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STRATEGIES TO REDUCE THE NUMBER OF SEVERELY INJURED VICTIMS IN ADOLESCENT MOTORCYCLE RIDERS

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ABSTRACT: Statistical data in 2021 in Indonesia shows that the number of accident victims reached 103,645 cases. Around 25% of these accident victims were underage drivers. For this reason, efforts must be made to minimize the number of accident victims, especially avoiding severe injuries. The criteria for respondents are motorcycle riders aged 12 - 25 years who are still categorized as adolescent riders. The data collection was carried out by interviewing respondents for approximately 10 minutes. For data analysis, the number of respondents used was 308 respondents. The location for data collection was Riau Province, Indonesia. The data was analyzed by Bayesian network. To get a good model, the basic model was validated. The number of respondents used to validate this model was 107 respondents. The results of the analysis show that the probability of an adolescent driver to experience severe injury is 27% and mild injury is 73%.Scenario 1 shows that poor driving performance will increase the probability of severe injury by 3%.Scenario 2 shows that driver fatigue will increase the probability of severe injury by 3%.Scenario 3 shows that drivers who conduct traffic violations will increase the probability of severe injury by 5%.Scenario 4 shows that drivers who perform long trips(more than 1 hour) increase their fatigue from 28% to 60%, which also increases the probability of severe injury by 1%.Scenario 5 shows that late night driving (between 24:00 – 06:00) not only increases the probability of fatigue but also increases the probability of severe injury by 1%.Strategic steps to reduce severe injury among adolescent motorcyclists include driving with good performance, avoiding fatigue-inducing conditions, abiding by all traffic rules, and avoiding driving between the hours of 24:00-06:00.

ABSTRAK: Data statistik pada tahun 2021 di Indonesia menunjukkan jumlah mangsa kemalangan mencapai 103,645 kes. Kira-kira 25% mangsa kemalangan ini adalah pemandu bawah umur. Oleh itu, usaha perlu dilaksanakan bagi meminimumkan mangsa kemalangan, terutama dalam mengelakkan kecederaan parah. Kriteria responden adalah penunggang motosikal berumur 12 - 25 tahun yang masih dikategori sebagai penunggang remaja. Pengumpulan data dijalankan dengan menemu bual responden selama lebih kurang 10 minit. Analisis data ini melibatkan 308 orang responden. Lokasi pengumpulan data adalah di Riau, Indonesia. Data dianalisis dengan rangkaian Bayesian. Bagi mendapatkan model terbaik, model asas telah disahkan. Bilangan responden yang terlibat dalam mengesahkan model ini adalah seramai 107 orang responden. Dapatan kajian menunjukkan kebarangkalian pemandu remaja yang mengalami kecederaan parah adalah 27% dan cedera ringan sebanyak 73%. Senario 1 menunjukkan pemanduan tidak berhemah akan meningkatkan kebarangkalian cedera parah sebanyak 3%. Senario 2 menunjukkan bahawa memandu dalam keadaan letih akan meningkatkan kebarangkalian cedera parah sebanyak

3%. Senario 3 menunjukkan bahawa pemandu yang melanggar peraturan lalu lintas akan meningkatkan kebarangkalian cedera parah sebanyak 5%. Senario 4 menunjukkan pemandu yang melakukan perjalanan melebihi 1 jam akan meningkatkan keletihan dari 28% kepada 60%, juga menyumbang kepada peningkatan kebarangkalian cedera parah sebanyak 1%. Senario 5 menunjukkan bahawa pemanduan lewat malam (antara 24.00 – 06.00) bukan sahaja meningkatkan kebarangkalian keletihan tetapi juga meningkatkan kebarangkalian cedera parah sebanyak 1%. Langkah strategik bagi mengurangkan kecederaan parah di kalangan penunggang motosikal remaja termasuk: memandu dengan berhemah, tidak memandu dalam keadaan letih, mematuhi segala undang-undang jalan raya dan mengelak dari memandu pada jam 24.00 hingga 06.00.

KEYWORDS: *road trafficaccident; Bayesiannetwork;mildlyinjured;motorcycle rider;severelyinjured*

1. INTRODUCTION

The biggest contributing cause to traffic accidents is the human error factor. The age of the driver influences the driver's behavior when driving [1] and also influences the risk of accident [2]. Motorcycles have high mobility thus they are very popular with young riders. This vehicle is less stable and lacks protection for the driver while driving, resulting in greater risk of accident severity. In general, young drivers have very little experience in driving compared to adult drivers [3] which results in young drivers tending to commit more traffic violations due to mistakes or ignorance of traffic rules [4].This certainly results in young drivers having the potential to experience accidents [5] compared to experienced drivers who tend to drive more effectively [6].Unfortunately, the tendency for young drivers to commit traffic violations is well documented [7-12].Additionally, stress factors caused by work can also influence risky behavior when driving [13,14]. Other researchers state that personality and attitude factors also influence risky behavior when driving[15].In general, young drivers are less stable mentally and emotionally, increasing their risk of accidents [16,17].The accident rate at a young age is quite high compared to adult drivers, however this accident rate rises again for drivers aged 60-69 years [18].In general, young drivers' risks are influenced by road type, visibility conditions, gender [19], and speed [20].

Generally, young riders have better stamina than other age groups, which allows young riders to accept travel routes that quite far and long. Driving too far and for a long time can result in fatigue in the driver during the trip [21].Moreover, if the driver lacks sleep and then travels far, this will increase fatigue [22] and drowsiness that will affect the driver's performance [23,24].This can increase the risk of an accident [25] as well as and increase the level of severity when experiencing an accident [26,27].Besides that, driving time can also affect the level of driver fatigue, thereby increasing the risk of accidents [28] and their severity [29-31].Fatigue can reduce the driver's abilities and can even increase the risk of an accident [25,32,33]and the severity of said accident [34]. Apart from the age factor that influences accidents, another factor is the gender of the driver. There is a tendency for male drivers to be more involved in accidents than female drivers, however female drivers are more likely to be injured during accidents than male drivers [35,36]. Leading research in this area is as shown in Fig. 1.

