PROBABILITY OF SINGLE-VEHICLE ACCIDENTS AMONG ELDERLY MOTORCYCLISTS IN INDONESIA

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ABSTRACT: The number of accidents involving elderly motorcyclists is relatively high compared to other age groups. This is due to various limitations commonly experienced by older riders. This study aims to determine the probability of single-vehicle accidents among elderly motorcyclists in relation to human, road, and environmental factors. A total of 564 respondents participated in the study conducted in Riau Province, Indonesia. Data were collected through interviews with elderly motorcyclists who had previously experienced accidents. The data were analyzed using a Bayesian Network model with GeNIe 2.0 software. The results showed that the probability of single-vehicle accidents among elderly motorcyclists is 59%. Model validation indicated a Mean Absolute Deviation (MAD) of 23%. Male elderly motorcyclists have a 60% likelihood of experiencing single-vehicle accidents (Scenario 1), while female elderly motorcyclists have a 59% likelihood (Scenario 2). Those who ride while fatigued have a 65% probability of a single-vehicle accident (Scenario 3), compared to 57% for those who are not fatigued (Scenario 4). Riding in rainy conditions increases the probability to 70% (Scenario 5), whereas riding in dry conditions reduces it to 55% (Scenario 6). Elderly motorcyclists riding on potholed roads have a 64% chance of accidents (Scenario 7), compared to 57% on roads without potholes (Scenario 8). These findings indicate that elderly riders are highly vulnerable to single-vehicle accidents. Among human factors, fatigue is the most significant variable influencing accident probability. Regarding environmental factors, driving in the rain plays a key role, while riding on potholed roads is the primary influence for road factors. This study highlights the dominant factors contributing to single-vehicle accidents among elderly motorcyclists by integrating human, road, and environmental considerations.

ABSTRAK: Bilangan kemalangan dalam kalangan penunggang motosikal warga emas agak tinggi berbanding kumpulan umur yang lain.Hal ini disebabkan oleh beberapa batasan yang dialami oleh penunggang motosikal warga emas.Tujuan kajian ini adalah untuk menentukan kebarangkalian kemalangan bujang dalam kalangan penunggang motosikal warga emas berkaitan faktor manusia, jalan raya dan persekitaran.Jumlah sampel ialah 563 responden dan lokasi kajian adalah di Wilayah Riau, Indonesia. Pengumpulan data yang pernah dialami oleh penunggang motosikal dengan menggunakan analisis elderata. Rangkaian Bayesian dengan Perisian GeNie 2.0. Keputusan menunjukkan kebarangkalian kemalangan bujang dalam kalangan penunggang motosikal warga emas ialah 59%.Hasil pengesahan model menunjukkan nilai MAD sebanyak 23%. Penunggang motosikal warga emas lelaki berkemungkinan mengalami kemalangan bujang sebanyak 60% (senario 1), penunggang motosikal warga emas wanita sebanyak 59% (senario 2). Penunggang motosikal warga emas yang memandu semasa keletihan berkemungkinan mengalami satu kemalangan sebanyak

65% (senario 3), dalam keadaan tidak letih 57% (senario 4 yang memandu dalam keadaan hujan yang berkemungkinan besar dalam keadaan hujan). 70% (senario 5), dalam keadaan tidak hujan 55% (senario 6). Penunggang motosikal warga emas yang memandu di jalan berlubang berkemungkinan akan mengalami satu kemalangan sebanyak 64% (senario 7), di jalan tanpa jalan berlubang 57% (senario 8). Bermakna pemandu warga emas sangat terdedah untuk mengalami kemalangan bujang. Pembolehubah yang paling mempengaruhi kemungkinan pemandu warga emas mengalami kemalangan bujang ialah keletihan dari segi faktor manusia. Bagi faktor persekitaran, pembolehubah yang mempengaruhi pemandu warga emas yang mengalami kemalangan bujang ialah memandu dalam hujan. Bagi faktor jalan raya, pembolehubah yang mempengaruhi kemalangan tunggal ialah memandu di jalan berlubang. Dapatan kajian ini mendapat faktor dominan yang menyebabkan kemalangan bujang pada pemandu warga emas dengan mengambil kira faktor manusia, jalan raya dan persekitaran.

KEYWORDS:Accident, Bayesian, Elderly, Motorcyclists, Rider.

1. INTRODUCTION

One of the characteristics of drivers that influences driving behavior is age [1-3]. As drivers age, their driving abilities and skills tend to decline, especially among older individuals. Young drivers generally have better physical and cognitive functions than adults and elderly drivers. However, with increasing age, there is a decline in both physical and cognitive functions. Elderly drivers may experience several limitations, including impaired vision, reduced hearing, difficulty concentrating, and trouble remembering routes and traffic signs. These limitations can significantly impair an elderly driver's ability to respond quickly to sudden warnings or dangers. The decline in driving ability among older drivers is caused by several factors, including reduced visual clarity, decreased concentration, lower stamina or increased fatigue [4], slower response times [5], difficulty understanding vehicle technology [6–9], and medical conditions that may affect driving performance [1,10,11].

Poor vision can make it difficult for elderly drivers to understand traffic in front of or around them. In such conditions, they may be unable to make quick and accurate decisions, such as whether to brake, swerve, or continue driving, significantly increasing the risk of an accident. A lack of concentration while driving also heightens this risk, as elderly drivers may take longer to respond to sudden warnings or dangers. Additionally, elderly drivers generally have lower stamina than younger drivers, particularly teenagers. As a result, they tire more quickly, leading to a decline in driving performance and an increased likelihood of accidents. Another challenge elderly drivers face is difficulty understanding modern vehicle technology, especially when operating newer models. Their inability to use current technology effectively can prevent them from operating the vehicle optimally, raising the risk of accidents. Limited vision while driving can prevent drivers from correctly understanding their surroundings, leading to misidentification of potential hazards and inappropriate responses. These conditions can increase the risk of accidents. Limited visibility while driving is one of the causes of accidents because drivers may not fully understand the situation in front of or around them, leading to misidentification of problems and inappropriate responses.

Reduced concentration while driving can lower a driver's level of alertness, making it harder to detect nearby dangers. This often leads to inaccurate decision-making, which can, in turn, cause accidents. Older drivers are also more prone to fatigue, which slows their ability to respond to sudden hazards. This condition increases the likelihood of accidents [12] and can also worsen their severity [13]. Driver fatigue is influenced by several factors, including a

heavy workload before driving, lack of sleep the night before [14], extended driving durations [15], and the time of day driving occurs [16]. Sleep deprivation contributes to fatigue [14], which negatively impacts driver performance [17, 18], ultimately increasing the risk of accidents. Additionally, when drivers are not fully concentrated, their level of alertness decreases, making it more difficult for them to detect potential dangers around them. As a result, their decisions may be inaccurate, increasing the risk of accidents. Furthermore, older drivers tend to experience fatigue more quickly, slowing their response to hazards and raising the risk of accidents [12]. Fatigue can also contribute to the severity of accidents [13]. Driver fatigue may be caused by several factors, including a heavy workload before driving, a lack of sleep the night before [14], extended periods of driving [15], and the time of day the driving occurs [16]. In particular, a lack of sleep can lead to fatigue [14], which negatively affects driver performance [17, 18] and increases the likelihood of accidents.

