ASM Sc. J., 19, 2024

https://doi.org/1032802/asmscj.2023.1471

The Impact of Previous Accidents on The Probability of Repeat Accidents to Motorcyclists

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According to 2019 statistics in Indonesia, the number of motorcycle accidents is relatively high, at 84.4 percent. Other data show that 16.13 percent of accidents include drivers who have previously been in an accident. The purpose of this study is to obtain a model of the probability of an accident for motorcycle riders who have previously experienced an accident as well as for motorcycle riders who have never experienced an accident before. Data were collected by interviewing motorcycle riders who had only been in one traffic accident and those who had been in more than one. The results of the analysis suggest that a driver who has had a previous accident has a 16 percent probability of having an accident, but a driver who has never had an accident has an 84 percent probability of having an accident. Furthermore, validation is carried out by calculating the Mean Absolute Deviation (MAD) value. The MAD value calculated from the results is 11.16 percent. Following that, numerous scenarios were run, with scenario 1 demonstrating that female drivers who have previously been in an accident have a higher accident probability than male drivers who have previously been in an accident. Meanwhile, scenario 2 shows that drivers above the age of 20 who have had a previous accident are more likely to be involved in an accident than drivers under the age of 20. Scenario 3 reveals that drivers who are on varied roadside variable roads and driving on bends can reduce their monotone level from 45% to 22%, but this condition has no effect on the level of fatigue and the probability of accidents. The final scenario shows that a driver who drives between 24:00 and 06:00 will have probability of fatigue by 73% and will have accident probability by 17%. Finding of this study is the drivers who have previously been involved in an accident are less likely to be involved in another accident compared to the drivers who have never been involved in an accident before.

Keywords: accident; Bayesian Network; motorcycle; probability

I. INTRODUCTION

The impact of traffic accidents can result in property loss, minor injuries, serious injuries, and even death on the highway, so the driver's expertise and caution are essential when driving. Accidents are caused by a variety of reasons, including human error, road conditions, and vehicle condition. The most significant contributor to the cause of accidents in general is human error, particularly as it relates to the driver's characteristics, such as gender and age. The gender of the driver can have an impact on driving behaviour. Most male drivers are less cautious, even overconfident, and underestimate the risks that may arise during the trip (Chang & Yeh, 2007). This situation, of course, poses a risk to the severity of the accident at the time of the accident (Boufous & Williamson, 2009; Lumba *et al.*, 2017; Lumba *et al.*, 2018). Furthermore, men drivers are more prone than female drivers to commit traffic violations on the highway (Putranto & Rostiana, 2015). In addition to gender considerations influencing driving behaviour, age also has an impact. In general, motorcyclists are young

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riders (Joewono & Susilo, 2017). The mental immaturity of young drivers is one of the factors that cause young drivers to be prone to accidents (Ambarwati, 2010; McKnight & McKnight, 2002) and even this condition is also at risk for fatal accidents (Clarke *et al.*, 2009; Zambon & Hasselberg 2006; Vorko-Jovic *et al.*, 2005; Gray *et al.*, 2008; Lumba *et al.*, 2017; Lumba *et al.*, 2018). In addition, young drivers are also often involved in traffic violations, both intentional and unintentional. Even young drivers tend to modify their vehicles so that they do not meet the specified requirements.

Driving for too long can produce fatigue (Ma *et al.*, 2003; Lumba, 2022), hence, drivers are advised to take a short break when they begin to feel fatigued. Beside long duration of driving factor, the heavy workload performed prior to driving can contribute to exhaustion on the road. Similarly, drivers who have lack hours of sleep will hasten the process of fatigue when driving (Ma *et al.*, 2003). This lack of sleep can also lead to traffic violations (Philip *et al.*, 2003), which of course is a risk of accidents (Stutts *et al.*, 2001). Moreover, monotonous road conditions might cause driver fatigue (Ma *et al.*, 2003; Lumba, 2022), so it is necessary to limit the length of the trip when driving on a monotonous road (Ting *et al.*, 2007; Lumba *et al.*, 2016). Furthermore, driving time influences fatigue and even the risk of an accident (Vorko-Jovic *et al.*, 2005; Haworth & Rechnitzer, 1993; Horberry *et al.*, 2008; Hensher *et al.*, 1992). Fatigue can cause of drowsiness, thus that it will reduce the level of alertness and the ability of the rider (Dingus *et al.*, 2006).

Indonesia has a high rate of accident, with one person killed on the road every 20 minutes. In 2019 the number of motorcycles involved in accidents was 112,771,136 units or 84.4% compared to other vehicles (Land Transportation Statistics, 2019). Aside from that, it is common in Indonesia for one person to own multiple motorcycles (Wedagama DP, 2009). The increasing number of motorcycles in Indonesia is accompanied by a high number of motorcycle accidents. Motorcycles are less stable than other types of transportation because they only have two supports; hence the stability of this vehicle is dependent on the rider's balance. Besides that, this vehicle is somewhat open where the driver is not protected from heat or when it rains and is even at risk of the impact of the accident caused.