Accident cases in Indonesia from 2020 to 2021 are likely to increase, as shown in Fig. 2 [37]. In addition, about 25% of accident victims are underage drivers. Ninety two percent of adolescent drivers often experience distractions while driving [38]. Accident statistics in Indonesia show that every 20 minutes, one life is lost on the highway. Other data shows the number of accident victims for drivers aged 10-19 years amounted to 26,906 and drivers aged

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20-29 years amounted to 29,281 [39]. The use of motorcycles is quite high among adolescents, resulting in high accident rates for this age group. In 2021, the number of motorcycles in Indonesia reached 124,042,298 units [37], as shown in Fig. 3.

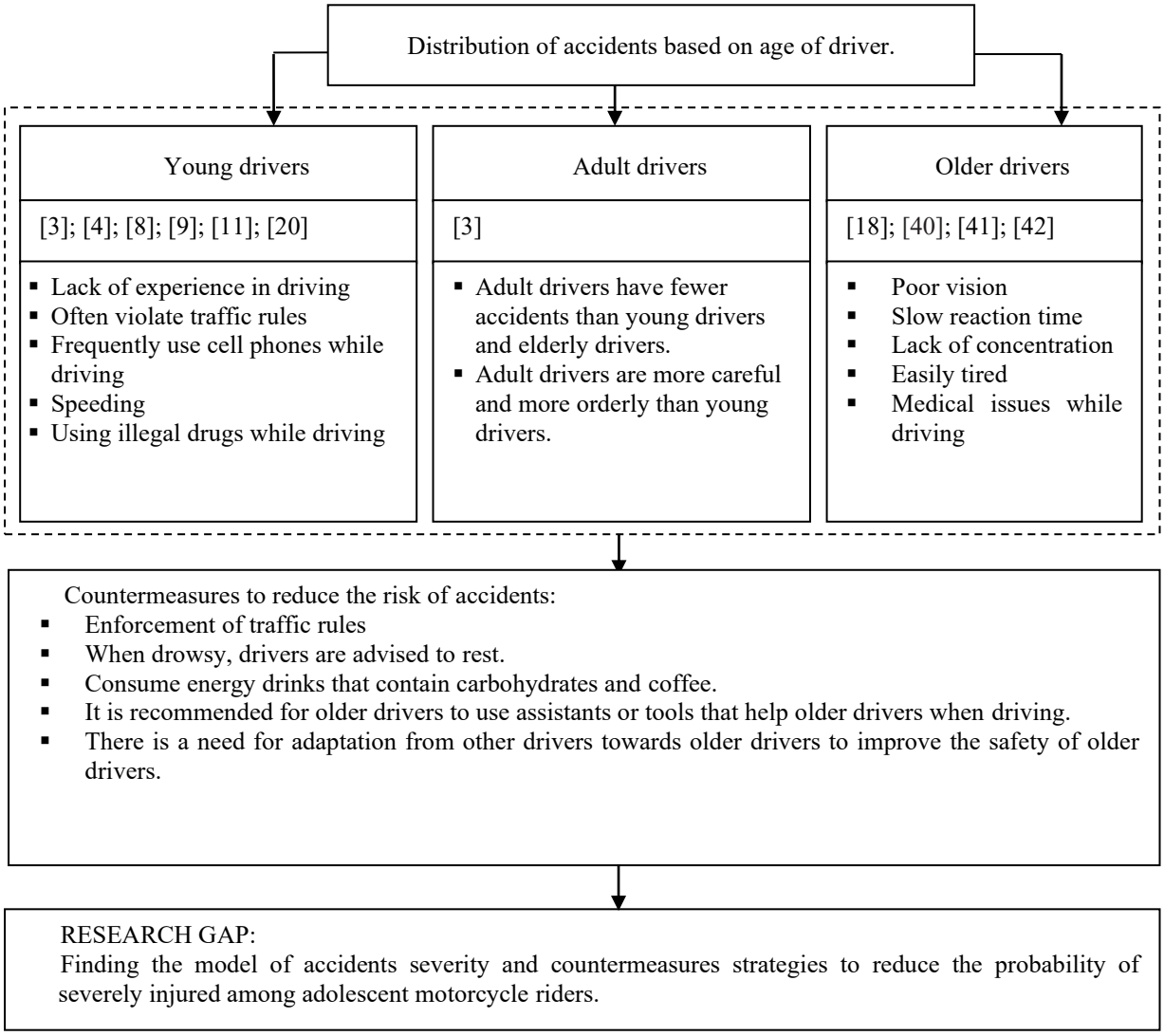

Fig. 1: Category of'drivers' and previous of road accidents in the world.

Thus, it is necessary to conduct the research to reduce the number of severely injured victims in Indonesia, namely by finding the dominant variable that affects the severity of accidents in adolescent motorcycle riders and finding the model and strategies to reduce the risk of severe injury. The research parameters of this study are: 1) respondents are adolescent motorcycle riders aged 12 until 25 years and have had accidents;2) the data was analyzed by Bayesian Network;3) the probability of accident severity in terms of human factor, road and environmental factor and vehicle factor.

2. METHODS

The research was carried out in Riau Province. A total of 415 respondents were used, of which 308 respondents were used for modeling and 107 respondents were used for model validation. The number of samples was calculated by using the equation:

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

Information: n=number of samples, N=population, e=margin of error, The number of accident victims in Riau Province = 2750 people, e value = 5%.

