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The Impact of Fatigue and Behaviour of Driver on Probability of Accidents Severity in Motorcyclists

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This study focuses on the influence of fatigue factors and driving behaviour on the probability of severely and mildly injured to motorcyclists. The respondents of this study were motorcyclists who had suffered an injury. The results of the analysis of 282 respondents with Bayes Theory and GeNie 2.0 Software showed that the probability of severely injured was 16% and mildly injured was 84%. Furthermore, the validation of the model use 100 respondents. The results of the validation show that the Mean Absolute Deviation (MAD) value was 10.11%. Meaning that accuracy of model is high. After that, several scenarios were performed with the aim to know the effect of each variable on the accidents severity at the time of an accident, such as: effect of driving license ownership to accident severity, effect of long duration of driving and condition of road to the fatigue, effect of machine capacity of vehicle to accident severity. This condition will give an initial description to policy makers in an effort to minimise the victim of fatality and severely injured.

Keywords: Accident; Bayesian; Mildly injured; Severely injuried; Victim

I. INTRODUCTION

The statistical data shows that 35.29% of motorcyclists aged over 20 years suffered fatigue before the accident, while 33.8% of drivers aged 20 years or below suffered fatigue before the accident (Lumba *et al.*, 2018). Fatigue that is suffered can be caused by the workload (Hensher *et al.*, 1992) that has been done before driving or driving too long (Ma *et. al.*, 2003; Stutts *et al.*, 2001), resulting in the driver in unsafe conditions (Ma *et. al.*, 2003; Stutts *et. al.*, 2001; Dingus *et al.*, 2006). The heavier the work that is performed before driving, the more likely the driver will suffer fatigue while driving. Besides that, lack of rest factors such as lack of sleep can lead to fatigue when driving (Ma *et. al.*, 2003; Lumba *et al.*, 2017), even at risk of accidents (Stutts *et. al.*, 2001; Philip *et al.*, 2003). In addition, road factors can also cause fatigue when driving, especially on roads that can cause sense of monotony (Ma *et. al.,* 2003; Thiffault & Bergeron, 2003a), such as driving on a straight road (Larue *et al.*, 2011). To avoid accidents on monotonous road, it is necessary to be limited long duration of driving on monotonous roads (Ting *et. al.*, 2007; Lumba *et al.*, 2017).

Behaviour factors in driving also affect the safety of drivers on the highway. Statistical data shows that 66.67% of female motorcyclists performed traffic violations before the accident, while 33.33% of female motorcyclists performed traffic violations before the accident (Lumba *et al.*, 2018). In addition to the driver's gender, engine capacity or vehicle performance can also affect driving behaviour. Motorcycles with engine capacity > 125 cm3 will influence the driver to increase their speed compared to motorcyclists with engine capacity ≤ 125 cm3, thus it will probability of accident severity when the driver experience accidents (Vorko-Jovic *et. al.*, 2005; Gray *et. al.*, 2008; Zainuddin, 2016; Teoh & Campbell, 2010; Bjørnskau *et. al.*, 2011; Yannis *et. al.*, 2004; Eliana, 2015; Lumba *et. al.*, 2017; Lumba *et al.*, 2018).

The level of education will affect the probability of accident severity (Sami *et al.,* 2013). Driver's education level is related to SIM ownership. The ownership of driving license also affects the occurrence of head injuries at the time of an

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accident (Subekti, 2011). In addition to, the ownership of driving license and the level of education also affects the driver's understanding of traffic regulation, thus it is less likely the drivers will perform unintentional violations of traffic regulation.

Land Transportation Statistics (2019) shows that last 3 years data shows that the number of accident cases increase every year, meanwhile the number of fatality and severely injured tends to decrease, however this number of injury victim are quite high, as shown in Table 1.

Table 1. Accident and accident severity

	2017	2018	2019
Number of accident	104.327	109.215	116. 411
Fatal accident	30.694	29.472	25.671
Severely injured	14.559	13.315	12.475
Mildly injured	121.575	130.571	137.342
Material loss	217.031	213.866	254.779

Table 2. The number of vehicles

	2017	2018	2019
Passenger car	13.968.202	14.830.698	15.592.419
Bus	213.359	222.872	231.569
Truck	4.540.902	4.797 254	5.021.888
Motorcycles	100.200.245	106.657.952	112.771.136
Total	118.922.708	126.508.776	133.617.012

One of the causes of the increasing the number of accidents is due to the widespread the use of motorcycles in Indonesia. Statistical data in 2015 showed that 70.93% of accidents in Indonesia involved motorcyclists (Korlantas Polri, 2015). In 2019 the number of motorcycles in Indonesia have reached 133,617,012 (Land Transportation Statistics, 2019), as shown Table 2.