Besides the above problems, the factors of drivers who have never had an accident and factors of the drivers who have had accidents also affect the risk of future accidents (Daigneault *et al.*, 2000). Several factors affect the risk of future accidents, especially for drivers who have been in an accident, namely the age of the driver, gender of the driver, injuries during previous accidents, and education of the driver (Gabbe *et al.*, 2012). Women who have had an accident in the last 1 year are twice as likely to experience anxiety in travel compared to men (Mayou & Bryant, 2003). In addition, the impact of this accident also carries a positive meaning for drivers to be much better than before (Rinaldi *et al.*, 2017; Gabbe *et al.*, 2012; Kim, 2011; Walton *et al.*, 2013).

For this reason, it is necessary to conduct research in an effort to improve safety in driving, especially for motorcycle riders who have had an accident before or on motorcycle riders who have never had an accident before. This study aims to obtain model of probability of accident for motorcycle riders who has been in accident before and on motorcycle riders who has been never in accident before. This model examines the occurrence of accidents from the factor of human error and also from the factor of the road. This research is useful for motorcycle riders in understanding the dominant factor causes of accidents. Besides, this research is also useful for policy maker in making decisions that can protect motorcycle riders against the possibility of accidents.

II. MATERIALS AND METHOD

The research took place in Bekasi City, Indonesia. Bekasi is home to approximately 14.8% of the 2.43 million people who commute to Jabodetabek. Furthermore, 58.19% of commuter trips in Jabodetabek and 51.79% of commuter trips in Bekasi City that travels to activity places use motorbikes.

Number of respondents were used for data analysis by 186 respondents. In this study, respondents' criteria included motorcycle riders who had previously been in an accident and motorcycle riders who had never been in an accident before. Respondents consisted of 147 male and 39 female drivers, 125 drivers under the age of 20, and 61 drivers over the age of 20.

The sample was taken from the population using a purposive sampling method or based on certain criteria. The sample size is determined by using equation (2), the results show that a minimum sample size of 88 respondents is required. Information: n = sample, N = population, e = margin of error. The number of motorcycle accidents in Bekasi City = 675 cases, and the value of e = 10%. The number of respondents in this study was 186 respondents.

$$n = \frac{N}{1 + Ne^2}$$

$$n = \frac{675}{1 + 675(0.1)^2} = 87.1 \text{ respondents}$$

Data is collected by interviewing motorcycle riders who have been in an accident and asking various questions on the cause of the accident, both from the human and the road factors. Some of the questions posed to responders included:

1. What is your gender? **(answer choices: male or female)**
2. What is the condition of the road geometry at the accident site? **(answer choices: Straight roads and Hilly or curve)**
3. What is the condition of the roadside variability at the accident site? **(answer choices: variability and invariability)**
4. What is the condition of road at the accident site? **(answer choices: monotonous or unmonotonous)**
5. What time did you have the accident? **(answer choices: 06.00-12.00 AM, 12.00-18.00 PM, 18.00-24.00 PM, 24.00-06.00 AM)**
6. How long did you drive until you had an accident? **(answer choices: ≤ 30 minutes, 30 min < LD ≤ 60 min, > 60 min), LD=Long duration of driving**
7. Were you tired before the accident? **(answer choices: yes or no)**
8. How long did you sleep the night before the accident? **(answer choices: ≤ 6 h, 6 h < LD ≤ 7 h, > 7 h), h=hour**

The obtained data were probabilistic, making it ideal for analysis with a Bayesian Network. Bayesian Network Analysis is derived from Bayes Theory, which states that the occurrence of event A is conditional on the occurrence of event B, or P(A|B), as illustrated in the following Figure 1 and the formula:

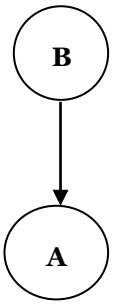

Figure 1. The relationship between variable A and variable B.

$$P(A|B) = \frac{P(B|A)P(A)}{P(B|A)P(A) + P(B|-A)P(-A)}$$

Examples of Bayesian Network calculation are shown in Figure 2 and Figure 2 below:

Analysis of the Bayesian Network in Figure 2 (with 3 variables) can be calculated with the formula:

P(Y) = P(Z|X, Y) x P(X) x P(Y) +
P(Z|X,-Y) x P(X) x P(-Y) +
P(Z|-X,Y) x P(-X) x P(Y) +
P(Z|-X,-Y) x P(-X) x P(-Y)

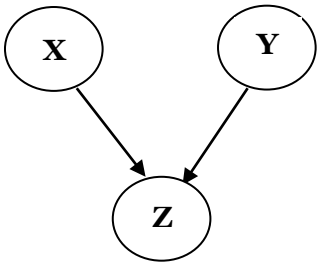

Figure 2. Example of structure of Bayesian network with 3 variables

Note: (-X) = X complement

Analysis of Bayesian Network in Figure 3 (with 4 variables) can be calculated with the formula:

P(Y) = P(Z|X,Y,W) P(X|W) x P(Y|W) +
P(Z|X,-Y,W) x P(-X|W) x P(-Y|W) +
P(Z|-X,-Y,W) x P(-X|W) x P(Y|W) +
P(Z|-X,-Y,W) x P(-X|W) x P(-Y|W)