$$349.21 = \frac{2750}{1 + 2750 \text{ x } 0.05^2}$$

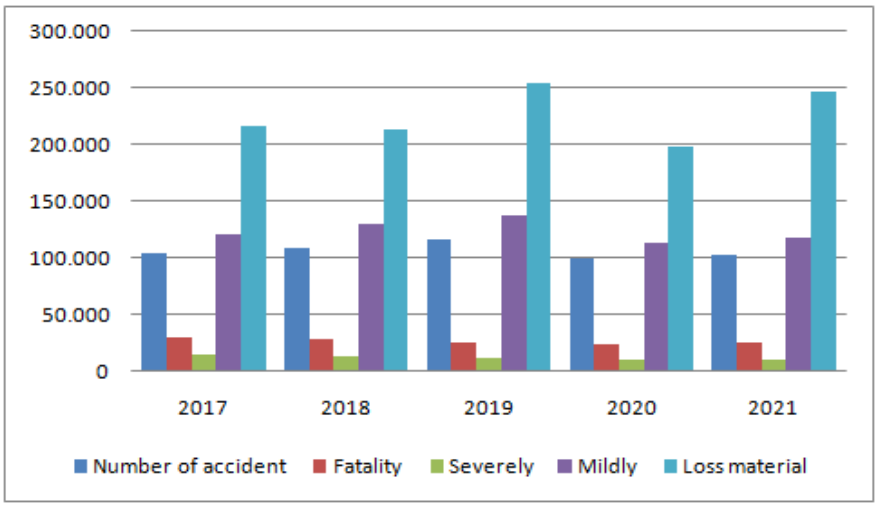

Fig.2: Number of accidents and number of victims of accidents severity in Indonesia [37].

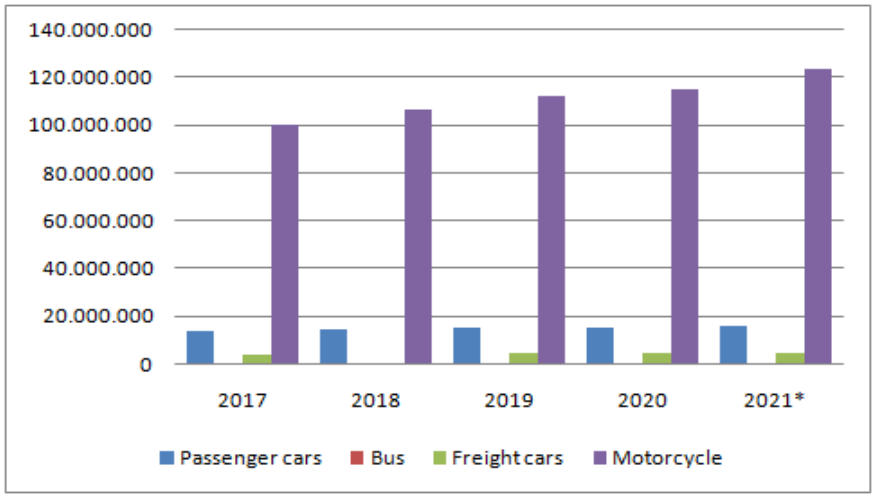

Fig.3: Number of motorcycle vehicles in Indonesia [37].

The number of samples that were used to analyze data and validate the model was 415 respondents.

The criteria for respondents in this study were adolescent motorcycle riders (12 years to 25 years) who had experienced an accident by either hitting another vehicle, being hit by another vehicle, or without the involvement of another vehicle. The data was collected by interviewing adolescent motorcycle riders who had experienced accidents.

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Variables that affect the model included driving behavior, driving fatigue, driving performance, time of accident, driving time before the accident, gender, engine capacity, driving license ownership, monotony while driving, roadside variability at the accident site, and road geometry at the accident scene. Details of variables and questions asked to the respondents are given in Table 1.

Table 1: Variables and statistics

Variable	Value	Percentage
Gender	Male	61
	Female	39
Possession of a Driver's License	Have	15
	Do Not have	85
Rider performance	Good	74
	Not good	26
Risky behavior	Violating	21
	Not violating	79
Fatigue	Yes	28
	No	72
Duration of driving	≤ 30 minutes	67
	30 < DURATION ≤ 60	21
	> 60 minutes	12
Time of the accident occurred	06.00 – 12.00	28
	12.00 – 18.00	49
	18.00 – 24.00	21
	24.00 – 06.00	2
Road geometry	Flat and straight	72
	Curve	28
Roadside variability	Varied	52
	Not varied	48
Road condition	Monotonous	47
	Not monotonous	53
Engine capacity	≤ 125 cc	74
	> 125 cc	26

Data was analyzed with Bayesian network using GeNiE 2.0 software [43]. Bayesian networks originate from Bayes theory, which is an approach used to analyze probabilistic data or data that is uncertain. Bayesian theory is more suitable for predicting accident severity than regression models [44]. The Bayesian network shows the relationship between the probability of event A occurring provided that event B has occurred P(A|B), with the following formula:

$$P(A|B) = \frac{P(B|A)P(A)}{P(B|A)P(A)+P(B|-A)P(-A)} \quad (2)$$

After the data was analyzed, a probability model for accident severity among adolescent motorcycle riders was obtained. The model was validated to know its accuracy. Validation was conducted by calculating the MAD (Mean Absolute Deviation) value with the formula:

$$MAD = 1/2 \sum |Actual - Forecast| \quad (3)$$

The model was considered accurate if the results of the model and the results in the field were not significantly different. If the model was accurate enough, then several scenarios

were carried out in the next step to find strategies to reduce the number of cases of severe injury to motorcyclists. The research flow chart is shown in Fig. 4.