The purpose of this study is to explore the dominant variables that affect accidents severity on motorcyclists in terms of fatigue and driving behaviour. The contribution of this study is as an initial description for policy makers in an effort to make programs to minimise the risk of accidents.

II. MATERIALS AND METHOD

This research was conducted in Indonesia with sample of 282 respondents. The respondent's criteria are motorcyclists who had had an accident and aged at least 17 years old. Analyse of data use the Structure of Bayesian Network Method. The structure of this Bayesian Network is derived from Bayes Theory, with the formula:

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

Analysis of data use Genie 2.0 software (BayesFusion Downloads for Academia, 2017) and an example of calculation of Structure of Bayesian Network in Figure 1.

$$\begin{aligned} P(Y) = {} & P(Y|H,I,G) \times P(H|G) \times P(I|G) + \\ & P(Y|H,\text{-}I,G) \times P(\text{-}H|G) \times P(\text{-}I|G) + \\ & P(Y|\text{-}H,\text{-}I,G) \times P(\text{-}H|G) \times P(I|G) + \\ & P(Y|\text{-}H,\text{-}I,G) \times P(\text{-}H|G) \times P(\text{-}I|G) \end{aligned}$$

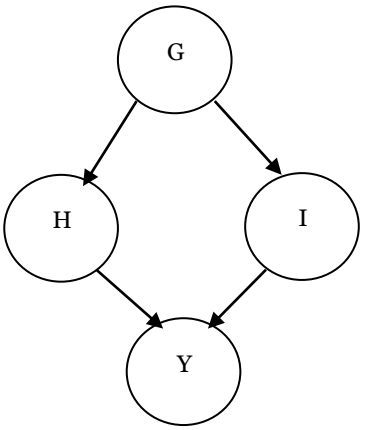

Figure 1. Example of analysis of bayessian network with 4 variables

Furthermore, the model is validated first by calculating the MAD value. The number of samples are used to validate this model by 100 respondents. If the result of validation show that the results of the model and the reality in the field are close, meaning that the model has high accuracy.

III. RESULT AND DISCUSSION

In this model, the probability of the accident severity is directly influenced by 3 variables including: driving license ownership, fatigue and speed. Meanwhile, the driving license ownership variable is influenced by the driver's education level, and the fatigue variable is influenced by the long duration of driving and road conditions. In addition, the variable speed is influenced by the variable engine

capacity of the vehicle. Each variable have values that are obtained from the survey results and this value also inputs in the GeNie 2.0 Software, as shown in Table 3.

Table 3. Variable dan statistic

No	Variable	Value	Percen-tage
1	Driving license ownership (DL)	Yes (DL1) No (DL2)	50,35 49,65
2	Fatigue (F)	Yes (F1) No (F2)	47,16 52,84
3	Speed (S)	≤ 50 km/h (S1) 50 <Speed ≤ 70 (S2) > 70 km/h (S3)	48,94 41,49 9,57
4	Educational Background (EB)	Under graduate (EB1) Senior high school and below (EB2)	61,35 38,65
5	Long Duration of Driving (LD)	≤ 30 minute (LD1) 30 < LD ≤ 60 (LD2) > 60 minute (LD3)	70,21 19,50 10,28
6	Condition of Road (CR)	Monotonous (CR1) Unmonotonous (CR2)	43,97 56,03
7	Machine Capacity (MC)	≤ 125 cm3 (MC1) > 125 cm3 (MC2)	56,03 21,99

The results of the analysis with GeNie 2 software show that the probability of severely injured is 16%, the probability of mildly injured is 84% as shown in Figure 2. After that from the structure bayesian network is obtained the equation as shown in Table 4. Furthermore, to obtain the accuracy of the model, this model needs to be validated by calculating the MAD value. The results of the validation calculations show the MAD value is 10.11% as shown in Table 5. Meaning that the difference in the calculation of the probability of accident severity between the model and actual condition were 10.11%. Because the accuracy of the model is quite good, then several scenarios are made to get the best alternative in an effort to minimise the number of victims of injury especially motorcyclists.

