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Modelling Malaysian operating speed prediction model at two-lanes rural highway while exiting curve

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ABSTRACT

The number of Traffic Prediction Model for Malaysia is relatively very few if to be compared to other developing country. Although it is important to have a prediction model as reference for Malaysian designer or planner of the highway, yet there are very limited numbers of prediction model specifically on Malaysia Traffic Prediction Model. Thus, this paper aims to produce a prediction model for highway environment in Malaysia. The derivation of this paper is particularly on the empirical data, model development, and the validation of models by comparing between empirical and predicted data. Empirical works involved 7 different sites across Malaysia, specifically the two-lane horizontal rural highway. Major on-site data is obtained by using Automatic Traffic Counter that is installed for a minimum of 24 hours at the site. The prediction model with a positive relationship between V85 CE and curve length is developed, but has negative relationship with curve radius, super elevation and deflation angle. As the result, final model for Curve End has been developed with 83.8% of R-sq, validated with Mean Absolute Percentage Error (MAPE), Root Mean Squared Error (RMSE) and Mean Absolute Error (MAE), with the result of 6.38%, 6.32 and 4.80. The Normality Test using Anderson Darling has indicated a P-Value of 0.717 and R-sq for Goodness of Fit of 0.9319.

1. Introduction

Highway design is a crucial issue for road user in terms of safety and comfort ability. The designer should not only consider the economic value but need to take into consideration on safety aspects of human factor while manoeuvring along horizontal curve while on their wheels. In having a good prediction model, it can lead to smooth and safe traffic operation and can contribute to safer highway and traffic movement in urban and rural roadway road. This is in line with some issue discussed in the previous research (Mohamed et al., 2012). In general, highway planner and designer play vital roles in highway geometric design as they contribute to the safety of the road user and to achieve sustainable road infrastructure. It can be seen that there is only a limited number of localized prediction model on highway curve in Malaysia and this can create limitations in terms of references and guideline for the relevant parties such as for local academic and highway practitioner and thus, the objective of this paper is to develop a prediction model based on the empirical data for Malaysian highway environment. This would be an additional scope on top of the existing model on horizontal curve carried out by previous researchers (Abbas et al., 2011).

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2. Literature review

The purpose of design consistency in establishing operating speed or also known as 85th percentile operating speed is to discover the relationship between the operating speed and elements of geometric design on the two-lane highways. This is due to the different measures in evaluating geometric design consistency, as presented in available research work, mainly between the designer design speed and driver operating speed to identify their potential applicability and any required future research; In a study on design consistency (Stamatiadis and Gong, 2007), the researcher discussed on the relationship between design consistency measures and safety, which is the main objective of the design consistency concept. He found that consistency measures were successful in identifying inconsistencies in the proposed alignments. However, he stated that the practice which had been done has suggested that; there is a need for more research work in a number of areas for complete and accurate consistency evaluation. One other study explored the concept of context sensitive design which is an emerging project development and geometric design approach. Design speed is perhaps the most influential factor and current practices on how this speed is selected and used may need to be reconsidered. The designer need to incorporate all the elements order for driver to drive at desired operating speed (Hassan et al., 2001). These have the similarity on the element for this study on the highway geometric towards the speed, either on the empirical speed on the selected site, or indirectly involved which happen to influence the prediction speed. This provides the similarity of this study with other previous studies conducted (Stamatiadis and Gong, 2007; Hassan et al., 2001).

Apart from that, guidelines (Aashto, 2001) especially for most USA country, concerned on most aspects of design such as recommending that the minimum values for design speed provided in an area to be higher, which may influence the driver expectation when driving on the roadway. The drivers may drive at the speed in the range of operating speed when approaching the curve. However, in this paper, the behaviour of the driver might differ due to the geographical location or subject to change on some local driver behaviour.

One of the study on the highway in Malaysia (Syed Abas, 2012) had found which was of the empirical research had presented design consistency models to estimate the 85th percentile operating speed models for the horizontal and vertical alignments at two-lanes rural highways. The study had been conducted in Lenggong, Perak. The spotted speed data were measured using laser gun detector. The researcher had conducted linear regression analysis to develop the 85th percentile speed models by combining the operating speed data and geometric element data from different selected horizontal and vertical alignment. Finally, he developed the horizontal and vertical alignment models in the study. As the study in (Syed Abas, 2012) have some similarity with the country the study was conducted, equipment and types of curve, this paper also comes with an additional aspects in terms of the addition of equipment and also the number of locations selected for the study. Furthermore, this paper only focuses specifically on the end of horizontal curve.

A study had been done on 15 lanes of rural highway. From the output of the study, the flow, the average platoon length, the traffic intensity, the percent-time-spent following, and the freedom of flow were observed. The study recommended that the data should be collected at field study during free flow condition. This somehow presented similarities and differences in a way that the similarity includes the rural highway and considering the free flow as recommended in (Syed Abas, 2012). This study is particularly conducted on two lanes highway compared to 15 lanes highway as conducted in the previous study (Syed Abas, 2012).

