Influence of pavement condition towards accident number on Malaysian highway

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Abstract. Accidents in Malaysia are alarming and have been in the rise for the past decades. Increasing numbers of road users, condition of road surface, expanded road network and weather conditions are being carefully looked into determining the contributors towards fatality. Human factors has been widely known and established as one of the main contributor to road accidents. Therefore, this study had focused more on to pavement conditions, where its relation with accidents needs to be further explored. The purpose of this study is to determine the influence of pavement condition towards accident number on Malaysian Highway. Pavement condition data which consist of Mean Texture Depth (MTD), Rutting Depth (RD) and also International Roughness Index (IRI) were measured along 265 km southern stretch of Malaysia highway, by using Multi Laser Profiler (MLP). Accident data were also collected from the accident report prepared by Southern region of Malaysian Highway Authority. Based on the results, it was found that more than 70% of the accidents happened at a good condition of road which having high MTD, low RD and minimum IRI. MTD was found as the most significance parameters that relates to accident. Other factors such as human negligence and environments (weather and lighting), might be the major cause that contribute to the accidents that happened along Malaysian highway.

1. Introduction

Road accidents are caused by more than one factor such as the location of accident, the condition of road mainly on surface condition, behaviour of driver and also weather condition [1]. For an example, when an accident takes place during wet weather condition, the effect of wet weather and the impact of road conditions need to be looked into besides the drivers' factor itself. According to the statistics by the World Health Organization (WHO), approximately 1.25 million people died due to traffic accident. People aged between 15 to 29 years old were recorded as the highest death due to road traffic injuries [2]. Road accidents are very high in Malaysia amongst ASEAN countries.

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Accidents in Malaysia keep increasing year by year although the quality of highway is set to be good and safe for road users. Malaysia recorded the highest road casualties among the ASEAN countries by 24 deaths out of 100000 inhabitants. Europe countries such as United Kingdom, Iceland, Norway and Denmark show improvement in reduction of death rates [3]. Therefore, an investigation on the increasing number of accident on Malaysian roads needs to be addressed.

A pavement is found to reach its terminal life when the pavement suffers from distresses with lower skid resistance besides unable to provide smooth surface for road users [4]. Road conditions is one of the factors that contribute to the increase in accident number in Malaysia.-Road conditions ratings stated by PLUS are classified into four categories which are good, fair, poor and bad road conditions [5, 6].

Roughness is correlated to serviceability and relates to the inadequate skid resistance and friction as well. Reduction in friction is influenced by the mega texture can be associated with variation of load at the tire pavement interface [7]. Road roughness affect the ride quality of vehicles, the vehicles vibrations, operating speed, the wear and tear of tyre and also the operating cost of the vehicle due to the irregularities on road surface. Pavement roughness affects the tire and pavement surface which affects the lateral forces required to control the steering and vehicle which may lead to accidents [8]. PLUS recommended having 2m/km and below to be good IRI conditions for Highways [5]. FHWA suggests that the threshold of 2.7 m/km is recommended for acceptable ride quality [9]. Study by Park et al. shows that the lower the IRI value, the flatter the profile will be. IRI of 0.0 m/km means it is perfectly flat profile while IRI above 8 m/km is impossible to travel [10].

In a study by Anastasopoulos et al. [11] the increase in IRI increases the accident rates by 95.72% of the roadway segment. Al- Masaeid [12] found that the road roughness will decrease single-vehicles accidents due to reduced speed but increases the multiple-vehicle accidents rate due to lateral shifts and speed differentials between road users. Inadequacy of roughness during wet road decreases the friction thus increases the IRI value [13].

Rutting is a deformation which was created by repetitive vehicle loading along the wheel path. Strat et al. [14] quantifies that rut accidents increases when the rut depth is higher than 7.6mm. Anastasopoulos et al. [11] stated that accident rates decreases with lower rutting depth through her models. Severe rutting might distract the driver from driving normally causing them to steer avoiding the defects which resulted into collision or running off track [15]. Chan *et al.* [16] found that accidents increase due to the rutting and roughness during night and under rainy weather conditions. Difficulty to observe rut path during night and wet weather and unawareness of driver usually when water film present are also may impose accidents. Hicks et al. [17] implemented 3 severity levels for rut which are low severity where rut depth is less than 6mm, moderate severity with rut depth ranging between 7 to 12mm which may lead to hydroplaning and high severity rut depth greater than 13mm that can increase the hydroplaning effect significantly. Laboratory test proves that the hydroplaning begins to occur even at the rut depth as low as 7.6mm. Lack of road microtexture to break down the developed thin water film also is a cause of hydroplaning [14].