All of the above factors are important when driving, especially in preventing the risk of accidents. Another significant factor influencing the risk of accidents among elderly drivers is the driver's gender. Male drivers over 80 and female drivers over 70 are more likely to be involved in single-vehicle accidents [19]. Research also indicates that elderly male drivers have a higher probability of fatal single-vehicle accidents [20]. In 2020, the number of accident victims by age group was as follows: 26,906 for ages 10-19, 29,281 for ages 20-29, 18,553 for ages 30-39, 17,980 for ages 40-49, and 31,740 for those aged 50 and above. The number of accident victims aged 50 and older exceeds that of younger drivers. Furthermore, drivers who complete courses before the age of 75 have a lower risk of accidents [21]. Other studies also suggest that elderly drivers benefit more from understanding their physical and cognitive limitations than merely memorizing traffic laws [22]. This highlights the importance of self-awareness in older drivers over knowing highway regulations.

In addition to human factors, road conditions also impact the driving abilities of elderly drivers, including driving on straight roads, curves [8], intersections [23], and roads with slight roadside variation [24]. Driving on long, straight roads often requires minimal actions, such as braking or accelerating, while drivers maintain a constant speed. This can lead to increased fatigue and drowsiness, reducing driver alertness. Similarly, roads with monotonous surroundings, such as stretches bordered only by rice fields, can cause boredom and decreased focus. Elderly drivers tend to respond more slowly at intersections, which can reduce traffic flow capacity. While long straight roads may induce sleepiness and increase accident risk, drivers usually stay more alert on curves because they must carefully monitor road and traffic conditions [14, 24]. Poorly visible potholes, especially at night, can cause drivers to lose vehicle control and lead to single-vehicle accidents. Rain also limits visibility, making driving especially dangerous for elderly drivers.

In addition to the factors mentioned above, vehicle-related factors also influence the driving behavior of elderly drivers. These include incompatibility between the driver's body posture and the vehicle, limited understanding of in-vehicle technology, weather conditions, and poor or inadequate vehicle lighting. A car that does not suit the driver's posture can cause discomfort while driving, affecting the driver's behavior, especially during maneuvers. Furthermore, limited ability to understand and operate modern vehicle technology can make it difficult for elderly drivers to control the vehicle, potentially endangering their safety.

Statistical data from 2020 in Indonesia indicate that the accident rate is high among young drivers. As drivers age, the accident rate decreases significantly; however, it rises again in older age groups [25–27]. In that year, the number of traffic accident victims aged 10–19 was 26,906, those aged 20–29 reached 29,281, followed by 18,553 victims aged 30–39, and 17,980 aged 40–49. Surprisingly, the number of victims aged 50 and above was the highest at 31,740. This

indicates that elderly drivers are involved in more accidents than both adolescents and middle-aged adults. In Indonesia, motorcycles are popular not only among young drivers but also among middle-aged and elderly riders. A survey conducted in 2024 among motorcyclists revealed that those who had been involved in accidents and showed low levels of alertness included 355 elderly riders (aged 46 to 65), 270 adult riders (aged 26 to 45), and 235 young riders (aged 12 to 25). In 2022, the number of motorcycles in Indonesia reached 125,305,332 units [28], and currently, the highest number of traffic accidents involves motorcycle riders. To reduce the risk of accidents among elderly drivers, further research is needed to determine the probability of single-vehicle accidents involving elderly motorcyclists, particularly in terms of human, road, and environmental factors. To date, no regulations in Indonesia set a maximum age limit for motorcycle riders. Additionally, existing studies have rarely addressed this issue. When discussed, researchers tend to recommend that older drivers use assistive tools or rely on support while riding, or that other road users adapt to older drivers to enhance safety [29].

2. METHODS

The research location is in Riau Province, Indonesia. The reason for choosing this location is that the number of motorcycles in Riau Province is relatively high, with a total of 3,485,246 units. Riau is among the top 10 provinces in Indonesia with the highest number of motorcycles. According to police data from 2022, the number of road accident victims in Riau Province was 2,750 people, consisting of 651 fatalities, 357 people seriously injured, and 1,742 people with minor injuries [30]. This study involved 564 respondents: 425 respondents were used to analyze the accident probability model for elderly motorcycle riders, and 139 respondents were used to validate the model. The respondents' criteria included elderly riders aged 46 to 65 years who had experienced a motorcycle accident while riding. Respondents were selected randomly by asking candidates whether they had ever been involved in a motorcycle accident as a driver. If the candidate answered "no," the questioning was discontinued; if the candidate answered "yes," the questionnaire was completed in full. To develop this model, data were analyzed using Bayesian Network analysis with GeNie 2.0 software [31]. Since the data are probabilistic (uncertain), probabilistic analysis was carried out using GeNie 2.0 software, which is well-suited for this analysis. The author also conducted manual calculations, and the results were consistent with those produced by GeNie 2.0. However, manual calculations are slower and less efficient. Therefore, the author concluded that using GeNie 2.0 software is more effective for building the model. The formula used in this Bayesian Network analysis is shown in Eq. (1).

$$P(A|B) = \frac{P(B|A)P(A)}{P(B|A)P(A)+P(B|-A)P(-A)} \tag{1}$$

Figure 1 and Figure 2 are examples of Bayesian Network structures. The Bayesian Network analysis in Figure 1 (which includes 3 variables) can be calculated using the following Eq. (2), where P is the probability.

$$P(Y) = P(Y|AX, BX) \times P(AX)P(BX) + P(Y|AX, -BX) \times P(AX)P(-BX) + \\ P(Y|-AX, BX) \times P(-AX)P(BX) + P(Y|-AX, -BX) \times P(-AX)P(-BX) \tag{2}$$
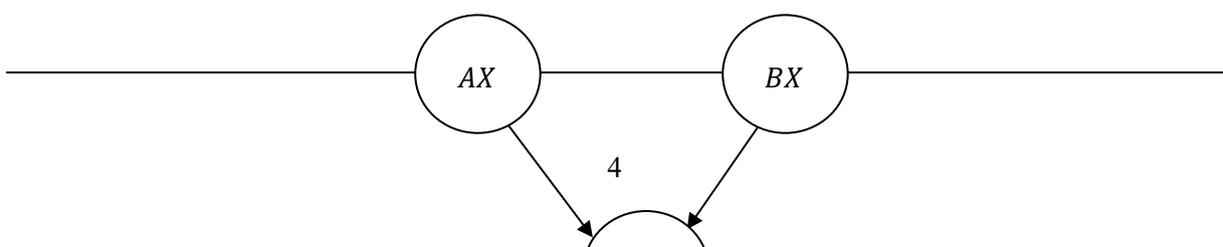
Figure 1. Example of Bayesian Network analysis with 3 variables.