Scenario 1 show that effecting of driving license ownership on the probability of accident severity. The results of the analysis show that drivers who had driving license had probability of severely injured is 15% and 17% for drivers who does not have a driving license, as shown in Figure 3 and Figure 4. The high probability of severely injured to a driver who does not have a driving license is caused by lack of knowledge of the driver to traffic regulation that result in the driver commit traffic violation unintentional and the ownership of this driving license has effecting on injury at the time of the accident. This research is in line with research conducted by (Subekti, 2011).

Scenario 2 shows that there are relationship between long duration of driving and road conditions to an increase of fatigue. The results of the analysis show that drivers who drive for about 30 minutes to 60 minutes and drive on monotonous roads can increase driver fatigue by 21% from 48% to 68% as shown in Figure 5. This is because the longer the trip, the greater the fatigue, as well as driving on monotonous roads such as a long straight road can cause drowsiness when driving because on a straight road. This study is in line with research conducted by (Ma *et. al.*, 2003; Stutts *et. al.*, 2001; Thiffault & Bergeron, 2003a; Larue *et al.*, 2011).

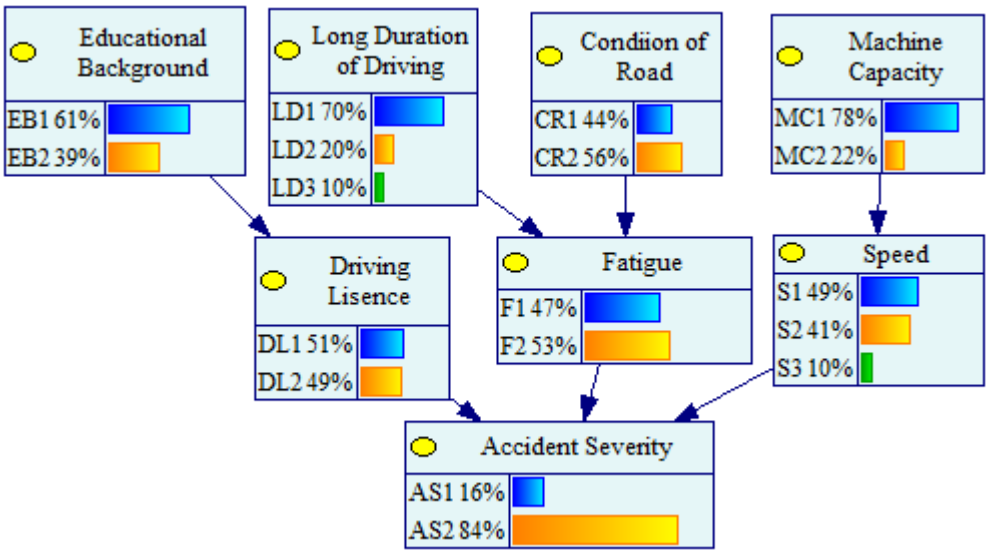

Figure 2. Structure of bayesian network of probability of accident severity

Table 4. Equation of probability of accident severity (AS)

No	P(DL)	P(F)	P(S)	P(AS=Accident Severity)		
1	DL1	F1	S1	P(AS)1=P(AS|DL1,F1,S1,EB,LD,CR,MC) P(S1|MC)	P(DL1|EB)	P(F1|LD,CR)
2	DL1	F1	S2	P(AS)2=P(AS|DL1,F1,S2,EB,LD,CR,MC) P(S2|MC)	P(DL1|EB)	P(F1|LD,CR)
3	DL1	F1	S3	P(AS)3=P(AS|DL1,F1,S3,EB,LD,CR,MC) P(S3|MC)	P(DL1|EB)	P(F1|LD,CR)
4	DL1	F2	S1	P(AS)4=P(AS|DL1,F2,S1,EB,LD,CR,MC) P(S1|MC)	P(DL1|EB)	P(F2|LD,CR)
5	DL1	F2	S2	P(AS)5=P(AS|DL1,F2,S2,EB,LD,CR,MC) P(S2|MC)	P(DL1|EB)	P(F2|LD,CR)
6	DL1	F2	S3	P(AS)6=P(AS|DL1,F2,S3,EB,LD,CR,MC) P(S3|MC)	P(DL1|EB)	P(F2|LD,CR)
7	DL2	F1	S1	P(AS)7=P(AS|DL2,F1,S1,EB,LD,CR,MC) P(S1|MC)	P(DL2|EB)	P(F1|LD,CR)
8	DL2	F1	S2	P(AS)8=P(AS|DL2,F1,S2,EB,LD,CR,MC) P(S2|MC)	P(DL1|EB)	P(F1|LD,CR)
9	DL2	F1	S3	P(AS)9=P(AS|DL2,F1,S3,EB,LD,CR,MC) P(S3|MC)	P(DL2|EB)	P(F1|LD,CR)
10	DL2	F2	S1	P(AS)10=P(AS|DL2,F2,S1,EB,LD,CR,MC) P(S1|MC)	P(DL1|EB)	P(F2|LD,CR)
11	DL2	F2	S2	P(AS)11=P(AS|DL2,F2,S2,EB,LD,CR,MC) P(S2|MC)	P(DL1|EB)	P(F2|LD,CR)
12	DL2	F2	S3	P(AS)12=P(AS|DL2,F2,S3,EB,LD,CR,MC) P(S3|MC)	P(DL1|EB)	P(F2|LD,CR)
				∑ P(AS=Accident Severity)		

