Prediction for Probability of Fatigue-Related Accident in Motorcyclists

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Abstract: This study emphasizes on the probability of fatigue-related accidents in motorcyclists. 70.93% accidents that occured from July 1, 2015 until December 31, 2015 throughout Indonesia involved motorcycles. The research took place in Bekasi City, Indonesia. Samples were comprised of 238 respondents taken using interview. Attributes that affect the probability of fatigue-related accidents were: long duration of driving, age, road side variability, road geometry, road condition, riding time. The result of Structure of Bayesian Network Model indicates that the probability of fatigue-related accidents was 48%. Model accuracy calculation employed new data consisting of 60 respondents. The model accuracy calculation indicated that the Mean Absolute Deviation (MAD) was 26.28%. Scenario 1 indicated that a 90 minute trip was a safe limit for a monotonous highway driving. Scenario 2 indicated that road side variability and winding road would decrease the monotonous levels from 43% to 22%. Furthermore, scenario 3 indicated that the probability of fatigue-related accidents increased from 06:00 AM to 12:00 PM, 12:00 PM to 06:00 PM, 06.00 PM-12.00 AM by 39%, 47%, 67% respectively. Meanwhile, in the period of 12:00 AM to 06:00 AM the probability of fatigue-related accidents decreased by 54%.

Keywords: Bayesian, Probability, Motorcyclist.

1. Introduction

Based on data in 2009, in Indonesia every 9.1 minutes one case of accident occured and every 20 minutes there was one life lost in highway [16]. Moreover, in 2010, 2011 and 2012 the number of accidents was increasing by 15,18%, 63.48%, 8.51% respectively [2,3,4]. In 2013 the number of accidents decreased by 15.1% [5]. Based on vehicle types, 70.93% accidents that occurred from July 1, 2015 to December 31, 2015 throughout Indonesia involved motorcycles [13]. Riders of age group 15-25 year are most vulnerable to traffic accidents in Indonesia [13]. In 2010 the number of motorcycles was 61,078,188, or 79.42% of other vehicles. The average annual growth of motorcycles in Indonesia was 13.43% [1]. There are several factors that contribute to accidents such as human error, road and environment as well as vehicle condition. Of these three factors, 75% of accidents are caused by human error, one of which is due to driver fatigue. Driver fatigue is caused by several factors: lack of rest, long duration of driving, and monotonous road [15]. There are not the study related to safe limit for monotonous highway driving for the motorcyclists until now unless for driver of the car. Based on the aforementioned conditions, a study is deemed necessary in order to reduce the risk of accidents, particularly in motorcyclists due to fatigue. This study aims to identify variables that affect the risk of fatigue-related accidents and to identify the extent that those variables affect the probability of accidents.

2. Literature Review

Fatigue can reduce the ability of the driver to drive safely [8]. Some of the factors that affect driver's fatigue and behavior on the road are: driver's job, long duration of driving, work routines, driving a vehicle in the middle of the night, the use of stimulants, work schedules and speed [10]. In addition, driver behavior is also affected by several factors that can increase the risk of accidents such as age, gender, experience, road conditions and characteristics of the vehicle [18]. Driver fatigue is caused by several factors: lack of rest, long trip duration, and monotonous road [15]. In general, fatigue-related crashes often occur between midnight and 6 AM. Overall, fatigue-related crashes occur between noon to 6 PM [9]. A study conducted by Queensland Transport of Australia by analyzing accident data from 2001 to 2005 indicated that 1.9% of fatigue-related accidents mostly occurred between 2 PM and 4pm [11]. Samples of more than 2000 accidents involving drivers aged 60 years or older in the United Kingdom (UK) from 1994 to 2007 indicated that the fatigue-related accidents on old drivers were concentrated in the afternoon, and almost half of the events occurred within 4 hours between noon to 4 PM [6].

A study in Northern California in 1998 with a sample size of 1403 people, 312 participants had sleep-related accidents, 155 participants had fatigue-related accidents, 529 participants had accidents not related to sleep and fatigue, and 407 participants did not have accidents. The job factor related to the sleep-related accidents includes: part-time job, night shift job, work schedules, and working 60 hours or more a week. In addition, the probality of accident in the driver who on average slept less than five hours each night increased nearly 5-fold. Furthermore, more than half of drivers who had sleep-related accidents had slept less than six hours before the crashes, and a third had slept less than five hours, and almost 1 out of 5 drivers who has sleep-related crashes was reportedly awake for 20 hours or more before the accident. Sleep disorders did not significantly influence the sleep-related accidents, but high levels of sleepiness during the day would likely increase sleep-related accidents [19]. A monotonous highway driving was influenced by *road design monotony* and *roadside variability* [14].