Texture depth involved the microtexture and macrotexture of the road. Microtexture plays important role on dry weather friction which is good in braking effect and for deceleration of vehicles. Microtexture controls the contact of tyre and road surface. Macrotexture is in bigger scale which is more to the aggregates arrangement that possess strong effect on wet conditions than in dry condition which controls the water film under the tyre to reduce the skid resistance. A good microtexture usually provides adequate skid resistance at speed of less than 48 km/h. Higher macrotexture led to a safer driving amongst the road users. However, macrotexture creates tire- road noise due to its high texture depth [18].

A study by Pulugurtha et al. [19] using data from 4 highways pavements at North Carolina indicated that macrotexture of the pavement greater than 1.524mm able to reduce accidents and improve the highway safety. Poor pavement condition decreases the single vehicle severity at low speed roads while it increases the multiple vehicle crashes on high speed roads [20]. Rural road accident in Jordan accumulated to 12% of total accidents. 8% of rural road accidents were from road defects. Road defects in Jordan is encompasses about 45% of rural road accidents [12]. 93% of crashes involves human factor

while 16% of are due to roadway environment factor and 7% of vehicle factor [21]. Therefore, pavement condition is considered an important factor towards traffic safety.

Pertaining to the high accident number and the various road conditions in Malaysia, this paper will look into the accident numbers due to road condition factor and weather only. The analysis of this paper will be fully based on the relationship between the road accident numbers and the road condition factors such as the Rutting Depth (RD), Mean Texture Depth (MTD) and also International Roughness Index (IRI) and also weather conditions.

2. Data Collection

Pavement condition data and accident data were collected from the Malaysian North South Highway Authority which is also knows as PLUS (Projek Lebuhraya Utara Selatan). The data obtained were for 2 years period which are year 2013 and year 2014. The accident data includes the time and date of accident, the weather during accident, sections of the highway which are divided into 5 sections, vehicle involved and also the casualties. The pavement condition data collected were Mean Texture Depth (MTD), Rutting Depth (RD) and also International Roughness Index (IRI) values for the stretch of highway road ranging from south 0km up to 265km covering the southern region of Peninsula Malaysia. For the length and distance of the road conditions assessment, Multi Laser Profiler (MLP) was used to determine roughness, rutting, macro texture depth throughout the 265km. The Multi Laser Profiler measures road condition in longitudinal profile (IRI), traverse profiles for rut and surface texture measurement for Macro Texture Depth (MTD). These data were collected and analysed based on the classification as per the PLUS guideline. Table 1 below shows the road assessment criteria by PLUS highways for Rut Depth, Roughness and Texture Depth through their Pavement Assessment Condition Report 2013 and 2014.

Table 1. Pavement assessment criteria [5,6].

Pavement Condition	Roughness (IRI) (m / km)	Rutting (RUT) (mm)	Mean Texture Depth (MTD)(mm)
Good	< 2	< 5	> 0.5
Fair	2 – 3	5 – 10	0.3 – 0.5
Poor	3 – 3.8	10 - 20	< 0.3
Bad	> 3.8	> 20	NA

Accident data were obtained from the PLUS reports for year 2013 and 2014 provided by the Lembaga Lebuhraya Malaysia (LLM). The accident data were then mapped with pavement condition data such as IRI, Rut and MTD by Kilometer distance of the 265km southern region highway stretch which were collected through the Multi Laser Profilometer. The road condition during and after accident event were recorded to look into if the accident taken place relates to any road condition problems. The main highlights of the analysis are based on the road relationship between the road condition criteria with the accident number.

3. Result and Analysis

Results were computed based on the pavement condition throughout the highway section length to determine the severity of road conditions based on the level of severity. Accident due to the pavement conditions also were determined to observe the influence of the pavement conditions towards accident number.

3.1 Pavement Condition Analysis

Based on Figure 1 and Figure 2 shown below, the percentage in length throughout the tested highway of 265km, for the year 2013 shows about 70% of the road sections have good level of IRI followed by

26% fair, 3% poor and 1% bad sector. For year 2014, 67% of the road sections have good level of IRI followed by 28% fair, 4% poor and 1% bad sector.