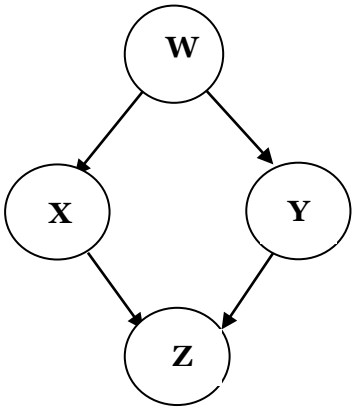

Figure 3. Example of structure of Bayessian network with 4 variables

Bayesian Network analysis was performed by using GeNie 2.0 software (https://download.bayesfusion.com/files.html?category=Academia, 2016). The first step in using this software is to draw nodes which are variables that are used in the model. These nodes are contacted by arrows that indicate the relationship between variables. Each node has a value which is the input to this software. After the analysis, the basic model will be obtained. This model is then validated to know the accuracy of the model that was obtained. Validation is done by calculating the MAD value, which is the average difference between the model results and the conditions in the field. For this validation, the numbers of samples used were 50 respondents. If the validation results show that there is a close relationship between the model results and the reality in the field, the basic model can be used to predict an event.

III. RESULT AND DISCUSSION

Table 1 shows several variables that affect the occurrence of accidents in motorcycle riders both directly and indirectly. Variables that affected accidents directly including: the age of the driver, the level of fatigue of the driver during the trip and the gender of the driver. Meanwhile, the level of fatigue experienced by the driver during the trip were influenced by: long duration of driving before the accident (≤ 30 minutes, 30 min < LD 60 min, > 60 min), road conditions (monotonous or not monotonous), and driving time (06.00 - 12.00, 12.00-18.00, 18.00-24.00, 24.00-06.00).

Table 1 also explains that the percentage of accidents that occurred on the straight roads is higher than those that occurred on the bends. This condition is caused when the driver is on a straight road; the driver tends to feel monotonous, which contribute to the emergence of drowsiness in the driver. Furthermore, the majority of accidents occurred between 12.00 and 18.00. This is due to the fact that the weather outside is very hot at the time, and the driver has also engaged in various activities, which will affect the driver's level of fatigue when driving. The majority of incidents occurred after the driver had been driving for 30 minutes or less. This demonstrates that accidents are caused not only by long periods of driving, but also by a variety of other factors such as driving behaviour, road conditions, and improper vehicle conditions. Fatigue is responsible for 45.16 percent of all accidents. Furthermore, male drivers were involved in more accidents than female drivers. Finally, 47.32 percent of motorcyclist who experienced accident were those who had slept for 6 hours or less the night before the accident.

Table 1. Statistic and data

Number	Variables	Value	Percentage
1	Road geometry	Straight roads	82,26
		Hilly or curve	17,74
2	Roadside variability	Variability	79,03
		Unvariability	20,97
3	Condition of road	Monotonous	44,09
		Unmonotonous	55,91
4	Driving time	06.00-12.00	33,33

		12.00-18.00	42,47
		18.00-24.00	18,82
		24.00-06.00	5,38
5	Long duration of driving (LD)	≤ 30 minutes (LD1)	68,82
		30 min < LD ≤ 60 min (LD2)	19,89
		> 60 min (LD3)	11,29
6	Fatigue before accident (FA)	Yes (FA1)	45,16
		No (FA2)	54,84
7	Gender (GD)	Male (GD1)	79,03
		Female (GD2)	20,97
8	Sleep duration (SD)	≤ 6 h	47,31
		6 h < SD ≤ 7 h	28,49
		> 7 h	24,19