Bayesian Network (BN) is based on Bayes' theorem, an approach to an uncertainty. Bayesian Network (BN) is a Directed Acyclic Graph (DAG) and is equipped with Conditional Probability distribution Table (CPT) for each node. Each node represents a variable domain and each arrow between nodes represents a probabilistic dependency [16]. Bayes' theorem is used to calculate the probability of the occurrence of an event based on the influence obtained from the observation. This theorem describes the correlation between the probability of occurrence of event A on condition that event B has occurred, which is formulated in the equation below:

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

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

Where P=Probability, P(A|B) = posterior probability of structure A, P(A) = prior probability distribution of B, P(B) = probability distribution of data set B.

The accuracy of a forecasting model can be measured by considering the value of error, which is a deviation between the results of forecast and actual data. The type of error in this study used as an indicator to measure the accuracy of the model was the Mean Absolute Deviation (MAD). The equation below is used to calculate the value of MAD :

$$\frac{1}{n} \Sigma \left| \text{Actual - Forecast} \right| \quad (2)$$

3. Materials and Methodology

3.1. Data

The research took place in Bekasi, Indonesia. Bekasi was chosen as the location for the study because it has the largest commuter line in Jabodetabek, around 2.43 million compared to other cities in Jabodetabek. Approximately 58.19% of commuter trips in Jabodetabek use the mode of motorcycles. In addition, 94.6% of commuter trips in the city of Bekasi have a travel time of over 30 minutes. Therefore, the city is appropriate to look for respondents for this study. Meanwhile, in order to validate the model, data were also collected outside Bekasi. Criteria for the respondents are motorcyclists who had experienced a traffic accident with a minimum age of 17 years old. The data were collected from April to June 2016. The samples of this study consisted of 238 respondents who had experienced an accident. The data then, were analyzed using the Bayesian network method, which indicates a causal relationship between the variables contained in the structure of Bayesian network and this Bayesian network was built with the conditional probability approach. The characteristics of respondents and accident location based on the perception of respondents are shown in Table 1. Accidents occured more frequently on a 30 minute trip duration than those on other trip duration. Energy drink and coffee did not affect significantly on the probability fatigue-related accident inmotorcyclists. In addition, accidents occured more frequently in the straight road than those in curve. Collection and analyze of data are shown in Figure 1.

Table 1. Characteristics of respondents and accident location

No	Variabel	Condition	Percentage
1	Time of Accident	06:00 AM -12:00 PM	34.45
		12:00 PM - 06:00 PM	42.86
		06.00 PM - 12.00 AM	17.23
		12.00 AM - 06.00 AM	5.46
2	Age	≤ 20 Year	67.65
		> 20 Year	32.35
3	Trip duration	30 minutes	69.75
		60 minutes	18.91
		90 minutes	2.10
		> 90 minutes	9.24
4	Road Side Variability	Variability	77.73
		Not variability	22.27
5	Road Geometry	Flat and straight	84.03
		Hilly and winding	15.97
6	Road Condition	Monotonous	42.02
		Unmonotonous	57.98
7	Energy drink	Yes	4.20
		No	95.80
8	Coffee	Yes	12.61
		No	87.39
9	Fatigue	Yes	47.90
		No	52.10

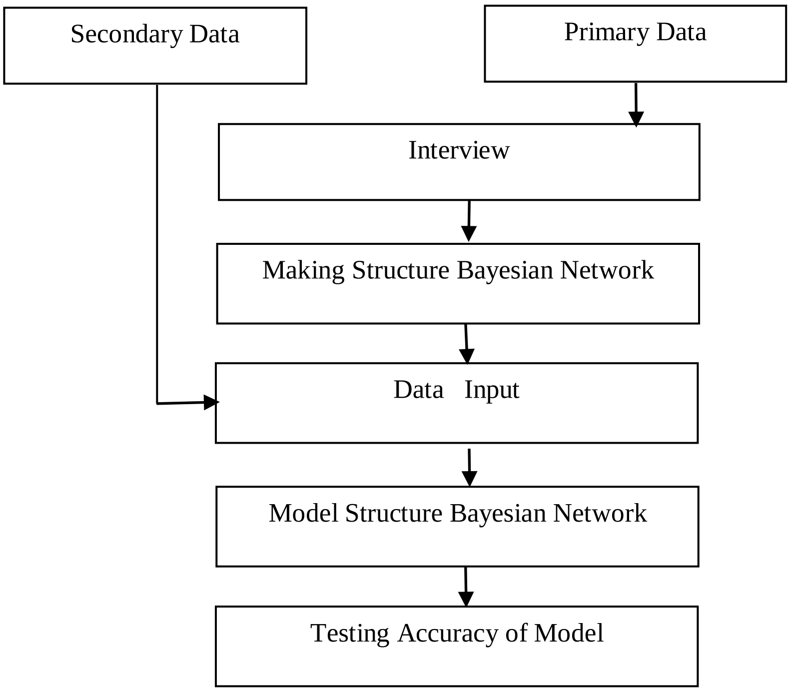

Figure 1. Research process flowchart

4. Results and Discussion

4.1. Results

Some attributes which affect the probability of fatigue-related accidents are: long duration of driving, age, road side variability, road geometry, road condition, driving time. The results of the analysis using the method of Bayesian network indicated that the probability of fatigue-related accidents was 48% as shown in Figure 2.