The Bayesian Network analysis in Figure 2 (with 4 variables) can be calculated using the following Eq. (3):

$$P(Y) = P(Y|BX, CX, AX)P(BX|AX) \times P(CX|AX) + P(Y|BX, -CX, AX) \times P(-BX|AX) \times P(-CX|AX) + P(Y| -BX, -CX, AX) \times P(-BX|AX) \times P(CX|AX) + P(Y| -BX, -CX, AX) \times P(-BX|AX) \times P(-CX|AX) \tag{3}$$
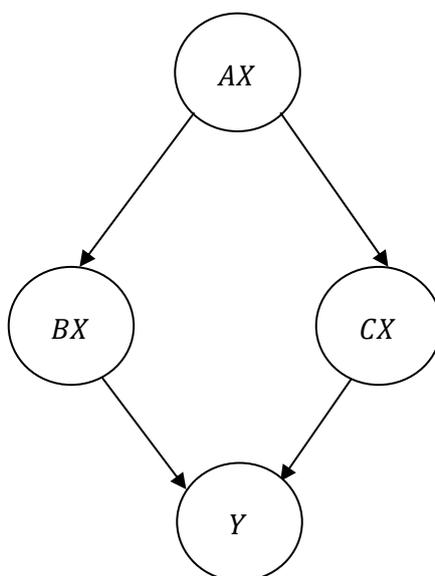

Figure 2. Example of analysis of a Bayesian network with 4variables.

Furthermore, to determine the accuracy of this model, it is first validated by calculating the Mean Absolute Deviation (MAD), which represents the average difference between the model's results and actual field conditions. The calculation utilizesEq. (4).

$$MAD = \frac{1}{N}\sum|Actual - Forecast| \tag{4}$$

The data used for model analysis and validation are not the same. For model validation, comparative data is used to determine the accuracy of the obtained model. The Mean Absolute Deviation (MAD) value is calculated to assess this accuracy, representing the average difference between the model's predicted values and the actual conditions in the field. The closer the MAD value is to zero, the more accurate the model. Suppose the model results closely match the field conditions. In that case, several scenarios are carried out, including: 1) Scenarios 1 and 2: the probability of a single-vehicle accident for elderly drivers based on the driver's gender; 2) Scenarios 3 and 4: the probability of a single-vehicle accident for elderly drivers based on the driver's stamina condition; 3) Scenarios 5 and 6: the probability of a single-

vehicle accident for elderly drivers based on weather conditions; 4) Scenarios 7 and 8: the probability of a single-vehicle accident for elderly drivers based on road surface conditions. These scenarios were selected to examine the dominant influence of each variable that directly affects the probability of a single-vehicle accident, including the driver's gender (male and female drivers), the fatigue variable (fatigued and not fatigued), and the weather variable (driving in rainy and non-rainy conditions). The road surface condition variable (potholed and not potholed). These four variables influence the probability of a single-vehicle accident.

3. RESULTS AND DISCUSSION

The survey results show that 29% of elderly motorcyclists who had accidents had a sleep duration of 6 hours or less the night before the accident. Meanwhile, 27% of elderly motorcyclists experienced fatigue before the accident. Most elderly motorcyclists experienced accidents during short trips lasting 30 minutes or less. Furthermore, most of these accidents occurred between 12:00 and 18:00. Among elderly drivers who had accidents, 52% were male and 48% were female. The data also revealed that 59% of accidents occurred on flat, straight roads. Moreover, 38% of elderly drivers involved in accidents were driving under monotonous conditions, and 34% of the accidents happened on roads with potholes.
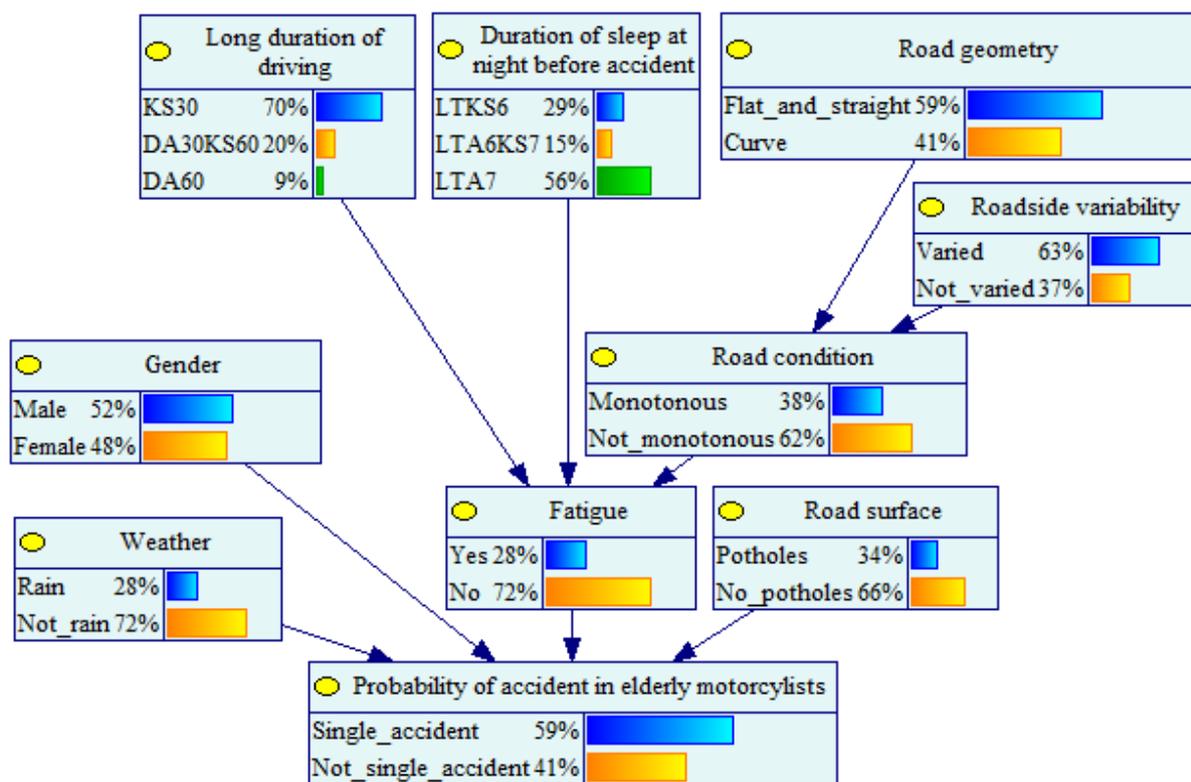

Figure 3. Structure model of the Bayesian Network showing the probability of a single-vehicle accident in elderly drivers.