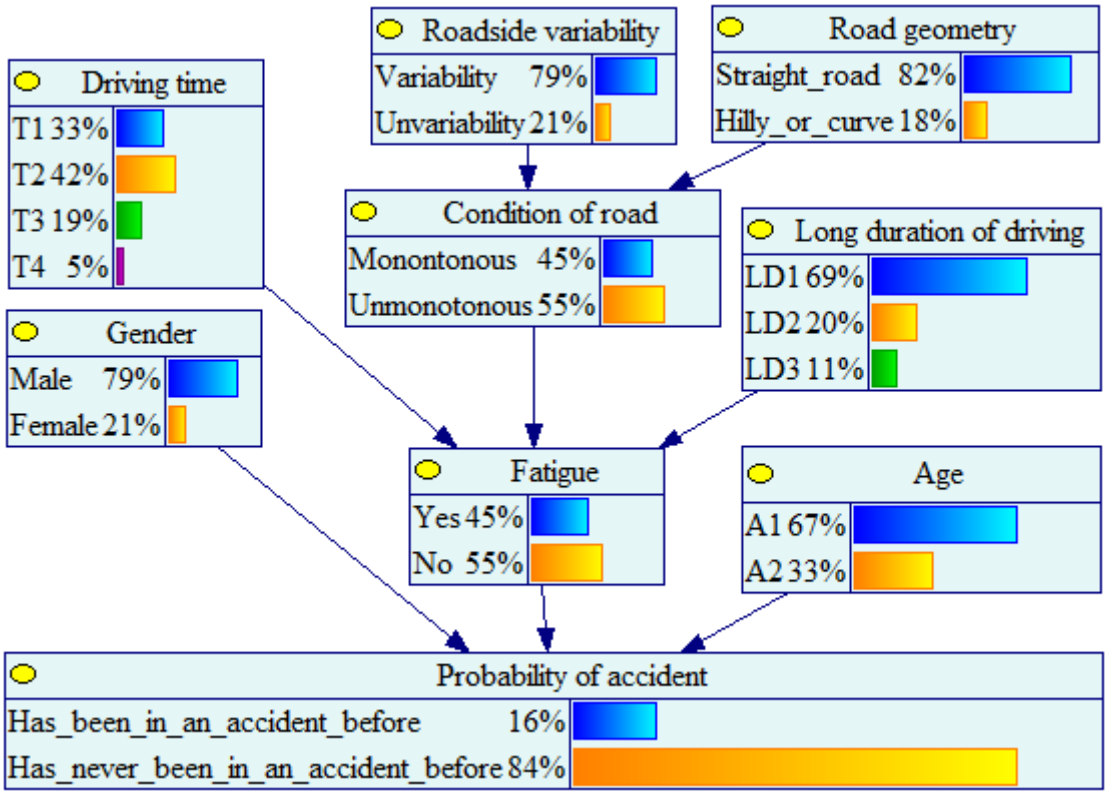

Figure 4. Structure Bayesian network of probability of accident

The results of the analysis with the Bayesian Network show that the probability of accident for a driver who has been in accident before is 16%, while the probability of accident for a driver who has never been in accident before is 84%. This shows that the experience of having an accident will make the driver to be more careful to avoid the occurrence of traffic accident. The results of this study are in line with the research conducted by (Patten *et al.*, 2006) which states that experienced drivers have more abilities than inexperienced drivers. The structure of the Bayesian

Network is in Figure 4, and then it is analysed using Bayes Theory, to get the equation displayed in Table 2.

Before making several scenarios to determine the effect of each variable, the basic model should be validated with the aim of knowing the accuracy of the model or the extent to which the model results are close to conditions in the field by using other data. Validation is done by calculating the MAD value, which is the average difference between the results of the model calculations and the conditions in the field. The MAD value obtained 11.16%, as shown in Table 3.

Table 2. Equation of model

Proba Bility (P)	P(AG)	P(FA)	P(GD)	P(AC=Accidents)
1	AG1	FA1	GD1	P(PAC)1=P(PAC|AG1,FA1,GD1,CR,RS,RG,LDD,DT) x P(FA1|DT,CR,LDD)x P(CR|RS,RG)
2	AG1	FA1	GD2	P(PAC)1 = P(PAC|AG1, FA1, GD2, CR, RS, RG,LDD, DT) x P(FA1|DT, CR, LDD) x P(CR|RS, RG)
3	AG1	FA2	GD1	P(PAC)1 = P(PAC|AG1, FA2, GD1, CR, RS, RG,LDD, DT) x P(FA2|DT, CR, LDD) x P(CR|RS, RG)
4	AG1	FA2	GD2	P(PAC)1 = P(PAC|AG1, FA2, GD2, CR, RS, RG,LDD, DT) x P(FA2|DT, CR, LDD) x P(CR|RS, RG)
5	AG2	FA1	GD1	P(PAC)1 = P(PAC|AG2, FA1, GD1, CR, RS, RG,LDD, DT) x P(FA1|DT, CR, LDD) x P(CR|RS, RG)
6	AG2	FA1	GD2	P(PAC)1 = P(PAC|AG2, FA1, GD2, CR, RS, RG,LDD, DT) x P(FA1|DT, CR, LDD) x P(CR|RS, RG)
7	AG2	FA2	GD1	P(PAC)1 = P(PAC|AG2, FA2, GD1, CR, RS, RG,LDD, DT) x P(FA2|DT, CR, LDD) x P(CR|RS, RG)
8	AG2	FA2	GD2	P(PAC)1 = P(PAC|AG2, FA2, GD2, CR, RS, RG,LDD, DT) x P(FA2|DT, CR, LDD) x P(CR|RS, RG)
				∑ P(AC=Accidents)

Table 3. Validation of model

Probability (P)	Age (AG)	Fatigue	Gender	Model	Actual	Deviation (%)
1	20 years and below (A1)	Yes	Male	13	25,00	12,00
2	20 years and below (A1)	Yes	Female	27	0,00	27,00
3	20 years and below (A1)	No	Male	7	0,00	7,00
4	20 years and below (A1)	No	Female	26	16,67	9,33
5	Above 20 years (A2)	Yes	Male	29	22,22	6,78
6	Above 20 years (A2)	Yes	Female	0	0,00	0,00
7	Above 20 years (A2)	No	Male	16	0,00	16,00
		Mean Absolute Deviation				11,16

Due to the MAD value obtained is 11.16% which shows the average difference between the model and field conditions are quite small, so the model is considered accurate enough. After that, several scenarios were made to determine the effect of each variable. Scenario 1 shows that male drivers who has been in accident before are 14% likely to get accident repetition, while female drivers who has been in accident before are 24% likely to get repeat accident as shown in Figures 5 and Figure 6. This suggests that female drivers who have previously been in an accident are more likely to have another accident than male drivers who have previously been in an accident. It also demonstrates that previous incidents traumatised female drivers, affecting their ability to drive safely.