Most of the models developed in previous research were developed by using the spot-speed data obtained from equipment such as radar gun and laser gun. In Malaysia, there is no design consistency models that can be used to evaluate the geometric design on horizontal curve at two lanes rural highway being provided in Arahan Teknik (Jalan) 8/86 'A Guide on Geometric Design of Roads' (1986) since there is no detail investigation which includes the 85th percentile operating speed for horizontal alignment on rural highway in Malaysia had being conducted. This paper discussed a result form a mix data collection method with the use of Laser Gun and Automatic Traffic Counter (ATC). The usage of the ATC has been discussed and validated by other researchers in combining with other equipment in their study (Adnan and Tuan Besar, 2013).

2.1. Terminology

Speed is one of the important parameters when it comes to geometric design of highways. The term 'speed' is the general term that is commonly used to describe the actual speed of vehicle over a certain section of the roadway (Syed Abas, 2012).

2.2. 85th percentile speed

The 85th percentile speed is the speed at or below where 85 percent of the free-flowing vehicles travel. The distribution of observed speed is the most frequently used descriptive statistics for the operating speed associated with a particular location or geometric feature (Ashto, 2004). The 85th percentile is used in evaluating or recommending posted speed limits based on the assumption that 85 percent of the drivers are travelling at the speed that they perceived to be safe. In other words, the 85th percentile operating speed is normally assumed to be the highest safe speed for a highway section.

2.3. 85th ppercentile of operating speed

It is known as the speed at or below where 85% of a sample of free flowing vehicles is travelling. This is typically used as a baseline for establishing the speed (based on a spot speed study).

The distribution of observed speed is the most frequently used descriptive statistics for operating speed associated with a particular location or geometric feature (Syed Abas, 2012). In other words, this percentile is the highest safe speed for a roadway section.

The 85th percentile operating speed affects the selection of posted speed limit for a roadway. The conditions at and near the roadway are also related to the posted speed (Fitzpatrick et al., 2005).

3. Methodology

During the on -site activities for the data collection, large amounts of data have been collected from various equipment for model development. Mostly, the data is collected using Automatic Traffic Counter Named Traxx Apollyon continuously for a minimum of 24 hours at the location of each lane; lane 1 and lane 2. Prior to the data collection using Automatic Traffic Counter, the equipment need to be installed on the road surface at the location by using two pneumatic tube across the highway. This tube is installed with two feet distance to each other

mounted to the Automatic Traffic Counter to receive the pulse as the reading on vehicle speed (Adnan and Tuan Besar, 2013). This can be shown in Diagram 1 on the layout for installation of Automatic Traffic Counter Traxx Appllyon. To produce a realistic model development, the data collection will be carefully performed. The model will be thoroughly calibrated and validated using independent data set empirically.
The data obtained from the Automatic Traffic Counter are then further analysed by using Minitab software in running the statistical test and modelling.

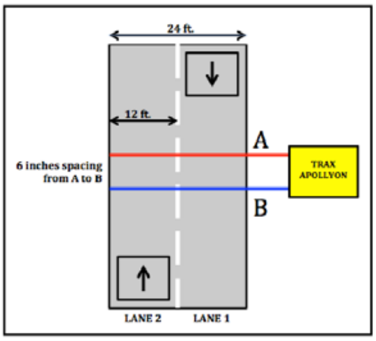

Fig. 1: Traxx Apollyon Layout Installation

3.1. Spot speed for data collection

Spot speed studies are conducted to estimate the distribution of speeds of vehicles in a stream of traffic at a particular location on a highway (Adnan and Tuan Besar, 2013). The speed of a vehicle is defined as the rate of movement of the vehicle; usually expressed in miles per hour (mph) or kilometres per hour (kmp/h) (Nicholas, 2009). Then, the data gathered in spot speed studies are used to determine vehicle speed percentile, which are useful in making many speed-related decisions. This method is adapted in collecting the data for the research.

3.2. Locations

The location for the data collection is at the various states in Malaysia at rural horizontal two lanes highway curve. Specifically, this paper will only discuss on Curve End while vehicle exiting curve for both lanes. The locations involved are Tasik Raban and Kampung Sumpitan in Perak,Kg Serating in Terengganu, Kg Felda Air Tawar 3 and 5 in Johor, Serian in Sarawak and Inanam in Sabah.

3.3. Equipment

The equipment for data collection is as follows:

3.3.1. Laser Gun Meter

Laser speed guns use a more direct method that relies on the reflection time of light rather than Doppler-Principle meters that used the reflection time of sound waves. This equipment requires human presence to operate the equipment (Adnan and Tuan Besar, 2013).