Table 5. Mean Absolute Deviation (MAD)

Probability	Driving license ownership	Fatigue	Speed	Probability of severely injured		Deviation
				Model	Actual	
1	Yes	Yes	S1	14	11	3
2	Yes	Yes	S2	16	17	1
3	Yes	Yes	S3			
4	Yes	No	S1	14	50	36
5	Yes	No	S2	11	7	4
6	Yes	No	S3			
7	No	Yes	S1	17	7	10
8	No	Yes	S2	11	0	11
9	No	Yes	S3			
10	No	No	S1	14	19	5
11	No	No	S2	21	10	11
12	No	No	S3	40	50	10
	Mean Absolute Deviation (MAD)					10,11

Scenario 3 shows that there is a relationship between the increasing engine capacity and the increasing speed when driving, thus it can lead to increasing the severity of accidents. The results of the analysis show that the motorcyclists with engine capacity of 125 cm3 have probability of severely injured by 16%, while the motorcyclists with an engine capacity of > 125 cm3 have probability of severely injured by 18% as shown in Figure 6 and Figure 7. The increasing of the engine capacity will impactof the increasing of performance of motorcycle, such as speed, it will influence the probability of accident severity. This study is in line with research conducted by (Vorko-Jovic *et. al.*, 2005; Gray *et. al.*, 2008; Zainuddin, 2016; Teoh & Campbell, 2010; Bjørnskau *et. al.*, 2011; Yannis *et. al.*, 2004; Eliana, 2015; Lumba *et. al.*, 2017; Dolphins *et al.*, 2018).

Scenario 4 shows that a driver with speed above 70 km/h can increase the probability of severely injured by 13% from 16% to 29% as shown in Figure 8. This study is in line with research conducted by (Vorko-Jovic *et. al.*, 2005; Gray *et. al.*, 2008; Zainuddin, 2016; Teoh & Campbell, 2010; Bjørnskau *et. al.*, 2011; Yannis *et. al.*, 2004; Eliana, 2015; Lumba *et. al.*, 2017; Lumba *et al.*, 2018).