Scenario 2 reveals that drivers under the age of 20 who have been in an accident before are 13 percent more likely to have another accident, and drivers over the age of 20 who have been in an accident before are 21 % more likely to have another accident, as shown in Figures 7 and Figure 8. That is, motorcyclists above the age of 20 who have previously been

in an accident have a higher risk of being in an accident than motorbike riders under the age of 20 who have previously been in an accident. So, it is hoped that motorcyclists aged over 20 years who has been in accident before to always be careful considering the high probability of an accident for a driver like this. The results of this study are not in line with research conducted by (McKnight & McKnight, 2002).

Scenario 3 reveals that driving on roads with roadside variability, as well as driving on hilly roads or on bends, reduces the monotone level by 23%, or from 45% to 22%, as illustrated in Figure 9. This is due to the fact that when the car is on a mountainous road or a bend, the driver's level of attention increases because they must pay attention to the road and other vehicles. On the other hand, when driving on a straight road, the driver tends to feel monotonous causing drowsiness and lowering the driver's level of awareness. The results of this study are in line with research conducted by (Larue *et al.*, 2011; Ma *et al.*, 2003).

Meanwhile, scenario 4 shows that driving from 24.00 to 06.00 can increase the driver's fatigue level by 23% or from 45% to 73%. Even driving in the middle of the night can also increase the probability of an accident by 1% or from 16% to 17% as shown in Figure 10. The results of this study are in line with the research conducted by (Stutts *et al.*, 2001). Another study showed that male drivers who drive from 24.00 to 06.00 are at risk of having a fatal accident (Vorko-Jovic *et al.*, 2005). This is due to the time that should be used to rest is used for activities, so that it will cause fatigue for the rider and will endanger the safety of the rider.

