation Modeling) is a statistical technique that is able to analyze patterns of relationships between latent constructs and their indicators, latent constructs with each other, as well as direct measurement errors. SEM allows analysis between several dependent and independent variables directly [23]. SEM-PLS is a modeling approach that aims to maximize the variance of the criterion latent variable that can be explained (explained variance) by predictor latent variables [24]. Therefore, the authors use SEM because it is relevant to the research objectives. The research variables to be analyzed can be seen in Table 1 below.

Table 1

Research Variable Indicators

| | |
|---|---|
| Socioeconomic Characteristics (*X*1) | |
| *X*1_1 | Age |
| *X*1_2 | Gender |
| *X*1_3 | Work |
| *X*1_4 | Education |
| *X*1_5 | Income |
| *X*1_6 | Driving Experience |
| *X*1_7 | Mileage |
| Equipment and preparation for driving (*X*2) | |
| *X*2_1 | SIM ownership |
| *X*2_2 | Checking the Condition of the Lights |
| *X*2_3 | Check brake condition |
| *X*2_4 | Check tire condition |
| *X*2_5 | Wearing a Seat Belt |
| Driver Habits (*X*3) | |
| *X*3_1 | Eat or Drink while driving |
| *X*3_2 | Using a cell phone while driving |
| *X*3_3 | Using Headset while driving |
| *X*3_4 | Chat/talk with friends |
| *X*3_5 | Driving sick |
| *X*3_6 | Driving while drowsy |
| *X*3_7 | Driving under the influence of drugs |
| *X*3_8 | Smoking while driving |
| Driver Behavior Characteristics (*X*4) | |
| *X*4_1 | Blame the turn signal |
| *X*4_2 | Through the red light |
| *X*4_3 | Violating Traffic Signs |
| *X*4_4 | Change lanes at high speed |
| *X*4_5 | Against Directions |
| *X*4_6 | Ignoring speed limits |
| *X*4_7 | Driving under the influence of alcohol |
| *X*4_8 | Overtake vehicles from the left |
| Accident Characteristics (*Y*) | |
| *Y*.1 | Accident involvement |
| *Y*.2 | Single Accident Causes |
| *Y*.3 | Vehicle Cons |
| *Y*.4 | Casualty accident rate |
| *Y*.5 | Weather Conditions at the Time of the Accident |
| *Y*.6 | Accident time |
| *Y*.7 | Collision Type |

Table 1 above shows the research design based on each indicator of socioeconomic characteristics (*X*1): age, gender, education, income, driving experience and mileage. Equipment and preparation for driving (*X*2); having a SIM, checking the condition of the lights, checking the condition of the brakes, checking the condition of the tires and wearing a seat belt while driving. Driver Habits (*X*3); eating or drinking while driving, using a cell phone while driving, using a headset while driving, chatting/talking with friends, driving while sick, driving while drowsy, driving under the influence of drugs and smoking while driving. Driving behavior (*X*4); blaming turn signals, running red lights, violating traffic signs, changing lanes at high speed, going against the direction, ignoring speed limits, driving under the influence of alcohol and overtaking vehicles from the left. Accident Chance (*Y*); accident involvement, single cause of accident, vehicle cons, accident victim rate, weather conditions at the time of accident, time of accident and type of collision. In the research design in Table 1, all questions come from previous studies. This question or variable will definitely affect the likelihood of an accident occurring.

## 5. Results of probability model of four wheel accident

### 5. 1. Factors that most influence traffic accidents

To find out which variables and indicators are the most influential in influencing accidents, it is necessary to carry out several analyzes as follows:

1. Test Feasibility/Model Validity.

This test aims to describe how well the indicators in this study can be used as instruments to measure latent variables. With a significant weight <0.05 (5 %). VIF value <10. As in Table 2, due diligence.

Table 2 above shows which indicators have the most influence on accidents with valid values for the feasibility test. *X*4.7 driving under the effect of alcohol, *X*1.6 represents driver age, *X*3.6 represents Driving while drowsy, *X*2.5 Wear a seat belt represents overspeed and *Y*.3 represents Vehicle Cons.