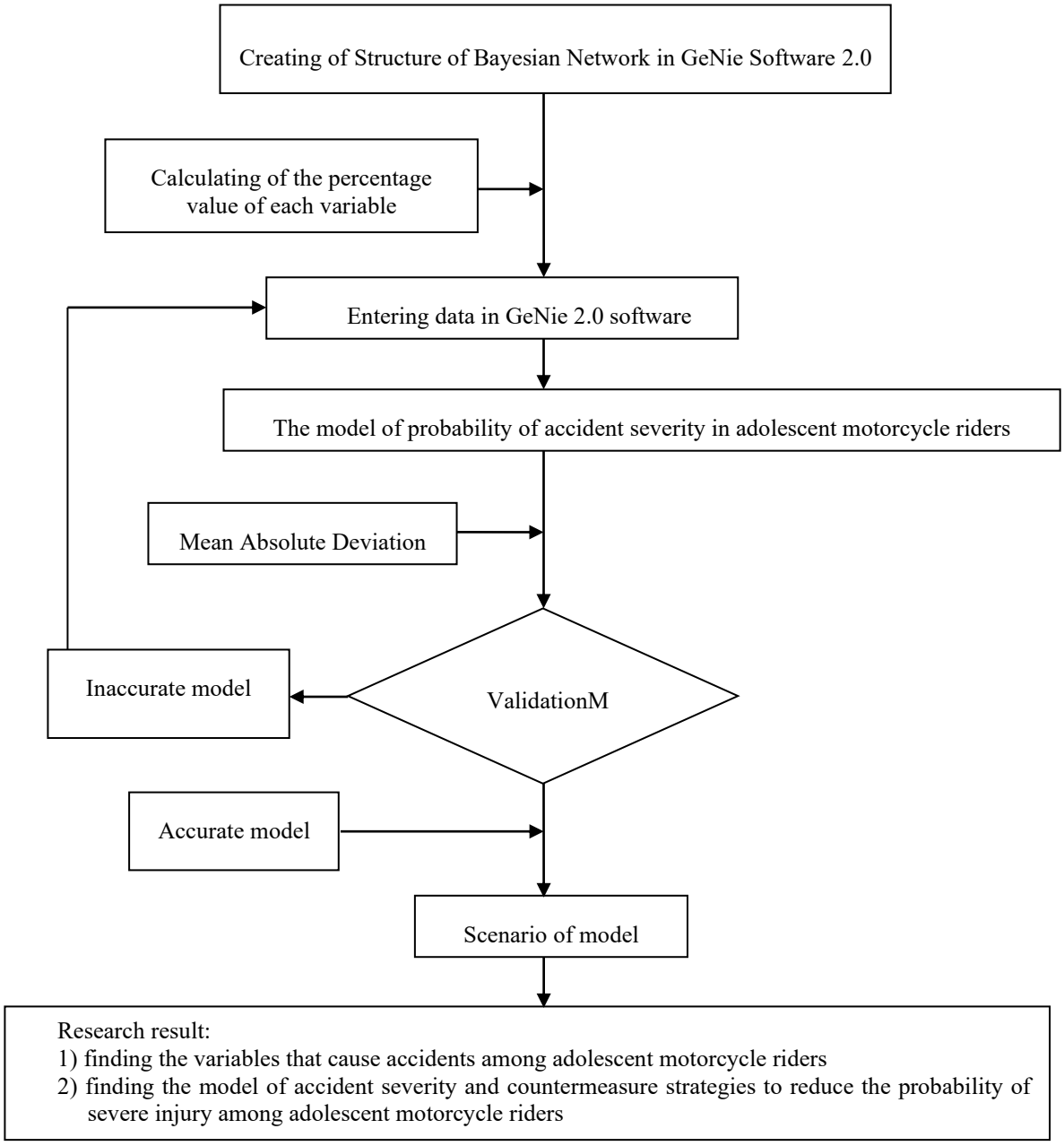

Fig. 4: Flow chart of research.

3. RESULTS AND DISCUSSION

Variables and accident statistics at the study sites are shown in Table 1. Meanwhile, the resulting structure of the Bayesian network model shows that the probability of adolescent drivers who experience severe injury is 27% and mild injury is 73%, as shown in Fig. 5. The root causes of probability of serious injury were quite high among adolescent motorcycle riders namely, risky driving behavior such as speeding, using cell phones while driving, and violating traffic rules. The model equations that were obtained from the structure of Bayesian network above can be seen in Table 2.

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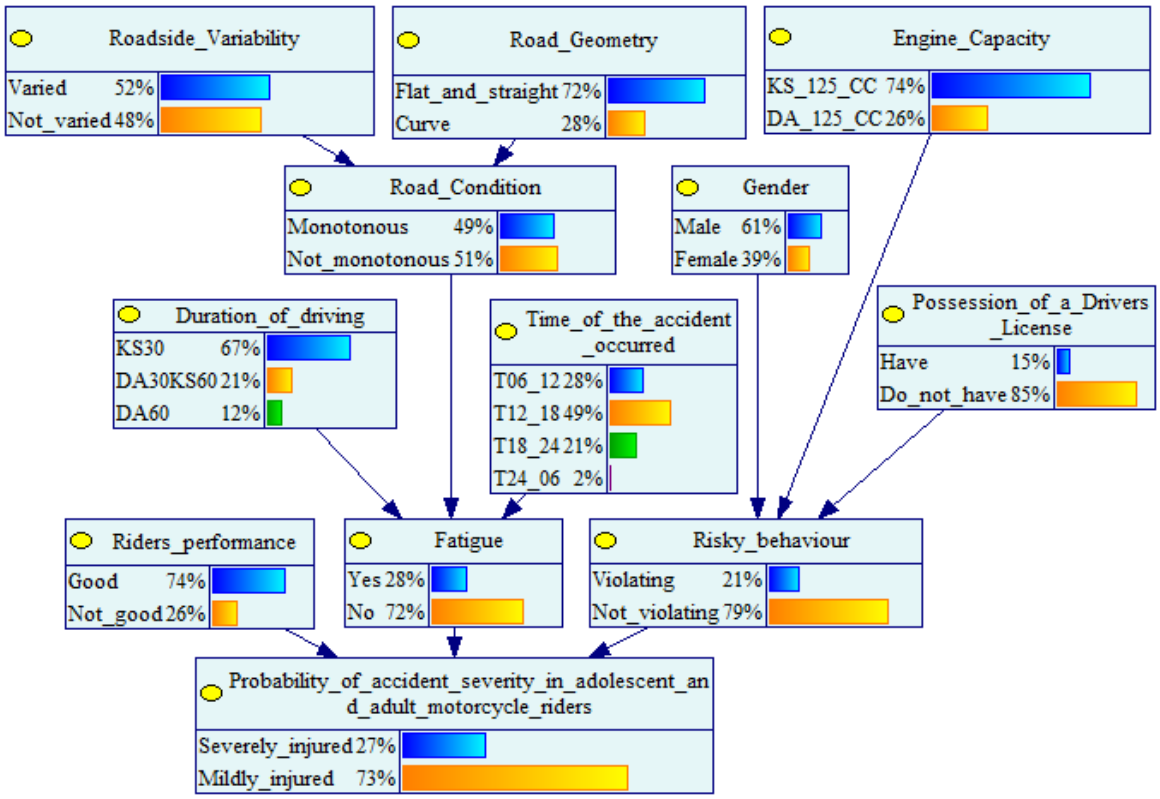

Fig.5: Model of the probability of accidents severity in adolescent riders.