Annotation:

- KS30 = Duration of driving for 30 minutes or less
- A30KS60 = Duration of driving for more than 30 minutes up to 60 minutes
- A60 = Duration of driving for more than 60 minutes
- LTKS6 = Sleep duration on the night before the accident of approximately 6 hours or less

- LTA6KS7 = Sleep duration on the night before the accident of more than 6 hours up to 7 hours
- LTA7 = Sleep duration on the night before the accident of more than 7 hours

The results of the Bayesian Network analysis, conducted using GeNie 2.0 software, show that the probability of elderly motorcyclists experiencing a single-vehicle accident is 59%. In comparison, the likelihood of a non-single-vehicle accident is 41%. This indicates a high probability that elderly drivers will experience a single-vehicle accident. This is attributed to the increasing age of the driver, which results in a decrease in driving ability due to both physical and non-physical limitations, including limited vision, reduced stamina, decreased ability to concentrate, lack of familiarity with vehicle technology, and health problems, as shown in Figure 3. This study is consistent with research conducted by [1,4-11]. The equality model of the probability of a single-vehicle accident is shown in Table 1.

Table 1: Equality Model for the Probability of a Single-Vehicle Accident

P	G	E	W	RS	P(AC)
1	G1	E1	W1	RS1	P(AC)1=P(AC|G1,E1,W1,RS1,LD,DS,RG,RD,RC) P(E1|LD,DS) P(RC|RG,RV)
2	G1	E1	W1	RS2	P(AC)2=P(AC|G1,E1,W1,RS2,LD,DS,RG,RD,RC) P(E1|LD,DS) P(RC|RG,RV)
3	G1	E1	W2	RS1	P(AC)3=P(AC|G1,E1,W2,RS1,LD,DS,RG,RD,RC) P(E1|LD,DS) P(RC|RG,RV)
4	G1	E1	W2	RS2	P(AC)4=P(AC|G1,E1,W2,RS2,LD,DS,RG,RD,RC) P(E1|LD,DS) P(RC|RG,RV)
5	G1	E2	W1	RS1	P(AC)5=P(AC|G1,E2,W1,RS1,LD,DS,RG,RD,RC) P(E1|LD,DS) P(RC|RG,RV)
6	G1	E2	W1	RS2	P(AC)6=P(AC|G1,E2,W1,RS2,LD,DS,RG,RD,RC) P(E2|LD,DS) P(RC|RG,RV)
7	G1	E2	W2	RS1	P(AC)7=P(AC|G1,E2,W2,RS1,LD,DS,RG,RD,RC) P(E2|LD,DS) P(RC|RG,RV)
8	G1	E2	W2	RS2	P(AC)8=P(AC|G1,E2,W2,RS2,LD,DS,RG,RD,RC) P(E2|LD,DS) P(RC|RG,RV)
9	G2	E1	W1	RS1	P(AC)9=P(AC|G2,E1,W1,RS1,LD,DS,RG,RD,RC) P(E1|LD,DS) P(RC|RG,RV)
10	G2	E1	W1	RS2	P(AC)10=P(AC|G2,E1,W1,RS2,LD,DS,RG,RD,RC) P(E1|LD,DS) P(RC|RG,RV)
11	G2	E1	W2	RS1	P(AC)11=P(AC|G2,E1,W2,RS1,LD,DS,RG,RD,RC) P(E1|LD,DS) P(RC|RG,RV)
12	G2	E1	W2	RS2	P(AC)12=P(AC|G2,E1,W2,RS2,LD,DS,RG,RD,RC) P(E2|LD,DS) P(RC|RG,RV)
13	G2	E2	W1	RS1	P(AC)13=P(AC|G2,E2,W1,RS1,LD,DS,RG,RD,RC) P(E2|LD,DS) P(RC|RG,RV)
14	G2	E2	W1	RS2	P(AC)14=P(AC|G2,E2,W1,RS2,LD,DS,RG,RD,RC) P(E2|LD,DS) P(RC|RG,RV)
15	G2	E2	W2	RS1	P(AC)15=P(AC|G2,E2,W2,RS1,LD,DS,RG,RD,RC) P(E2|LD,DS) P(RC|RG,RV)
16	G2	E2	W2	RS2	P(AC)16=P(AC|G2,E2,W2,RS2,LD,DS,RG,RD,RC) P(E2|LD,DS) P(RC|RG,RV)
					$\sum$ P(AC)

Annotation: P=Probability, G=Gender, G1=Male, G2=Female, E=Fatigue, E1=Yes, E2=No, W=Weather, W1=Rain, W2=Not rain, RS=Road surface, RS1=Potholes, RS2=Without potholes.

Furthermore, to determine the accuracy of the obtained model, the next step is to validate it. The validation results show that the MAD value, which is the average difference between the model results and real-world conditions, is 23%, as shown in Table 2. This means that the

model has an accuracy of 77%. Since the level of model accuracy is relatively high, several scenarios can be created from the basic model to identify the dominant variables that influence the risk of single-vehicle accidents.

Table 2: Calculation of the MAD value

P	G	E	W	RS	Probability		Difference (%)
					Actual	Model	
1	G1	E1	W1	RS1	90,00	75,00	15,00
2	G1	E1	W1	RS2	66,67	83,00	16,33
3	G1	E1	W2	RS1	66,67	50,00	14,29
4	G1	E1	W2	RS2	40,91	53,00	13,87
5	G1	E2	W1	RS1	100,00	75,00	0,00
6	G1	E2	W1	RS2	85,71	58,00	25,33
7	G1	E2	W2	RS1	63,64	69,00	7,46
8	G1	E2	W2	RS2	34,21	54,00	20,67
9	G2	E1	W1	RS1	100,00	80,00	20,00
10	G2	E1	W1	RS2	0,00	100,00	100,00
11	G2	E1	W2	RS1	80,00	73,00	14,50
12	G2	E1	W2	RS2	37,50	56,00	13,14
13	G2	E2	W1	RS1	66,67	53,00	47,00
15	G2	E2	W2	RS1	40,00	57,00	23,67
16	G2	E2	W2	RS2	25,00	47,00	13,67
							23,00

Scenario 1 shows that elderly male motorcyclists have a 60% likelihood of experiencing a single-vehicle accident, as shown in Figure 4. In contrast, Scenario 2 shows that elderly female motorcyclists have a 59% likelihood of experiencing a single-vehicle accident, as shown in Figure 5. Male drivers tend to be more aggressive than female drivers. In addition, male drivers are more likely to underestimate road risks than female drivers. This means that the probability of a single-vehicle accident for elderly male and elderly female motorcyclists is almost the same and relatively high. This finding aligns with studies conducted by [19, 20].