2. Dominant Test.

The dominant test determines which variables and indicators are the top priority in accident prevention so that it can be a consideration for policy makers to take strategic steps to minimize the incidence of motorcycle accidents resulting from the dominant test as shown in Table 3 below.

From the results of the dominance test in Table 3 above, *X*4's driving behavior, namely driving under the influence of alcohol (*X*4.7) is the main key indicator for local governments, as an evaluation material to minimize accident rates. Followed by *X*3 Driving habit which is the second highlight in accident prevention measures.

3. Model Fit Test (Goodness of Fit).

This test explains that the path coefficient formed can represent the observed data. The total R-square coefficient values range from 0.0 to 100.0 %, where the larger route coefficients can adequately describe the observed data if the total determination coefficients are large. Specific measures for the internal model test criteria are derived from the overall determination coefficients, as shown in Table 4.

Table 4 above explains the coefficient of determination (R-square) Behavioral Characteristics (*X*2), on the Accident Characteristics (*Y*) of 74.2 % and the remaining 25.8 % is influenced by other variables in outside of research. Based on the existing reference, the R-square value is considered strong in representing the research conducted.

Table 2

Feasibility test

| Latent Variable | Observed Variables | Formative Indicator Factor Weight Test | | | Formative Indicator Independence Test (Multicollinearity) | |
|---|---|---|---|---|---|---|
| | | Significance < 0.05 (5 %) = Valid | | | VIF < 10 = Qualified | |
| | | Weight Estimates | Significance of Weight | Conclusion | VIF | Conclusion |
| Socio-Economy & Travel Patterns (*X*1) | *X*1.6 | 0.709 | 0.000 | Valid | 1,762 | Valid |
| Driving Equipment & Preparation (*X*2) | *X*2.5 | 0.947 | 0.001 | Valid | 1,263 | Valid |
| Driving Habits (*X*3) | *X*3.6 | 0.843 | 0.000 | Valid | 1.422 | Valid |
| Driving Behavior (*X*4) | *X*4.7 | 0.638 | 0.000 | Valid | 1,900 | Valid |
| Accident Characteristics (*Y*) | *Y*.3 | 0.346 | 0.065 | Invalid | 6,606 | Valid |

Table 3

Dominant Test

| Influence between Latent variables | | | Path Coefficient | Ranking | Dominant Indicator |
|---|---|---|---|---|---|
| Var. Reason | → | Var. Consequence | | | |
| *X*1 (Socio-Economy & Travel Patterns) | → | *Y* (Crash Characteristics) | –0.139 | 3 | Driving Time (*X*1.6) |
| *X*2 (Equipment & Driving Preparation) | → | *Y* (Crash Characteristics) | –0.305 | 4 | Wearing Seat belt (*X*2.5) |
| *X*3 (Driving Habit) | → | *Y* (Crash Characteristics) | 0.208 | 2 | Drowsy driving (*X*3.6) |
| *X*4 (Driving Behavior) | → | *Y* (Crash Characteristics) | 0.319 | 1 | Driving under the influence of alcohol (*X*4.7) |

Table 4

Coefficient of Determination

| PLS models | | | R Square | Determination |
|---|---|---|---|---|
| *X*1 (Socio-Economy & Travel Patterns) | → | Y (Crash Characteristics) | 0.742 | 74.2 % |
| *X*2 (Equipment & Driving Preparation) | → | | | |
| *X*3 (Driving Habit) | → | | | |
| *X*4 (Driving Behavior) | → | | | |

### 5. 2. Accident Probability Model

The path diagram image shows the relationship between the path coefficients in the structural model and the weighted values of the manifest variables in the measurement model when considering the external factors of the study in Fig. 1 below: $Y=-0.203X1+-0.179X2+0.214X3+0.536X4$.