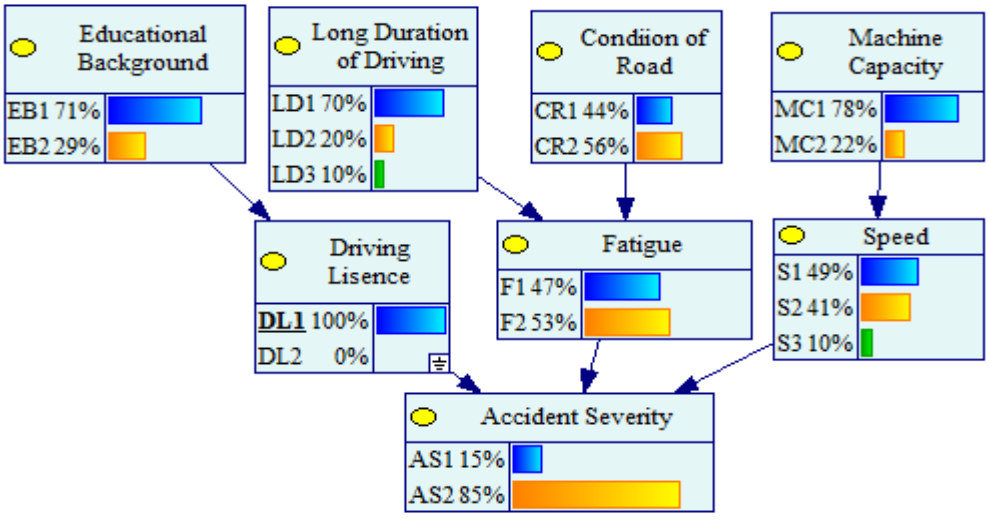

Figure 3. Scenario 1A: Effect of driving license ownership to accident severity

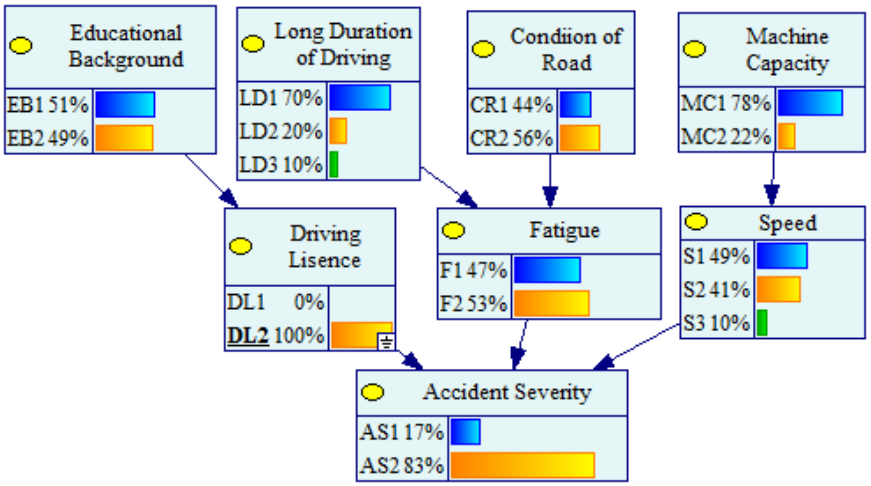

Figure 4. Scenario 1B: Effect of without driving license ownership to accident severity

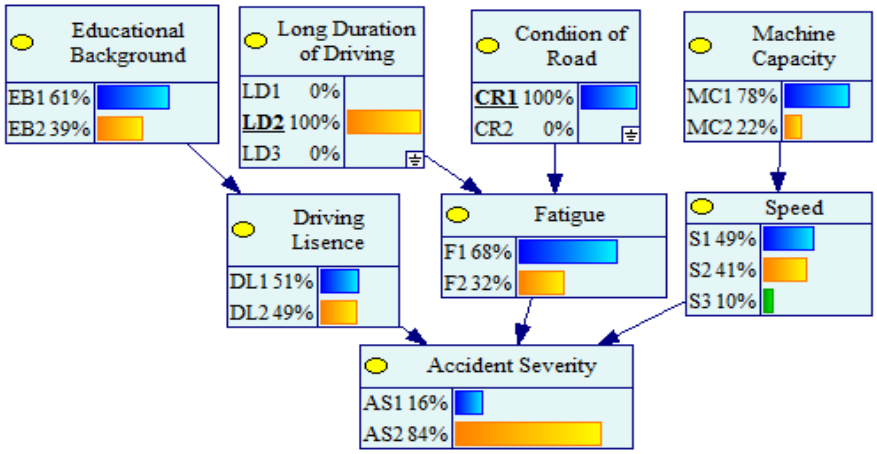

Figure 5. Scenario 2: Effect long duration of driving and condition of road to fatigue