Table 2: Equality model of probabilities of accident severity in adolescent motorcycle riders

P(BS)	P(TS)	P(FS)	P(ACS)
BS1	TS1	FS1	P(ACS)1 = P(ACS|BS1, TS1, FS1, LDS, TMS, LS, MS, GS, RSS, RGS, CS) P(BS1|LS, GS, CS) P(TS1|LDS, MS, TMS) P(MS|RSS, RGS)
BS1	TS1	FS2	P(ACS)2=P(ACS|BS1, TS1, FS2, LDS, TMS, LS, MS, GS, RSS, RGS, CS) P(BS1|LS, GS, CS) P(TS1|LDS, MS, TMS) P(MS|RSS, RGS)
BS1	TS2	FS1	P(ACS)3 = P(ACS|BS1, TS2, FS1, LDS, TMS, LS, MS, GS, RSS, RGS, CS) P(BS1|LS, GS, CS) P(TS2|LDS, MS, TMS) P(MS|RSS, RGS)
BS1	TS2	FS2	P(ACS)4 = P(ACS|BS1, TS2, FS2, LDS, TMS, LS, MS, GS, RSS, RGS, CS) P(BS1|LS, GS, CS) P(TS2|LDS, MS, TMS) P(MS|RSS, RGS)
BS2	TS1	FS1	P(ACS)5 = P(ACS|BS2, TS1, FS1, LDS, TMS, LS, MS, GS, RSS, RGS, CS) P(BS2|LS, GS, CS) P(TS1|LDS, MS, TMS) P(MS|RSS, RGS)
BS2	TS1	FS2	P(ACS)6 = P(ACS|BS2, TS1, FS2, LDS, TMS, LS, MS, GS, RSS, RGS, CS) P(BS2|LS, GS, CS) P(TS1|LDS, MS, TMS) P(MS|RSS, RGS)
BS2	TS2	FS1	P(ACS)7 = P(ACS|BS2, TS2, FS1, LDS, TMS, LS, MS, GS, RSS, RGS, CS) P(BS2|LS, GS, CS) P(TS2|LDS, MS, TMS) P(MS|RSS, RGS)
BS2	TS2	F2	P(ACS)8 = P(ACS|BS2, TS2, FS2, LDS, TMS, LS, MS, GS, RSS, RGS, CS) P(BS2|LS, GS, CS) P(TS2|LDS, MS, TMS) P(MS|RSS, RGS)
			∑ P(ACS)

P=Probability, ACS=Accident Severity, BS=Risky Behavior, BS1=Violating, BS2=Not Violating, TS=Fatigue, TS1=Yes, TS2=No, FS=Rider performance, FS1=Good. FS2=Not good, ACS=Accident, LDS=Long duration of driving, TMS=Time of the accident occurred, LS=Possession of a Driver's License, MS=Road Condition, GS=Gender, RSS=Roadside variability, RGS=Road Geometry, CS=Engine Capacity

The model needed to be validated to be able to move on to the next stage. After validation, the difference between the model results and the actual results (MAD) was 22.93%, as shown in Table 3. This shows that the accuracy of the model is 77.07%.

Furthermore, several scenarios were carried out to obtain strategic treatment to reduce serious injuries. Because rider performance variables, fatigue variables, and risky behavior variables have a direct influence on the severity level when an accident occurs, several scenarios were carried out to see the influence of these three variables on the accident severity. Meanwhile, to see the influence of long driving duration variables and driving time variables on the possibility of increasing fatigue and increasing the accident severity, several scenarios were carried out to determine the magnitude of the influence of these variables on the level of driver fatigue and accident severity.

Table 3: The calculation of mean absolute deviation (MAD)

Risky Behavior	Fatigue	Rider Performance	Probability of Accident Severity in Adolescents		Deviation
			Actual	Model	
BS1	TS1	FS1	25.00	44	19.00
BS1	TS1	FS2	66.67	17	49.67
BS2	TS1	FS1	33.33	23	10.33
BS2	TS2	FS2	14.29	27	12.71
					22.93

Scenario 1 shows the influence of driver performance on accident severity. The results of the analysis show that drivers who drive when their performance is not good will increase the probability of severe injury from 27% to 30%, as shown in Fig.6.Even though the rate of probability increase of serious injury to riders was only 3%, this certainly cannot be ignored because it is closely related to the level of accident severity. This research is in line with research conducted by[26,27].Meanwhile, scenario 2 shows the effect of driver fatigue on the accident severity. The results of the analysis identified that when a driver is in a fatigued condition, the probability of severe injury will increase from 27% to 30%, as shown in Fig. 7. When the rider feels tired, the ability to drive well will decrease, the driver's level of alertness will also decrease, resulting in a very high risk of accidents and high accident severity. This research is in line with research conducted by [26,27]. Scenario 3 shows the effect of traffic violations on the accident severity. The results of the analysis show that drivers who commit traffic violations will be at risk of increasing the probability of severe injury from 27% to 32%, as shown in Fig. 8. This means that the effect of violating traffic rules will increase the probability of severe injury by 5%. This research is in line with research conducted by [4,7-12]. Scenario 4 shows the effect of driving duration on the level of fatigue and the accident severity. The results of the analysis show that driving for only 1 hour increases the probability of fatigue but does not increase the probability of severe injury. However, for trips longer than 1 hour, apart from increasing the probability of fatigue, it also increases the possibility of severe injury from 27% to 28%, as shown in Fig. 9. This means that adolescent motorcycle riders who drive for more than 1 hour are more likely to suffer severe injury than riders who drive for less than 1 hour.