Scenario 3 shows that elderly riders who drive while fatigued have a 65% likelihood of experiencing a single-vehicle accident, as shown in Figure 6. Meanwhile, Scenario 4 indicates that elderly riders who ride while not fatigued have a 57% likelihood of experiencing a single-vehicle accident, as shown in Figure 7. This suggests that the probability of a single-vehicle accident is higher for elderly motorcyclists who are fatigued than those who are not. However, the likelihood of a single-vehicle accident in both fatigued and non-fatigued conditions is above 50%. This suggests that elderly motorcyclists generally have poor stamina due to declining physical function. One of the limitations of elderly drivers is low stamina, which causes them to become fatigued quickly, especially during long trips. Fatigue can slow the driver's response time, increasing the risk of a single-vehicle accident. The results of this study are consistent with research conducted by [4, 32].
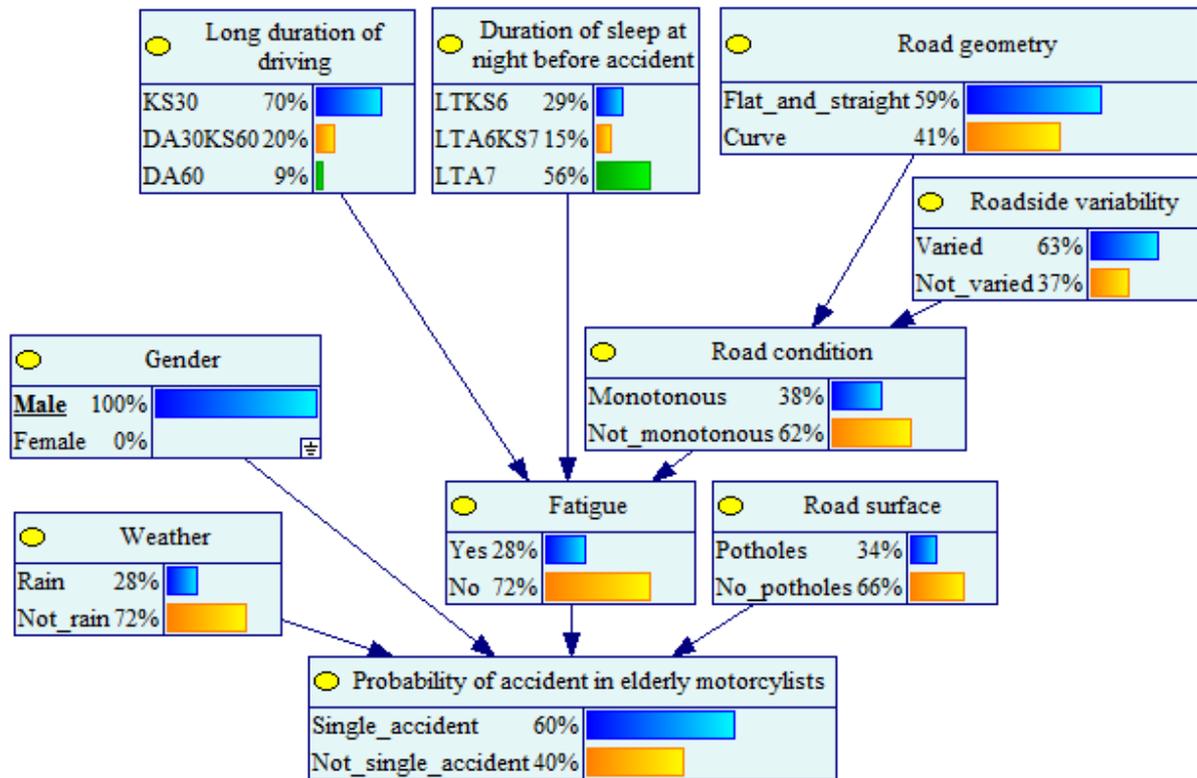
Figure 4. Scenario 1: Probability of a Single-Vehicle Accident Among Elderly Male Motorcyclists
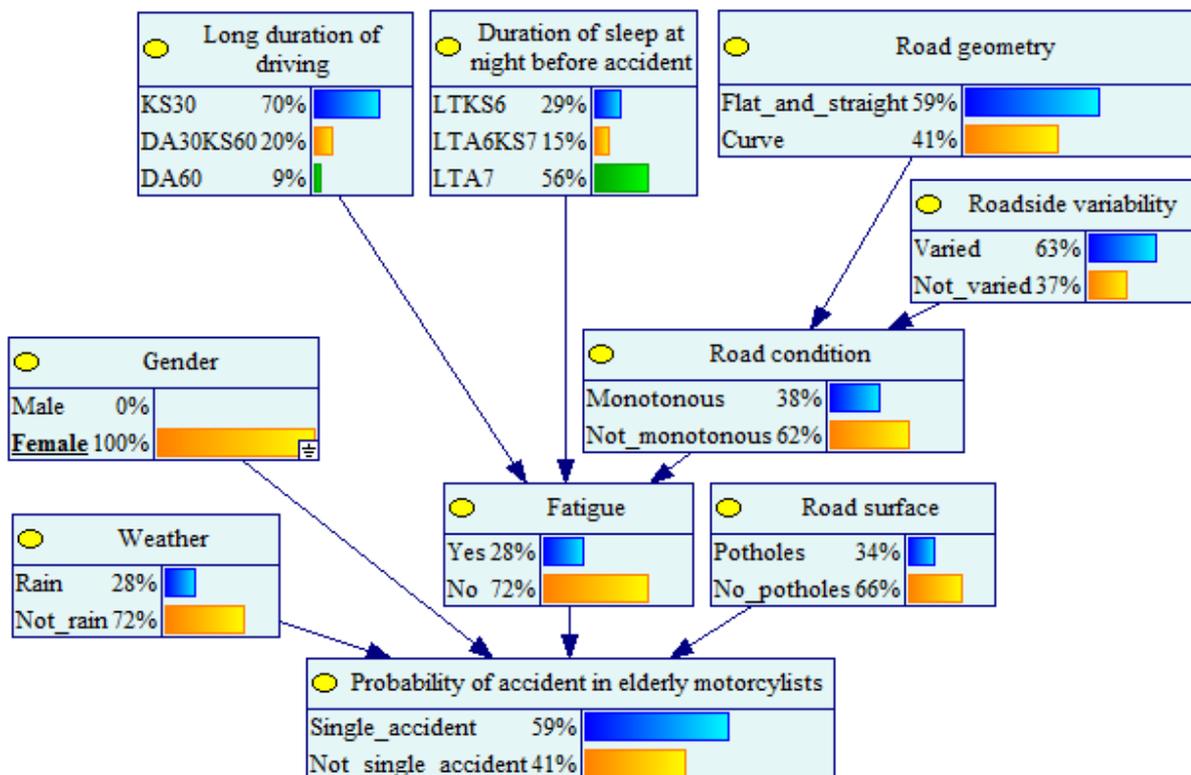