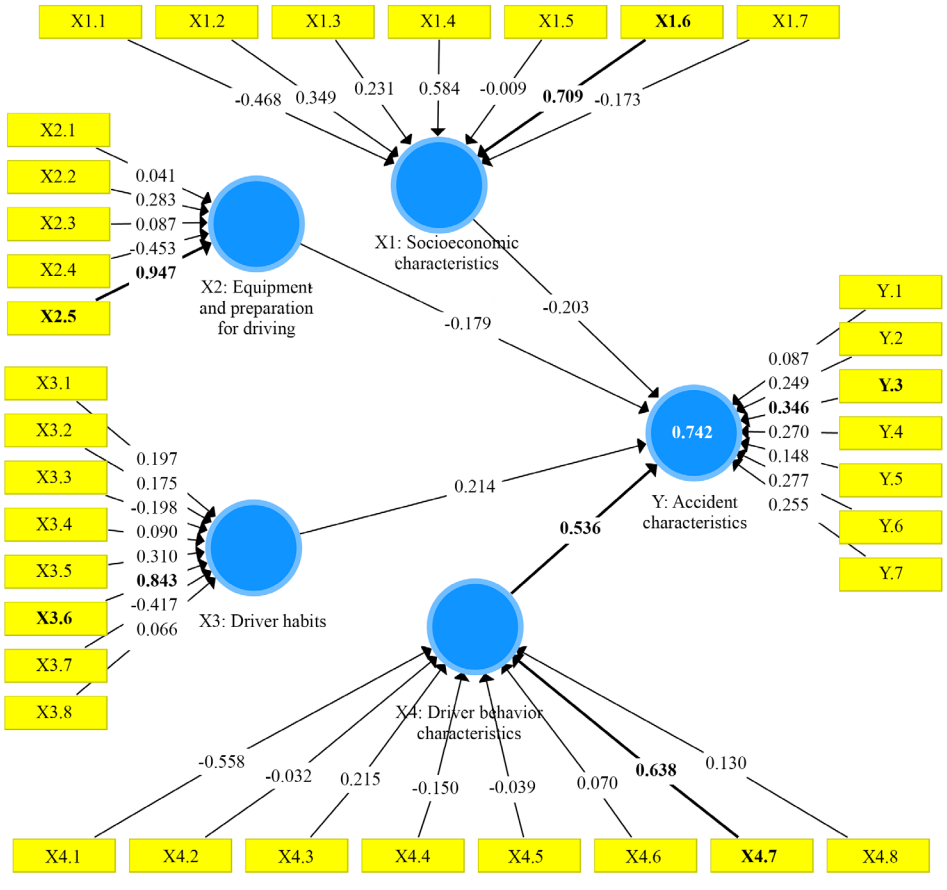


Fig. 1. Results of the four-wheeled vehicle accident probability model

Fig. 1 above explains the value of each variable and indicator, where the highest path coefficient of 0.536 is found in driving under the effect of alcohol ($X4.7$) with the highest factor weight of 0.638.

## 6. Discussion of the Accident Probability Model

The results of the analysis of the causes of accidents using SEM (Structural Equation Modeling) found that the main factor causing accidents is found in the driving behavior variable ($X4$) (Table 3, dominant test). These results are in line with previous research, where the human factor or driving behavior is still the main cause of accidents. In this study the dominant indicator forming the driving behavior variable ($X4$) is driving under the influence of alcohol ($X4.7$), with a factor weight of 0.638 (Table 3, dominant test). Thus, the more you drive under the influence of alcohol or while drunk, the greater your risk of having an accident.

The dominant indicator in forming the driving habbit ($X3$) is the driving drowsy ($X3.6$) show on (Table 3 dominant test). With a factor weight 0.208. The survey results show that the experience in driving 4–6 year (27 %). Accidents due to drowsy driving have become a major concern in transportation safety. In Louisiana, 14 % (1,758 of 12,512) of drowsiness-related driving accidents reported to police during 2015–2019 resulted in an injury (fatal, severe, or moderate). Amid calls for action against drowsy driving by national agencies, it is imperative to explore the main reportable attributes of drowsy driving behavior and its potential relationship to accident severity [25].