Scenario 5 shows the effect of driving time on the accident severity. Driving in the time periods of 06:00-12:00, 12.00-18.00, 18.00-24.00 only affects the increase in driver fatigue, but driving in the time period of 24.00 - 06.00 not only increases the probability of fatigue but also increases the probability of being severely injured from 27% to 28%, as shown in Fig. 10. This shows that driving in the time period of 24.00 - 06.00 is very risky, the possibility of the riders experiencing fatigue and driving at this time also increases the probability of severe injury. This research is in line with research conducted by [29-31].

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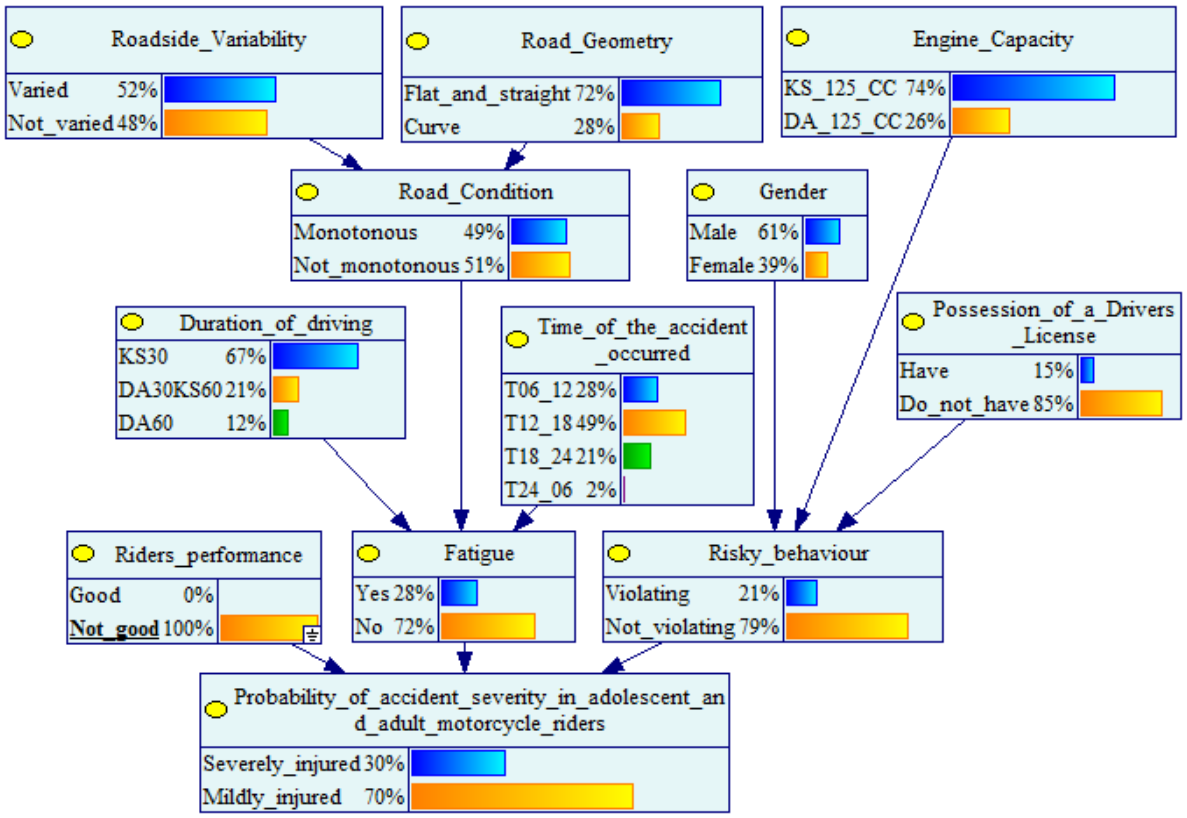

Fig.6: Scenario 1- Influence of driver performance on accident severity.