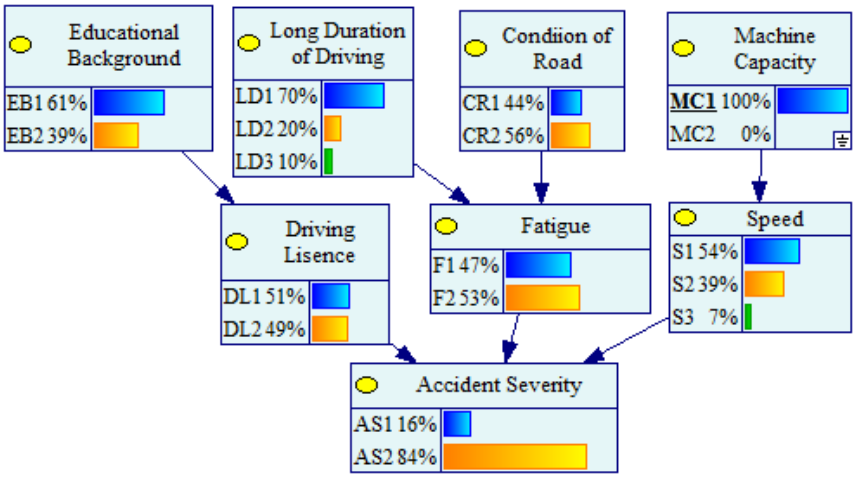

Figure 6. Scenario 3A: Effect of machine capacity ≤ 125 cm3 to accident severity

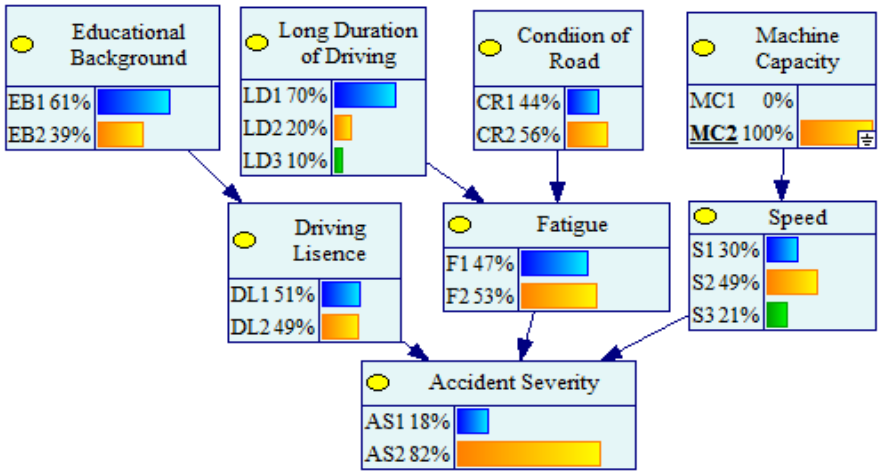

Figure 7. Scenario 3B: Effect of machine capacity > 125 cm3 to accident severity

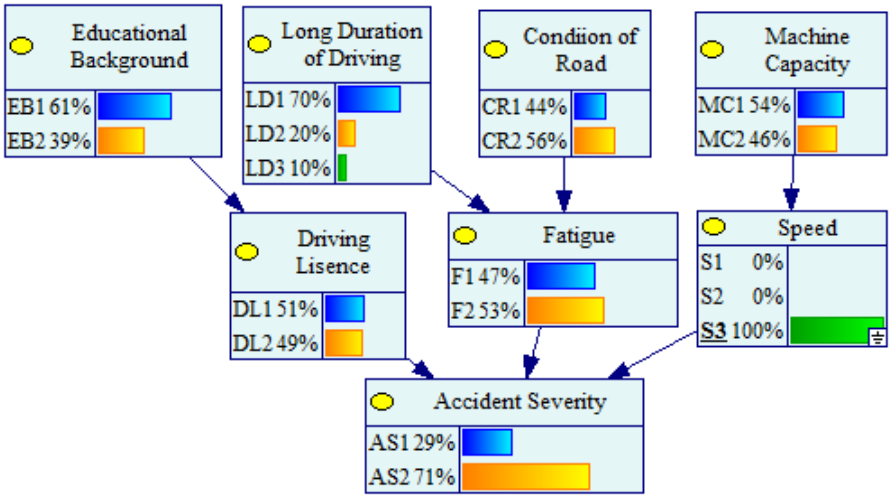

Figure 8. Scenario 4: Effect of speed to accident severity

IV. CONCLUSION

From 282 respondents, the results of the analysis show that the probability of severely injured is 16%, the probability of mildly injured is 84%. Scenario 1 shows that drivers who have a driving license have a lower probability of severely injured than drivers who do not have a driving license. The high probability of severely injured to a driver who does not have a driving license is caused by lack of knowledge of driver about traffic regulation, thus the driver conduct traffic violation both intentional and unintentional.

Scenario 2 shows that drivers who drive for about 30 minutes to 60 minutes and driving on monotonous roads can increase fatigue. This is caused by the longer the trip, the greater the fatigue, beside that the driver drive on monotonous roads can cause drowsiness when driving.

Scenario 3 shows that the drivers with a motorcycle engine capacity of 125 cm3 have a lower probability of severely injured than rider with an engine capacity of > 125 cm3. The increasing of the engine capacity will impact of the increasing of performance of motorcycle, thus, it will impact to probability of accident severity. Scenario 4 shows that driving at speeds above 70 km/h can increase the probability of severely injured.

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