Figure 5. Scenario 2: Probability of a Single-Vehicle Accident among Elderly Female Motorcyclists
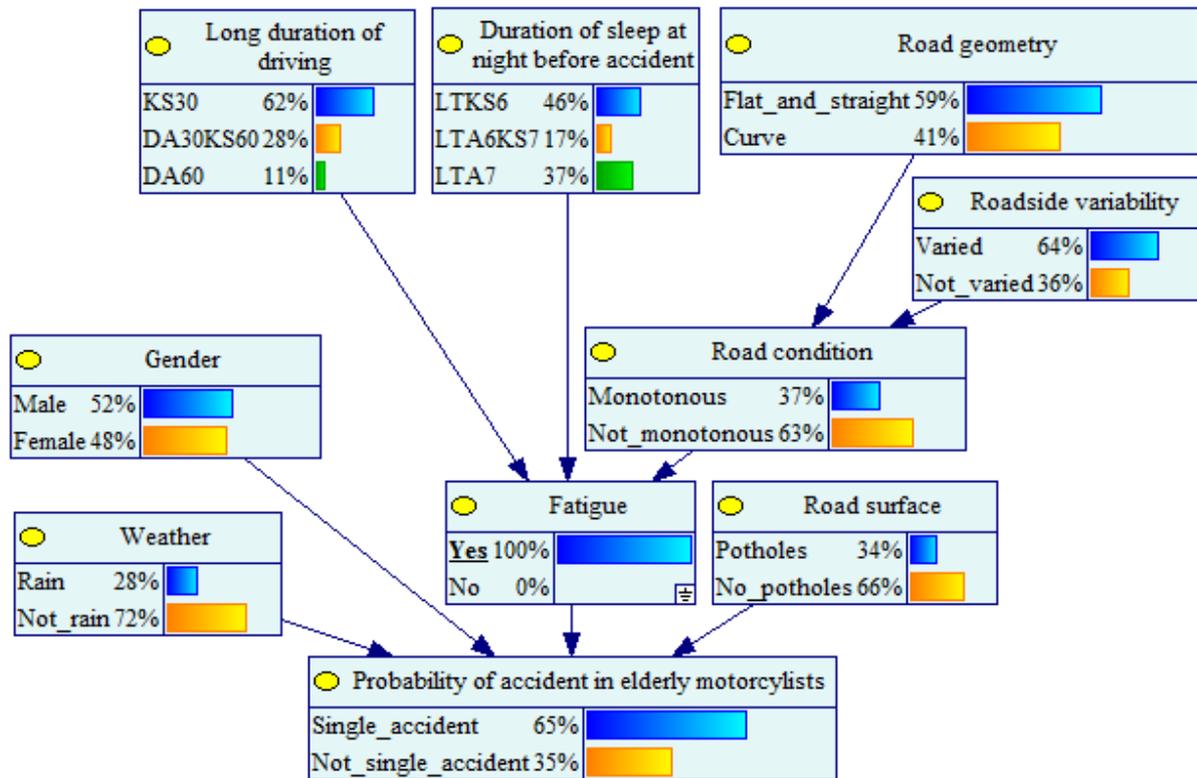
Figure 6. Scenario 3: Probability of a Single-Vehicle Accident Among Elderly Motorcyclists
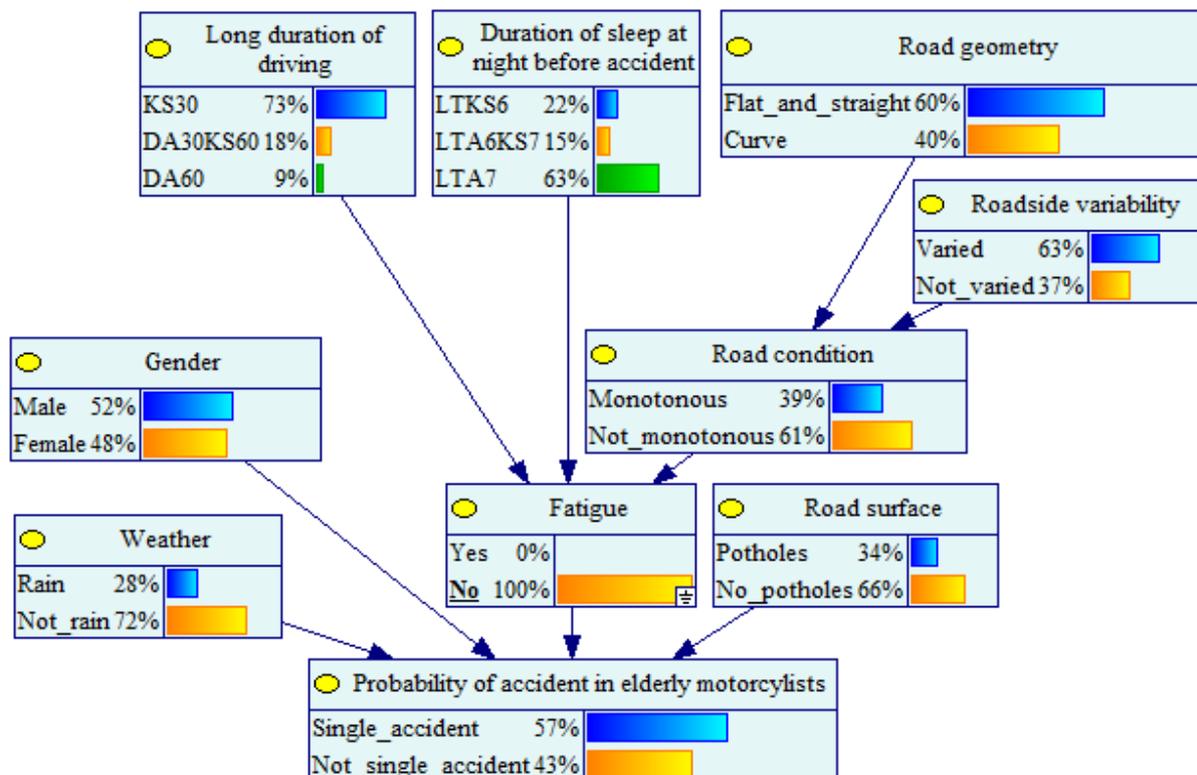Driving While Fatigued