The similar trend goes for the MTD in Figure 3 and Figure 4. Figure 3 shows the result of MTD where 93% of the road sections have good level of MTD followed by 7% fair. For year 2014, Figure 4 shows 98% of the road sections have good level of MTD followed by 2% fair. Apart from that, Figure 5 shows 90% of the road sections have good level of RD followed by 10% fair for year 2013. Meanwhile, Figure 6 shows 82% of the road sections have good level of RD followed by 17% fair. This indicates that PLUS Highway along Southern region was above accepted road condition level.

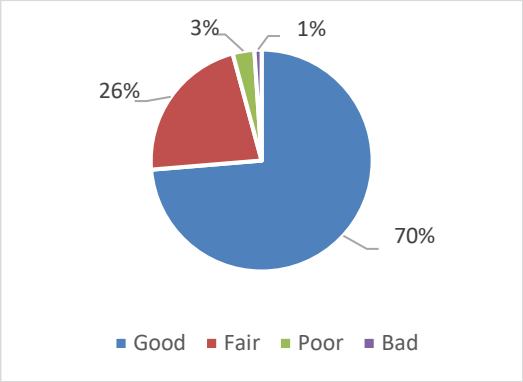

Figure 1. Percentage in Length of Road Based on of IRI Classification for Year 2013.

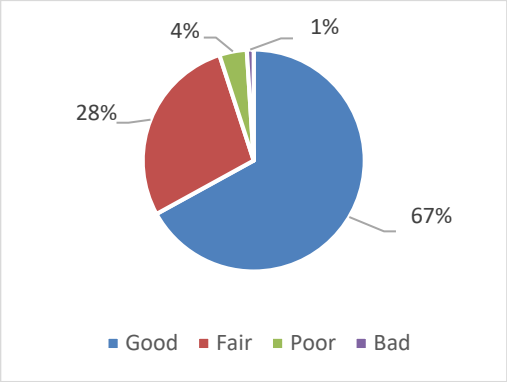

Figure 2. Percentage in Length of Road Based on IRI Classification for Year 2014.

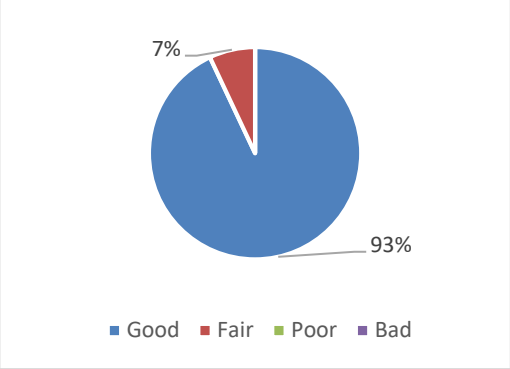

Figure 3. Percentage in Length of Road Based on MTD Classification for Year 2013.

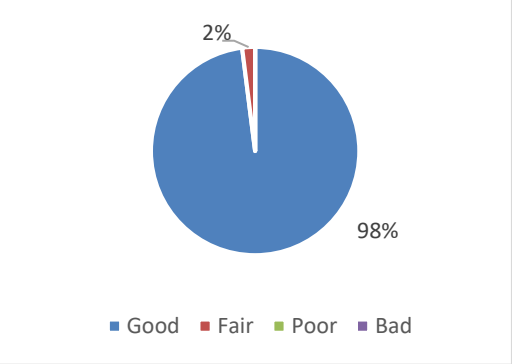

Figure 4. Percentage in Length of Road Based on MTD Classification Year 2014.

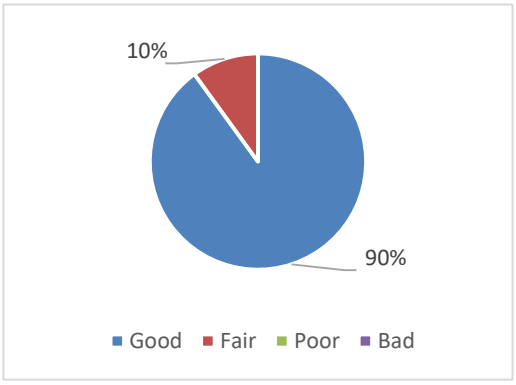

Figure 5. Percentage in Length of Road Based on RD Classification Year 2013.