The accuracy levels of Bayesian Network Model were measured by calculating the Mean Absolute Deviation (MAD). In order to calculate the value of MAD, new data numbering 60 respondents from outside Bekasi City were used. The results of the accuracy calculation of the model indicated that the MAD value was 26.28%, meaning that an average absolute deviation of the model was 26.28%, as shown in Table 2.

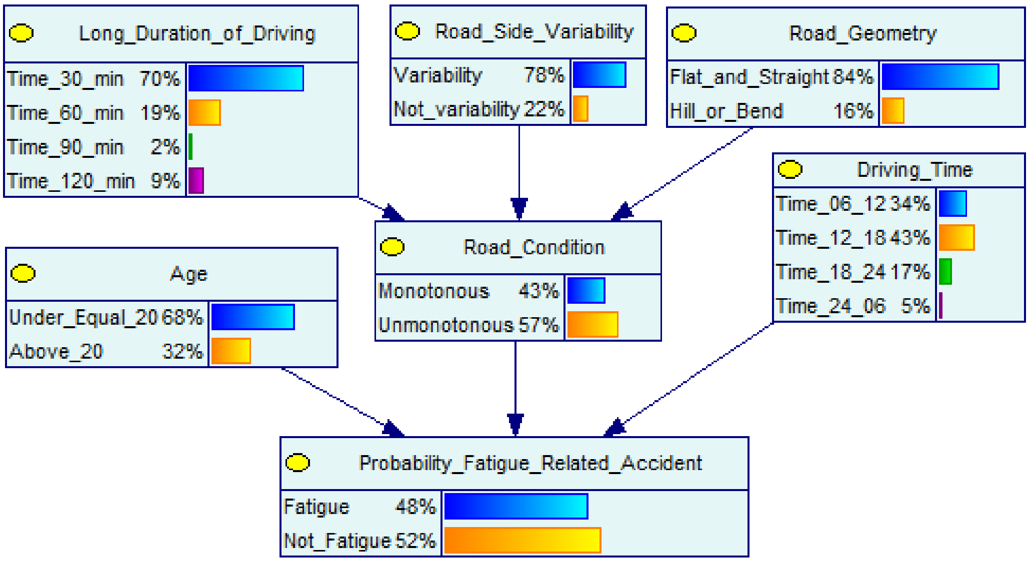

Figure 2. Structure of Bayesian Network

Table 2. The Calculation of the value of Mean Absolute Deviation (MAD)

Probability	Driving Time	Age	Road Condition	Probabiliy of Fatigue-related Accident		Difference %
				Actual %	Model %	
1	06:00 AM - 12:00 PM	< 20	Monotonous	33.33	37.00	3.67
2	06:00 AM - 12:00 PM	< 20	Unmonotonous	42.86	35.00	7.86
3	06:00 AM - 12:00 PM	> 20	Monotonous	33.33	45.00	11.67
4	06:00 AM - 12:00 PM	> 20	Unmonotonous	20.00	43.00	23.00
5	12:00 PM - 06:00 PM	< 20	Monotonous	30.00	54.00	24.00
6	12:00 PM - 06:00 PM	< 20	Unmonotonous	75.00	50.00	25.00
7	12:00 PM - 06:00 PM	> 20	Monotonous	26.92	41.00	14.08
8	12:00 PM - 06:00 PM	> 20	Unmonotonous	8.33	31.00	22.67
9	06:00 PM - 12:00 AM	< 20	Monotonous	100.00	61.00	39.00
10	06:00 PM - 12:00 AM	< 20	Unmonotonous	0.00	73.00	73.00
11	06:00 PM - 12:00 AM	> 20	Monotonous	0.00	79.00	79.00
12	06:00 PM - 12:00 AM	> 20	Unmonotonous	50.00	55.00	5.00
14	12:00 AM - 06.00 AM	< 20	Unmonotonous	50.00	41.00	9.00
16	12:00 AM - 06.00 AM	> 20	Unmonotonous	100.00	69.00	31.00
	Mean Absolute Deviation (MAD)					26.28

4.2. Discussion

Based on the basic model as shown in Figure 2, several scenarios were performed by changing the probability of particular variables, namely:

1) Scenario 1 indicated a 90 minute trip duration was the safe limit for monotonous higway driving, and after 90 minutes the probability of accident due to monotonous highway driving decreased as shown in Figure 3. There are differences in the results of this research with the research conducted by [20]. A previous research for driver of car indicated that a 80 minute long duration of driving was the safe limit for monotonous highway driving [20]. Based on data, after a 90 minute trip the motorcyclists took a rest for some times because of fatigue.