Figure 7. Scenario 4: Probability of a Single-Vehicle Accident Among Elderly Motorcyclists
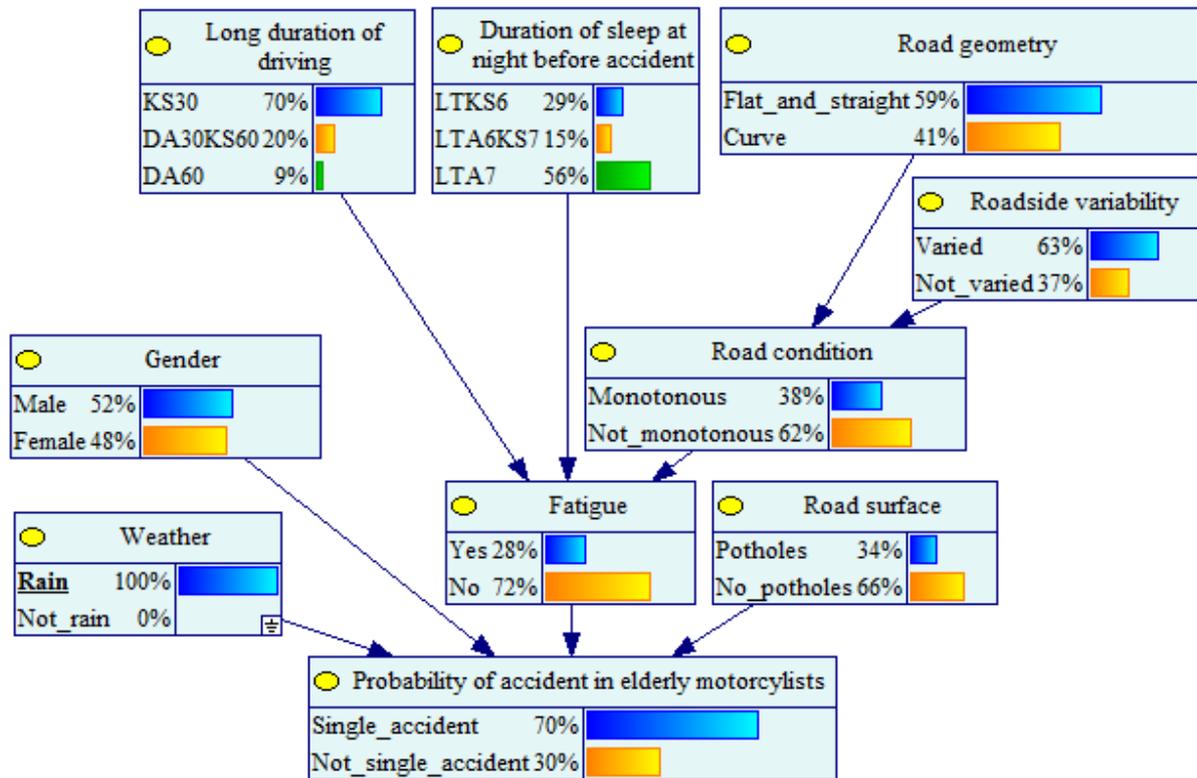Driving While Not Fatigued.

Figure 8. Scenario 5: Probability of a Single-Vehicle Accident Among Elderly Motorcyclists Driving in Rainy Conditions
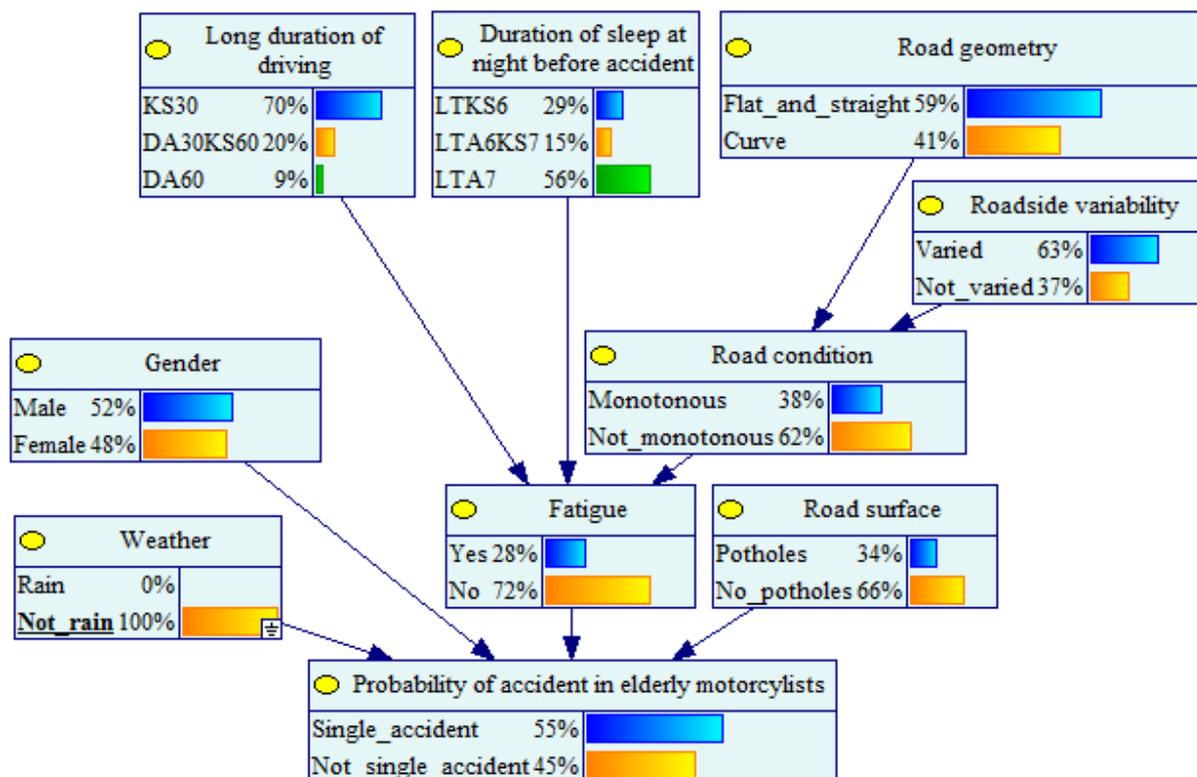