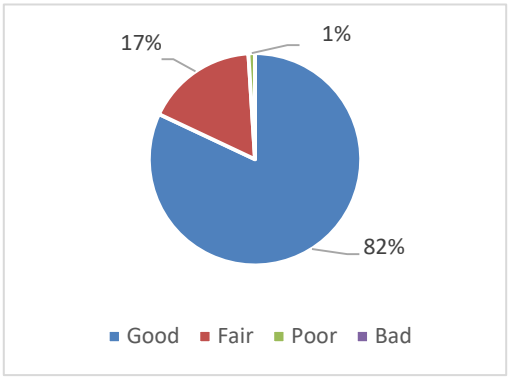

Figure 6. Percentage in Length of Road Based on RD Classification Year 2014.

Similarly, a study carried out by City University in collaboration with Selia Selenggara at Petaling District roads also shows that most of the roads fall under good and fair rating for IRI, RD and MTD. Results for the Petaling district roads are found to be in acceptable condition. Among the IRI, RD and MTD, the roughness is known to have more of the poor and bad rating level compared to rutting and mean texture depth [22]. Results in PLUS Malaysia reports also indicated that Malaysian North South highway stretch are mostly in good condition and above acceptable level for IRI, RD and MTD pavement conditions [5,6].

3.2 Accidents due to International Roughness Index (IRI)

Figure 7 shows the reduction in accident number as the IRI value gets higher. According to the PLUS guidelines in Table 1, the road condition is categorized as good when the roughness index is less than 2 m/km. The result shows that highest accident numbers is associated with the low IRI of 0 to 2m/km which is under good classification level. The percentage of accident occurred on good IRI condition is 69%, 27% on fair condition, 3% on poor 1% on bad IRI. In theory, good IRI level roads will have lesser or low accident numbers. This shows that high accident numbers for this particular PLUS highway could be caused by other factors instead of IRI since the percentage of length of the road sections having good IRI condition is relatively high.

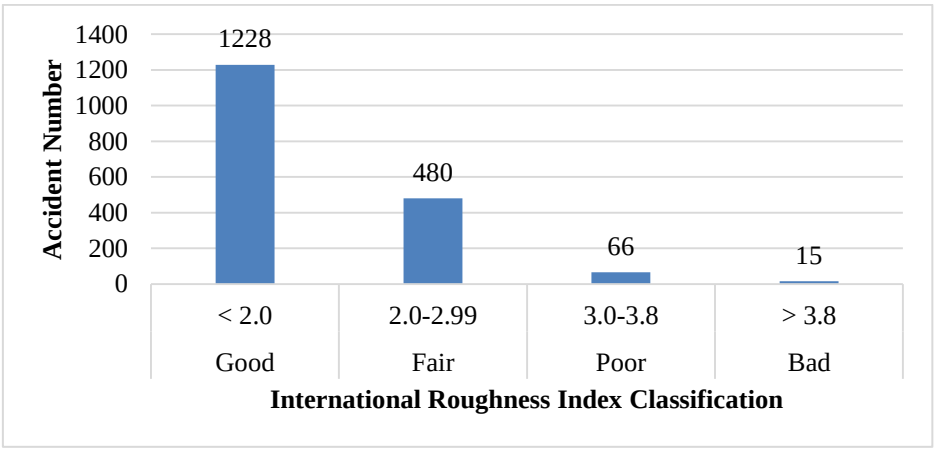

Figure 7. Accident number due to Roughness.

3.3 Accidents due to Mean Texture Depth (MTD)

Figure 8 shows reduction in accident number as the MTD value gets smaller. According to the PLUS guidelines, the road condition is categorized as good when the texture depth is more than 0.5 mm. The result shows that highest accident numbers is associated with the high MTD of more than 5m/km which is under good classification level. 95% of accident occurred on good MTD road condition while 5% on fair road condition. In theory, good MTD level roads will have lesser or low accident numbers. Accident that took place may not be particularly related to the texture depth along PLUS Highway. Other factors could be a possible cause for the accident to take place. This can be proven with Figure 3 and Figure 4 whereby the stretch of Highway section mostly is in the category of good MTD condition.