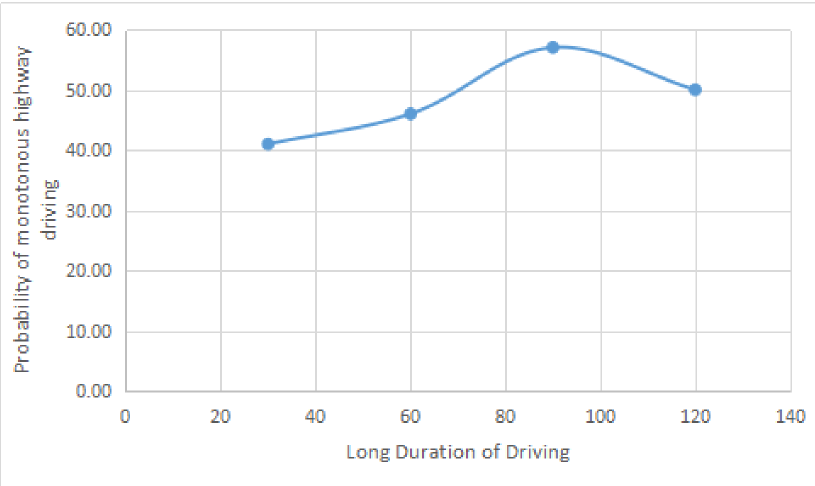

Figure 3. Correlation between the probability of monotonous highway driving and long duration of driving

2) Scenario 2 indicated that road side variability and winding road would decrease the monotonous level of the motorcyclists from 43% to 22% and it would decrease the probability of accident by 2%. The result is in accordance with the studies conducted by Laurea dkk (2001). The straight

road would decrease level of vigilance of the driver, whereas the curve would increase level of vigilance of the driver [14].

3) Furthermore, scenario 3 indicated that the probability of fatigure-related accidents tended to increase, especially in the periods of 06:00 AM – 12:00 PM, 12:00 PM to 06:00 PM, 06:00 PM – 12:00 AM by 42%, 50%, 66% respectively. Meanwhile, in the period of 12:00 AM – 06:00 AM the probability of accidents decreased by 50% as shown in Figure 4. Previous research related to the time of accident were conducted by ([21], [7]. The accident occurred in city of Zagreb was between midnight and 06.00 AM [21]. A research conducted in Saudi Arabia indicated that 59% of motorcycle accidents occured between 04:00 PM and 08:00 PM [7].

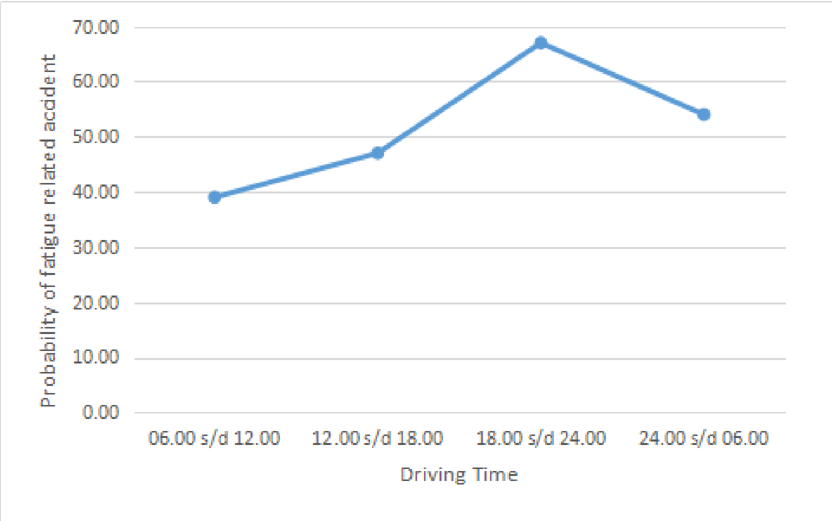

Figure 4 Correlation between the probability of fatigue-related accident and driving time

5. Conclusion

Based on the above conditions, several conclusions can be drawn as follows:

1. The probability of accidents was affected by several variables including: long duration of driving, age, road side variability, road geometry, road condition, driving time.
2. The results of the Bayesian Network analysis indicated that the probability of fatigue related accident was 48%.
3. 90 minutes was the safe limit for monotonous highway driving in order to minimize traffic accident.
4. Road side variability and winding road would decrease the monotonous level of the motorcyclists and it would decrease the probability of accident.
5. The probability of fatigure-related accidents tended to increase from 06:00 AM – 12:00 AM, Meanwhile, but in the period of 12:00 AM – 06:00 AM the probability of accidents decreased.

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