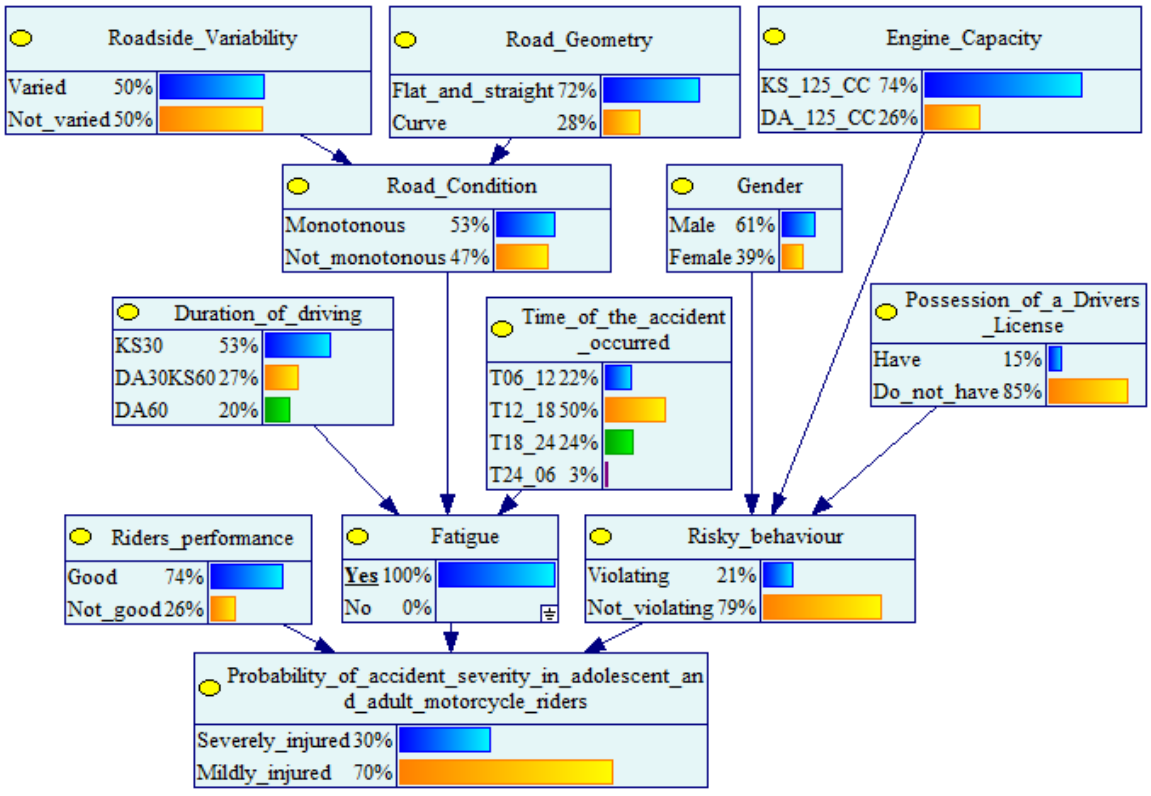

Fig.7: Scenario 2 - Effect of driver fatigue on accident severity.

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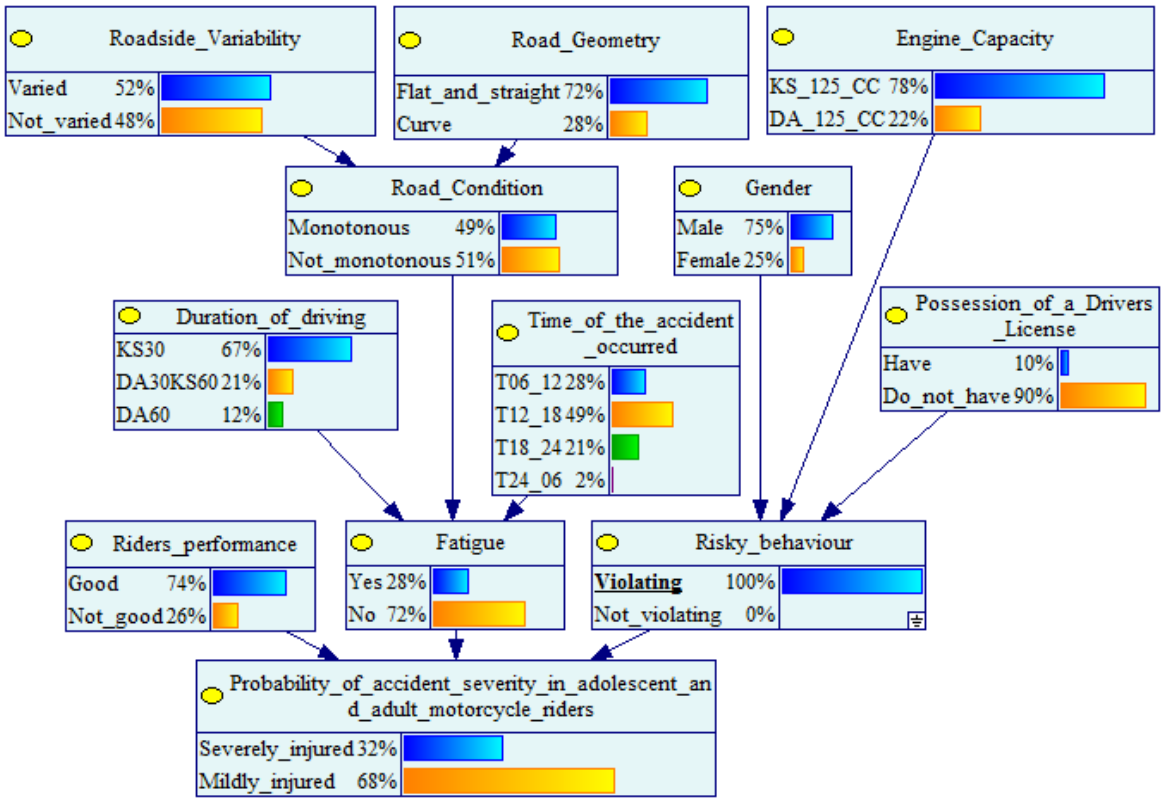

Fig.8: Scenario 3 - Effect of traffic violations on accident severity.