3.4 Accidents due to Rutting Depth (RD)

Based on the results in Figure 9, reduction in accident number can be observed as the RD value gets bigger. PLUS guidelines underlined that the road condition is categorized as good when the rutting depth is less than 5 mm. The result shows that highest accident numbers is associated with the low RD of less than 5m/km which is under good classification level. 86% of accident occurred on good RD road condition while 13% on fair road condition and 1% on poor RD condition. In theory, low RD level roads will have lesser or low accident numbers. Inline with the length analysis which shows that most of the assessed PLUS highway roads are in good condition, the RD is minimal and only focused at a certain road section. High percentage of length along the highway section were observed having god rut rating which indicated that the highway condition is above acceptable level. High accident along this road indicates that the possibility of other factors that contribute to accident such as human, environment, vehicle and behaviour factors.

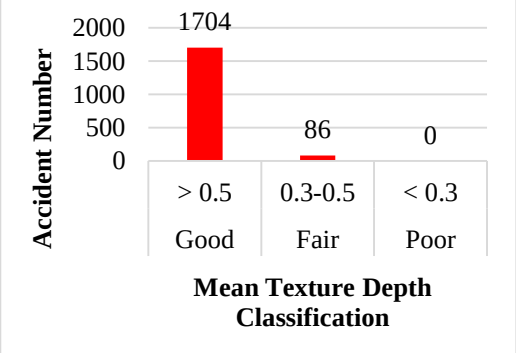

Figure 8. Accident Number due to Mean Texture Depth.

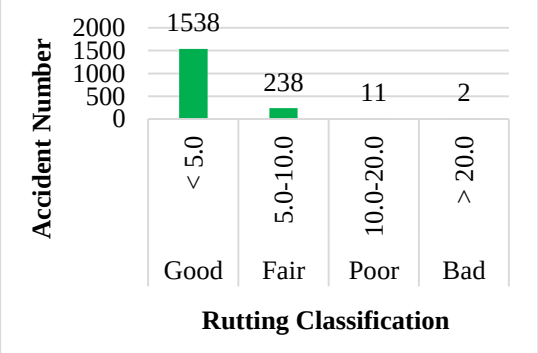

Figure 9. Accident Number Due to Rutting.

Based on results in Figure 7, Figure 8 and Figure 9 above, a large number of accidents took place on good road condition. It can be observed that the road conditions do not largely contribute road accident on Malaysian roads. A study by Sarabi et al. [23] in Iran indicates that human factors cause 90% of total accident while only 5% of the accident were from road factors. Results obtained by Darma et al. on their study done in Malaysia indicated that 11.25% of the total number of road traffic deaths is related to road defects whereas the remaining 88.75% is because of other reasons [24].

3.5 ANOVA Analysis

The ANOVA in Table 2 is computed using the data series of the accidents for the three road conditions types which are International Roughness Index (IRI), Mean Texture Depth, (MTD) and the Rutting Depth (RD).

Table 2. ANOVA analysis between road conditions.

	Df	Sum Sq	Mean Sq	F	P
Road Condition	2	56432	28216	22.72	0.000304
Residuals	9	11176	1242		

The ANOVA results shows significance value, P of 0.000304 of the three road conditions which is below 0.05. Therefore, there is a statistically significant difference in the accident numbers between road conditions.

Table 3. TUKEY HSD comparison.

	diff	lwr	upr	P adj
MTD-IRI	110.75	41.17825	180.32175	0.0041259
Rutting-IRI	-54.00	-123.57175	15.57175	0.1309158
Rutting-MTD	-164.75	-234.32175	-95.17825	0.0002582

Post hoc comparisons using the Tukey HSD test in Table 3 indicated that the IRI and the Rutting was significantly different than the MTD condition as both P adj value is lower than 0.05. However, Rutting-IRI did not significantly differ from each other where the P adj is 0.13. Taken together, these results suggest that MTD do contribute higher towards accident number compared to the IRI and Rutting.

4. Conclusion

All three road conditions IRI, MTD and RD indicates high accident numbers on good road condition rating. It is to be noted that the road condition throughout the measured roads mostly were in good condition road. The probability for accident to happen due to other factors could take place without depending on the road condition itself. Therefore, it can be concluded that accident on highway occur due to other factors apart from road conditions such as the human mistakes and also less safety concern. The road condition is mostly in good state and provides better safety for the road user.

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