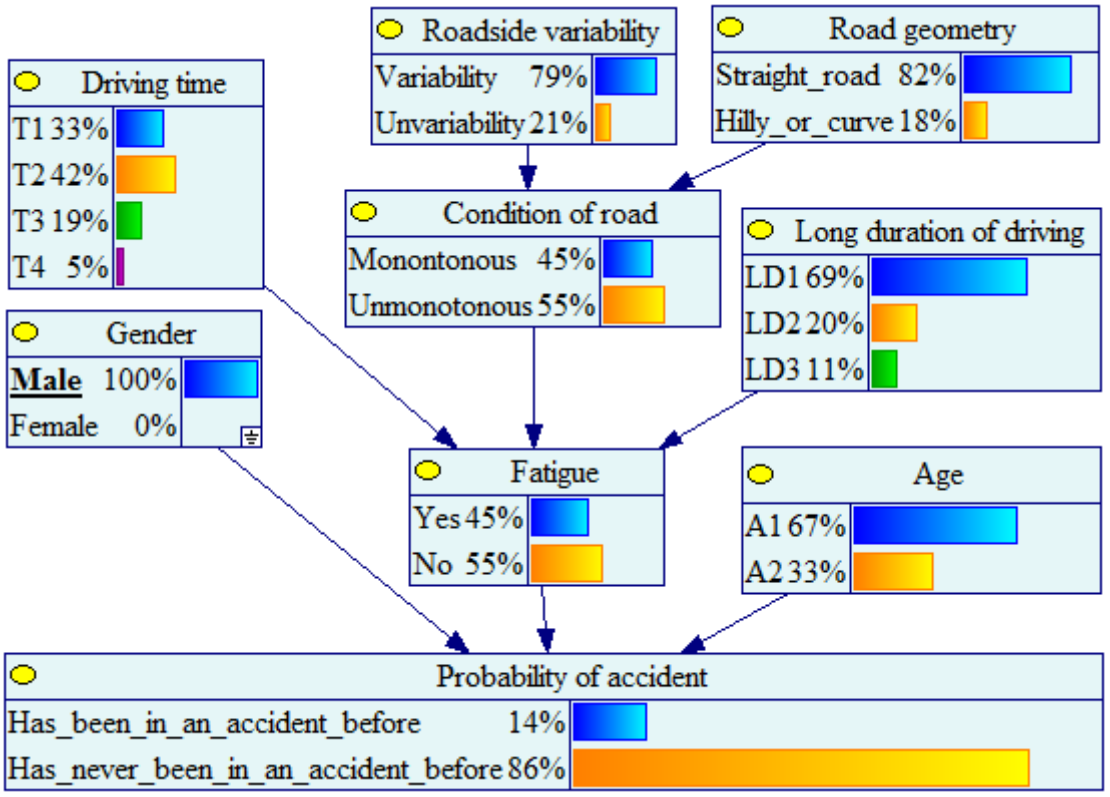

Figure 5. Scenario 1a

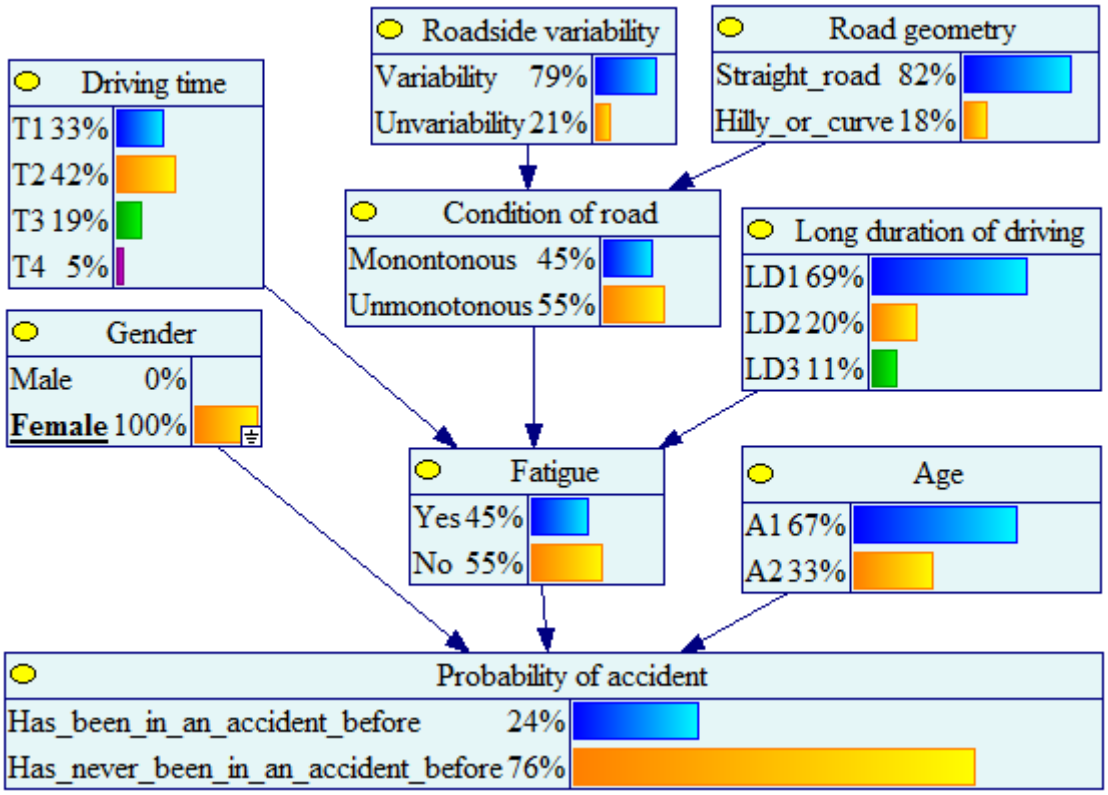

Figure 6. Scenario 1b

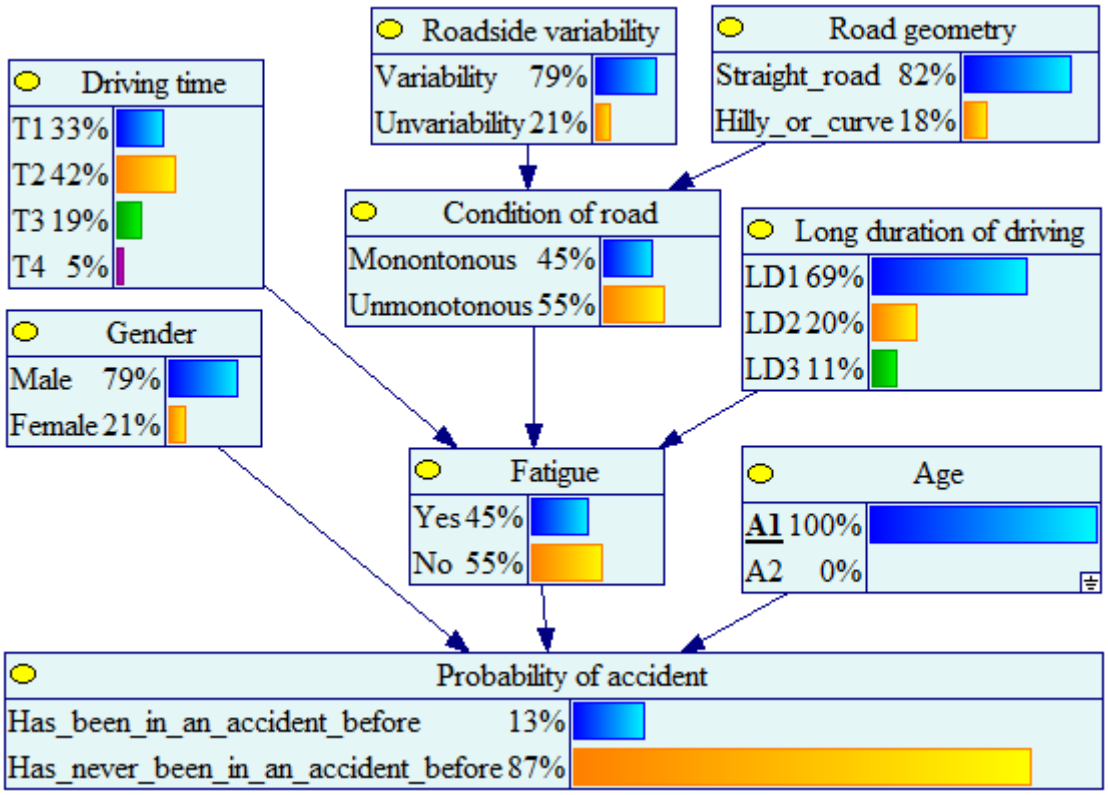

Figure 7. Scenario 2a

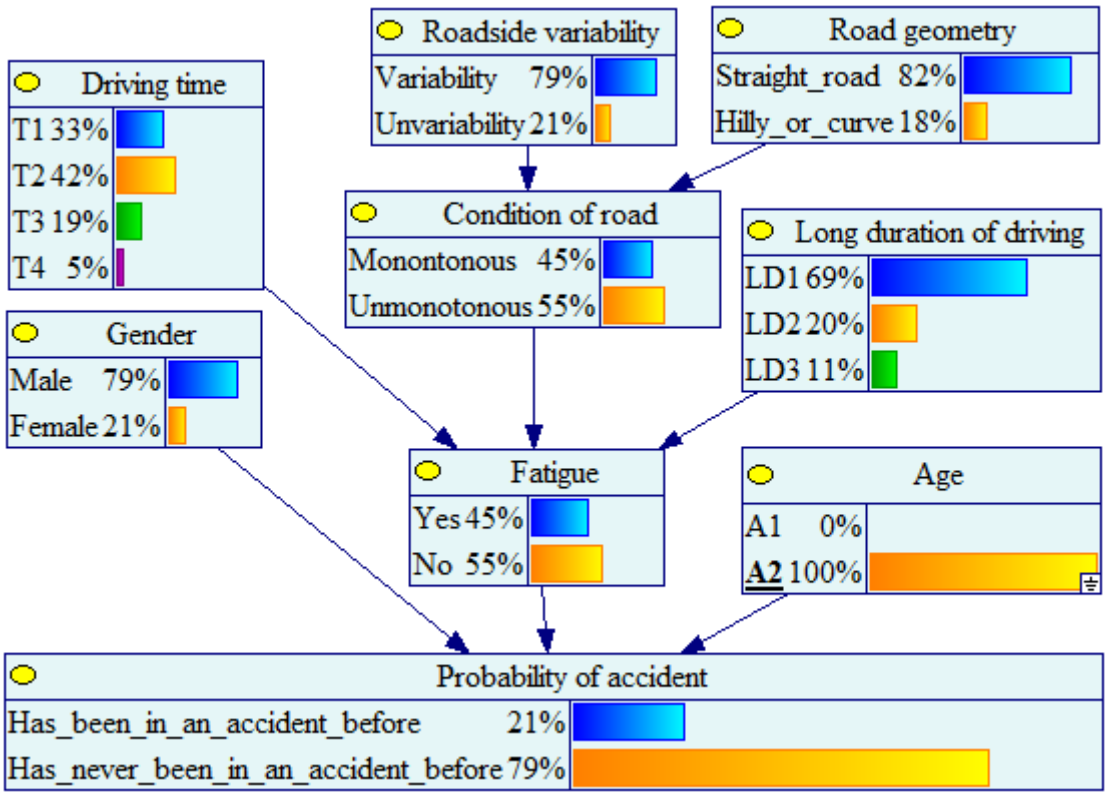

Figure 8. Scenario 2b

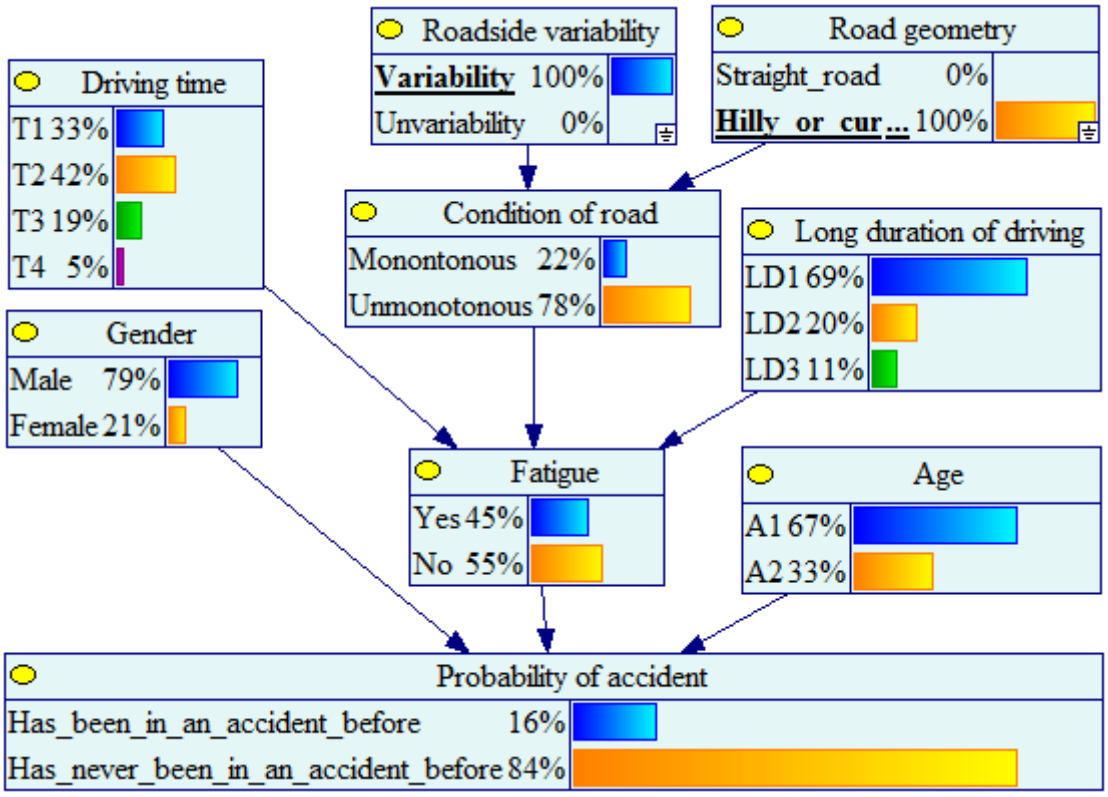

Figure 9. Scenario 3

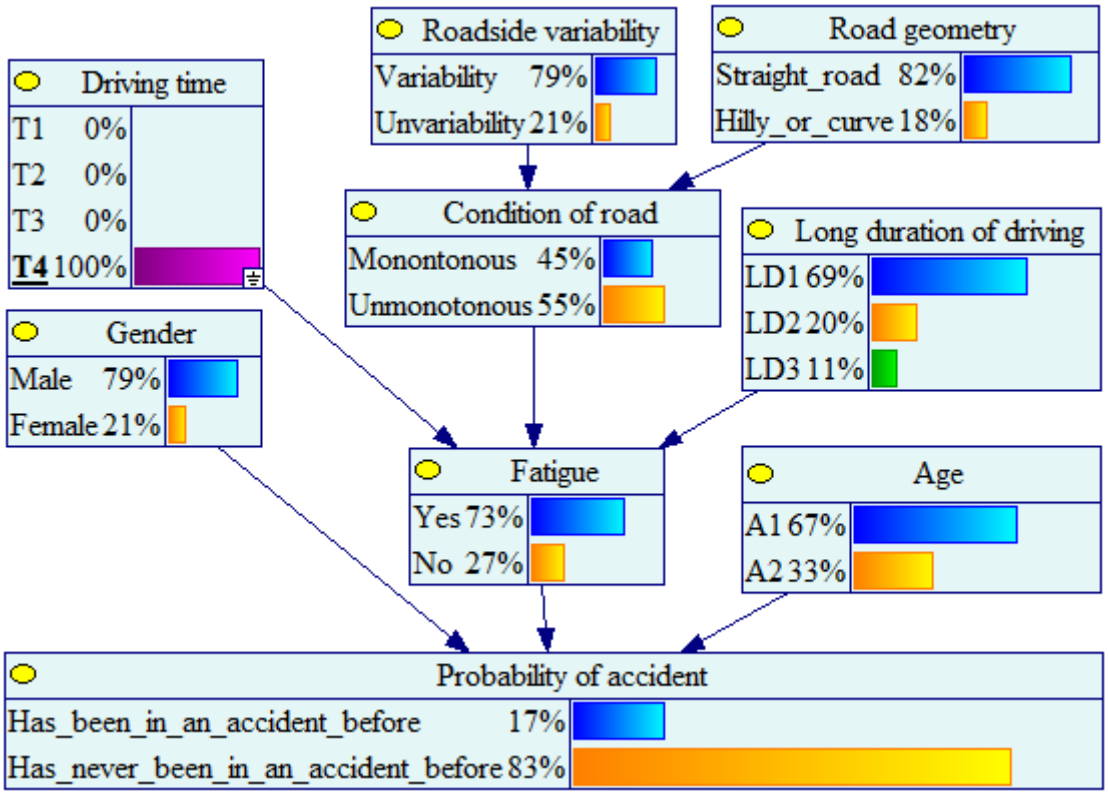

Figure 10. Scenario 4

IV. CONCLUSION

This study included 186 motorcycle riders who had previously been in an accident as well as riders who had never been in an accident. The sample included 147 male drivers and 39 female drivers. Meanwhile, further data from up to 50 respondents was used for validation. According to the findings of the study, a driver who has been in an accident before is 16 percent more likely to have another one, whereas a driver who has never been in an accident before is 84 percent more likely to have another accident. The mean absolute deviation value is 11.16 percent. Furthermore, multiple scenarios were run, with scenario 1 demonstrating that female drivers who have previously been in an accident are more likely to be involved in another accident than male drivers. Meanwhile, scenario 2 demonstrates that drivers above the age of 20 who have previously been in an accident are more likely to be involved in an accident than drivers under the age of 20. Furthermore, scenario 3 demonstrates that drivers who travel on roads with roadside variability and on bends reduce their level of monotony, but it has no effect on their level of fatigue or the probability of an accident. Scenario 4 shows that drivers who drive between 24.00 and 06.00 have a fatigue probability of up to 73 % and a 17 % accident probability.

V. ACKNOWLEDGEMENT

The author would like to express our sincere gratitude to Department of Civil Engineering, Universitas Pasir Pengaraian for its encouragement to publish the results of this study.

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