The dominant indicator in forming the characteristic socio-economic and travel pattern variable ($X1$) is the driving time variable ($X1.6$) (Table 3, dominant test), with a factor weight of –0.139. The survey results show that the experience in driving 4–6 year (27 %). The driver's experience also affects the incidence of accidents, this experience is also directly related to the age of the driver. an older age certainly has a longer experience than a young age, which means that mastery of driving is more mature than a young age [26].

The most dominant influence in influencing the chance of an accident ($Y$) On the first priority scale there is the path from $X4$ (Driving Behavior), with the first highest path coefficient of 0.536, where the most representative indicator to describe the chance of causing an accident in the variable $X4$ (Driving Behavior) is $X4.7$ (Driving under the influence of alcohol) with the highest factor weight of 0.638 (Table 3, dominant test).

Thus, the more often you drive under the influence of alcohol, the higher the chance of having an accident. Driving after consuming alcohol increases the risk of a traffic accident and the severity of the accident. Consuming alcohol reduces several important elements for driving safety, such as vision and reflexes, assessment of risky behavior such as speed and difficulty implementing safety rules (using seat belts and helmets) [27].

This study used the SEM (Structural Equation Modeling) method with SmartPLS software. The advantages of using SEM (Structural Equation Modeling) are (1) its ability to handle complex relationships between variables, where (1) variables can be hypothetical or unobservable (latent variables), (2) estimate all coefficients in the model simultaneously, so that one can assess the significance and strength of a particular relationship in the context of a complete model, (3) its ability to consider multicollinearity and measurement error is removed so that the coefficients are more valid [28]. Research [29] using Lisrel which analyzes driving behavior also produces the same variables in the causes of accidents.

However, the research carried out still uses the second generation SEM (Structural Equation Modeling) method, the SmartPls software is considered easier and does not

require many assumptions in the process. The drawback of this study is that there are still many variables that have not been analyzed in relation to the causes of accidents. The author hopes for further research to include more variables that cause accidents, so that they are more valid and can overcome existing problems. The analytical method also needs to be developed using the third generation (Structural Equation Modeling). Research can also be developed in other fields that have almost the same characteristics.

## 7. Conclusions

1. The analysis of the causes of accidents using SEM (Structural Equation Modeling). The highest path coefficient of 0.536 is found in the driver behavior variable ($X4$) with the highest factor weight of 0.638, namely driving behavior under the influence of alcohol ($X4.7$), Thus if you drive under the influence of alcohol, the higher the chance of having an accident. Second causes coefficient of 0.214 is found in variable $X3$ (Driving Habits) with the highest factor weight of 0.843, namely indicator $X3.6$ (Driving in Drowsiness). Thus, the more often you drive while drowsy, the higher the chance of having an accident. The results of the study show that the probability of traffic accidents experienced by four-wheeled vehicle drivers in Ambon City is largely due to the behavior of drivers who are not disciplined. Therefore, the authorities in preventing and overcoming the potential for traffic accidents, must pay more attention to how to reach the local community in order to minimize the incidence of accidents and the need for increased law enforcement and increased supervision by the Government, in this case the Ministry of Transportation as the road transport regulator and the State Police The Republic of Indonesia as law enforcement in the field of transportation.

2. The prediction model obtained is $Y=-0.203X1+$ $+(-0.179X2)+0.214X3+0.536X4$. The highest path coefficient of 0.536 is found in the driver behavior variable ($X4$) with the highest factor weight of 0.638, namely driving behavior under the influence of alcohol ($X4.7$). From this model, proper handling of steps must be taken, so that the problem of accidents can be handled properly, by promoting traffic safety programs, providing socialization or information, through print or electronic media to the people in Ambon City regarding the dangers of driving under the influence of alcohol as well as the importance of driving safety, especially for drivers who drive through the roads in the city of Ambon to always be careful while driving, always use seat belt, not use a cell phone while driving and rest if they are traveling long distances.

## Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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## Data availability

Data will be made available on reasonable request.

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