Figure 9. Scenario 6: Probability of a Single-Vehicle Accident Among Elderly Motorcyclists Driving in Non-Rainy Conditions
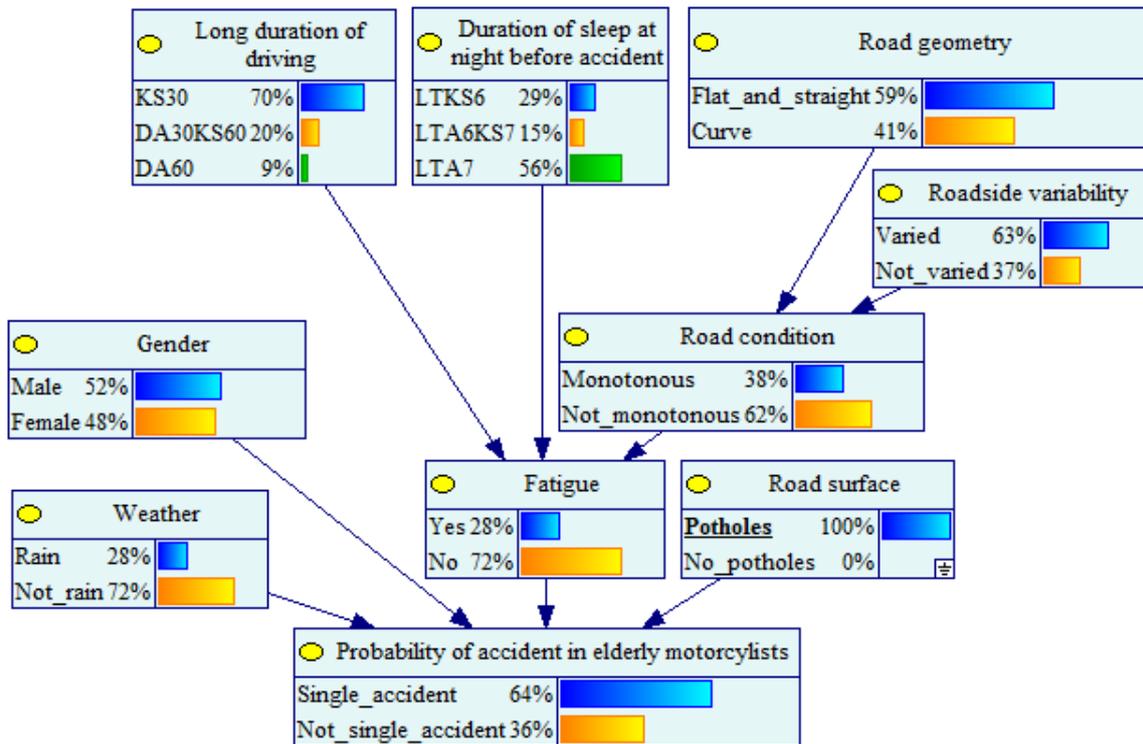
Figure 10. Scenario 7: Probability of a Single-Vehicle Accident Among Elderly Motorcyclists Driving on a Potholed Road.
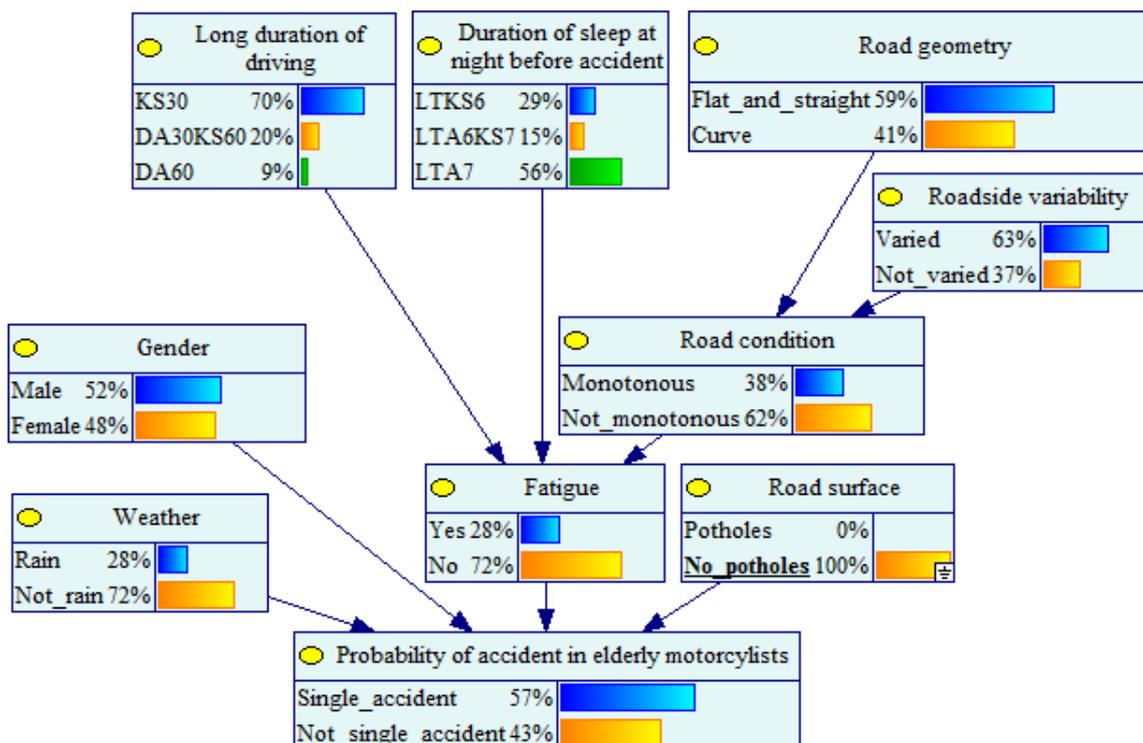

Figure 11. Scenario 8: Probability of a Single-Vehicle Accident Among Elderly Motorcyclists Driving on a Road Without Potholes

Scenario 5 indicates that elderly motorcyclists who ride in rainy conditions have a 70% likelihood of being involved in a single-vehicle accident, as illustrated in Figure 8. Meanwhile,

Scenario 6 shows that elderly motorcyclists who ride in non-rainy conditions have a 55% likelihood of experiencing a single-vehicle accident, as shown in Figure 9. Rainy conditions reduce rider visibility and create slippery road surfaces, increasing the risk of accidents. Under these circumstances, elderly drivers are more susceptible to single-vehicle accidents. These findings indicate that elderly motorcyclists riding in rainy conditions face a significantly higher risk of single-vehicle accidents. However, even in non-rainy conditions, the likelihood remains above 50%, suggesting a general decline in riding ability and skill among elderly individuals, primarily due to reduced physical function. As drivers age, their physical capabilities, such as vision, hearing, and stamina, tend to decline noticeably. Poor vision can prevent elderly drivers from recognizing traffic hazards ahead or around them. Similarly, the hearing ability of elderly drivers tends to decline, making it more challenging for them to detect warning signs, such as the sound of vehicle horns or engines. This condition increases their risk of accidents. Additionally, elderly drivers tend to become fatigued more quickly, further elevating the risk of accidents.

Scenario 7 shows that elderly motorcyclists riding on potholed roads are 64% likely to experience a single-vehicle accident, as shown in Figure 10. Meanwhile, Scenario 8 indicates that elderly motorcyclists riding on roads without potholes are 57% likely to experience a single-vehicle accident, as shown in Figure 11. This indicates that elderly motorcyclists on potholed roads are more likely to experience single-vehicle accidents than those without potholes. However, the probability of a single-vehicle accident for elderly motorcyclists remains above 50% in both scenarios. This suggests a decline in the ability and skills of elderly motorcyclists due to their physical and cognitive limitations. This decrease in ability is caused by elderly drivers' reduced ability to detect road conditions ahead or around them, which results in mistakes when responding to warnings or hazards nearby.

4. CONCLUSION

The probability of a single-vehicle accident among elderly drivers is relatively high, exceeding 50%. This indicates that elderly drivers are particularly vulnerable to such incidents. Based on eight scenarios analyzed in this study, several variables have been identified as significant contributors to single-vehicle accidents: male driver, driving while fatigued, driving in the rain, and driving on potholes. Among human factors, fatigue while driving is the most influential variable increasing the likelihood of a single-vehicle accident among elderly drivers. For environmental factors, driving in the rain is the primary contributor, while for road conditions, encountering potholes is a key factor contributing to single-vehicle accidents. These findings highlight the dominant factors contributing to single-vehicle accidents among elderly drivers, considering human, environmental, and road-related variables. This study is expected to serve as a reference for establishing a maximum age limit for motorcycle riders, as Indonesia currently lacks regulations regarding the maximum age for riding a motorcycle.

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