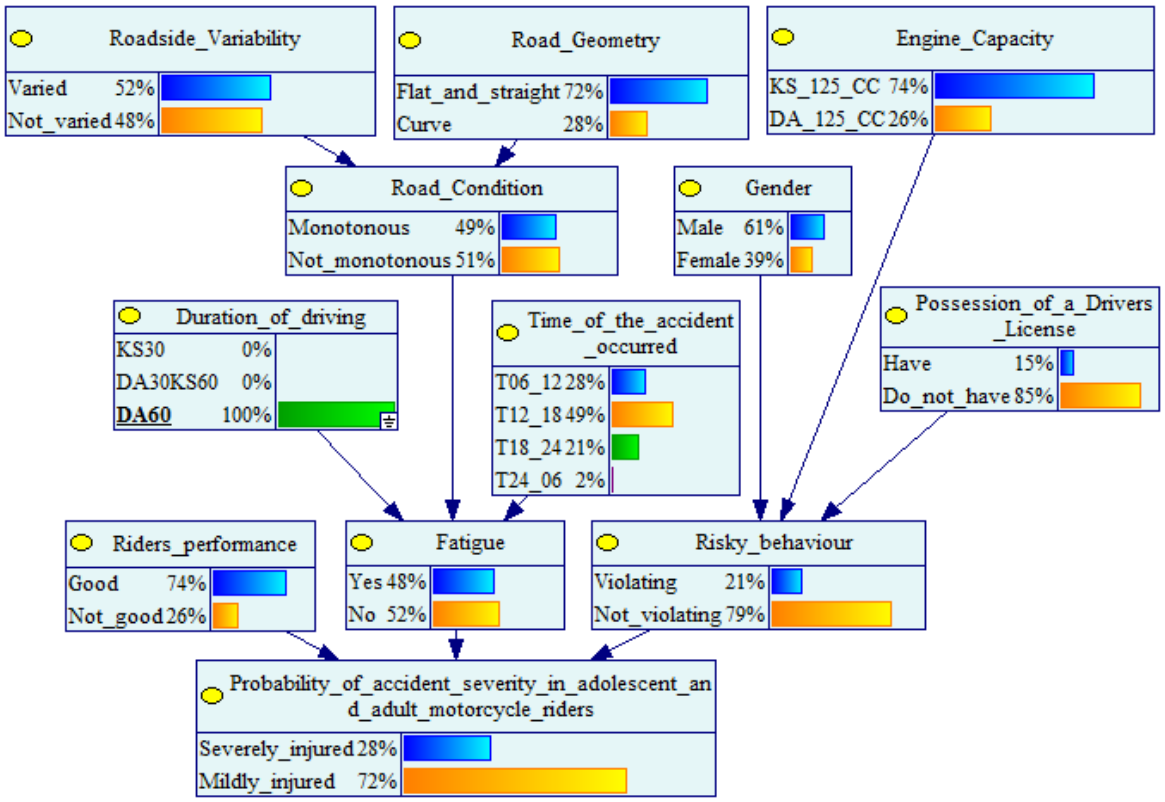

Fig. 9: Scenario 4 - Effect of driving time on fatigue level and accident severity.

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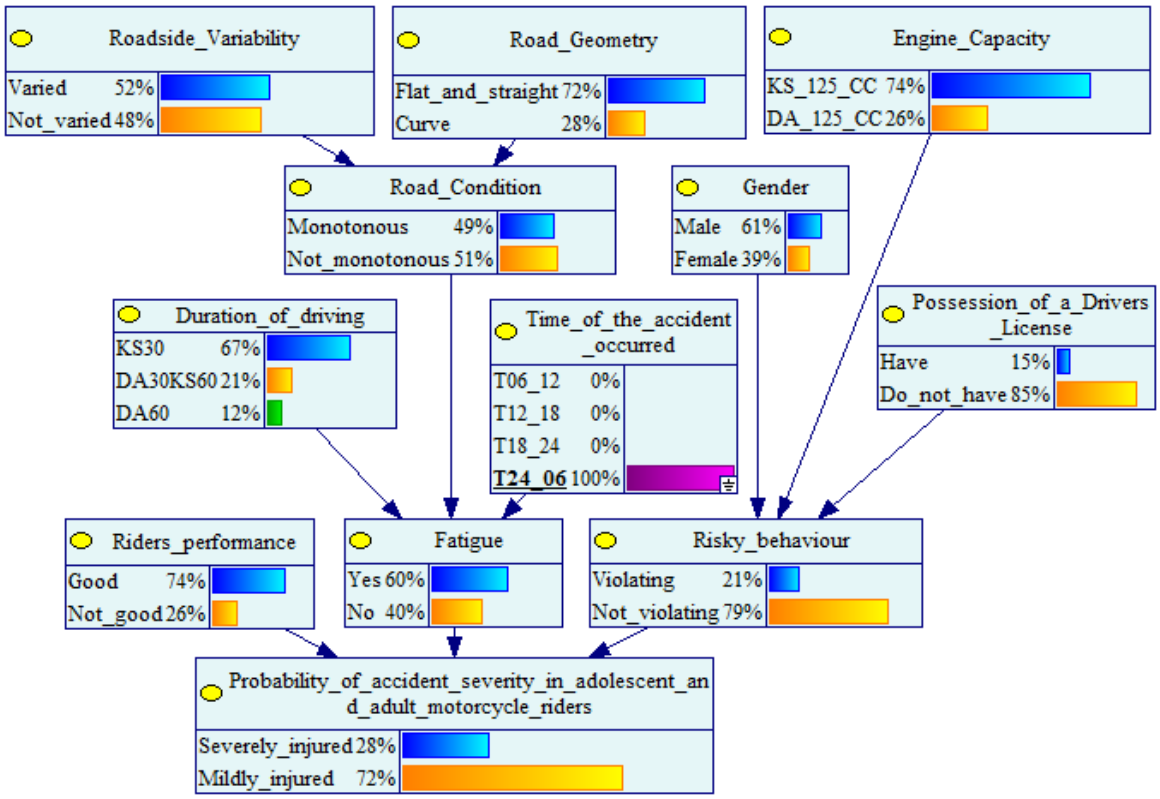

Fig. 10: Scenario 5 - Effect of driving time on accident severity.

Several strategic steps that can be taken to reduce the number of severe injuries include:

1. Adolescent drivers drive in good performance conditions because in this condition the probability of being severely injured decreases from 27% to 26%.
2. Adolescent drivers drive when they are not tired because this condition can reduce the probability of being severely injured from 27% to 26%.
3. The drivers do not violate traffic rules, because this condition can reduce the probability of serious injury from 27% to 26%.
4. Motorcycle riders do not drive during the time period 24.00-06.00, because during this time period the probability of fatigue increases from 28% to 60% and trips made during this period can increase the probability of severe injury by 1%.

5. CONCLUSION

The results of analysis using a Bayesian network show that the probability of adolescent drivers experiencing severe injury is 27% and mild injury is 73%.Scenario 1 shows that driving with poor performance will result in an increase in the probability of severe injury by 3%.Scenario 2 shows that when a driver experiences fatigue, the probability of severe injury will increase by 3%.Scenario 3 shows that traffic violations will increase the probability of severe injury by 5%.Scenario 4 shows that driving for only 1 hour increases the probability of fatigue but it does not increase the probability of severe injury. However, for trips longer than 1 hour, apart from increasing the probability of fatigue, it also increases the possibility of severe injury by 1%.Scenario 5 shows that the time periods of 06:00-12:00, 12:00-18:00, 18:00-24:00 only increase the driver's fatigue factor, but driving in the time period of 24:00–

06:00 not only increases the probability of fatigue but also increases the probability of severely injured by 1%.Several strategic steps that can be taken to reduce severe injury to victims include maintaining good driving performance, driving without being fatigued, not violating traffic rules, and not driving during the 24:00-06:00 time period.

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