3.3.2. Automatic traffic counter

Automatic traffic counter is the equipment that will be used for continuous data collection. The ATC installation of the equipment will be done at site location. Some ATC required a rectangle location or loop need to be formed by the tube (Adnan and Tuan Besar, 2013) and some required other method such as having the tube to be placed across the data collection area. These methods have similarity in having the road tube or Pneumatic road tubes which are made of rubber tubes and need to be placed across the selected location to detect vehicles where it works by sensing the change in pressure that is produced when a vehicle tyre bypass the tube. The air pulse is then created, recorded and processed by a counter located on the side of the road (Leduc, 2008).

3.3.4. Ball bank

Ball bank is the tool used in measuring the super elevation along the curve in which it has been used by other researcher on their study regarding speed zoning and super elevation (Nicholson, 1998).
The Table 1 illustrates the usage of each equipment and measurement, unit.

Table 1: the usage of each equipment and measurement

Predictor	Coef	SE Coef	T	P
Constant	87.399	3.335	26.20	0.000
Curve Radius -	0.015945	0.007569	-2.11	0.037
Curve Length	0.06167	0.01057	5.84	0.000
Deflection Angle	-0.25091	0.04931	-5.09	0.000
e	-1.4969	0.1394	-10.74	0.000
S = 4.79511	R-Sq = 83.8%			

4. Results and discussion

4.1. Prediction model

The statistical prediction model for Curve End ($V85_{CE}$) is derived from the regression and the equation is;

$$V85_{CE} = 87.4 - 0.0159R + 0.0617L - 0.251A - 1.50e \quad (1)$$

Whereby $V85_{CE}$ is the prediction value, R is the Curve Radius, L is the Curve Length and A is the Deflation Angle and lastly e is the value for super elevation. The result has shown that the significant P value for all elements is less than 0.05 and R-sq of 83.8%.

In equation (1), it has been indicated that there is a positive constant of 87.4 with $V85_{CE}$ together with

Curve Length and any increase in L will result in the increase in prediction speed as by norms, it is caused by comfortableness of driver while manoeuvring along the curve. On the other hand, Curve Radius, Angle and super elevation have negative impact on the prediction value and an increase of the number will lead to the driver to be more alert to curve in order to steer the steering along the curve.

4.2. Residual data

By using Anderson-Darling Normality Test, the result of the normality test for the residual data has been conducted, and the result has shown a valid result where the P-Value is 0.717 which is more than 0.05 as shown on Fig. 1.

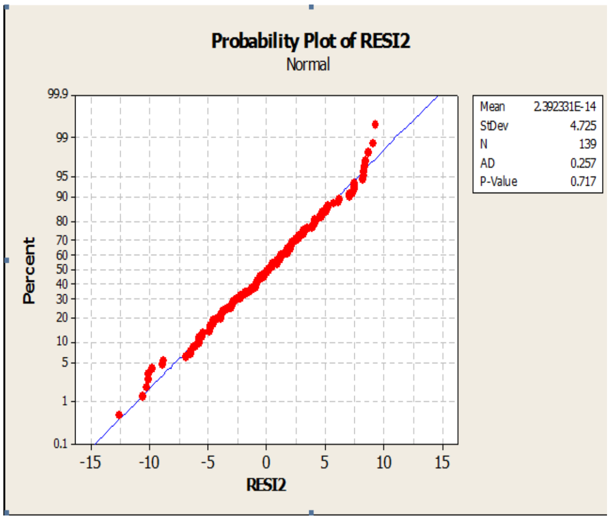

Fig. 1: Anderson-darling normality test

The discrete statistic indicates that distribution of data with the skewness and kurtosis are -.019 and -0.27 with standard deviation and median of 4.724 and 0.164 respectively.

The general distribution of data can be seen from the histogram in Fig. 2.

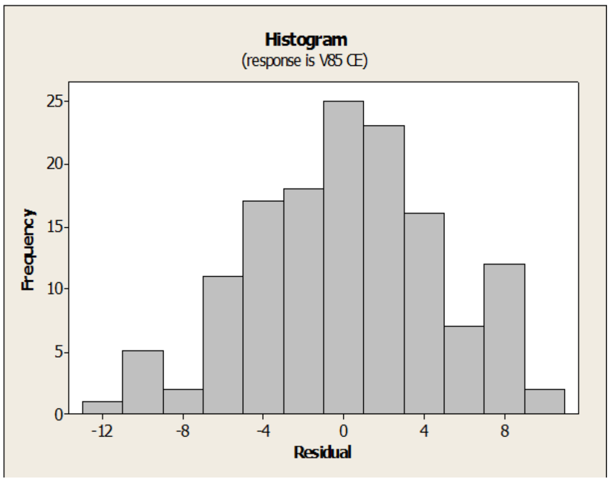

Fig. 2: Histogram of data distribution

The residual plot also does not show any pattern except for the distribution of data from 9 to - 12 in Fig. 3.

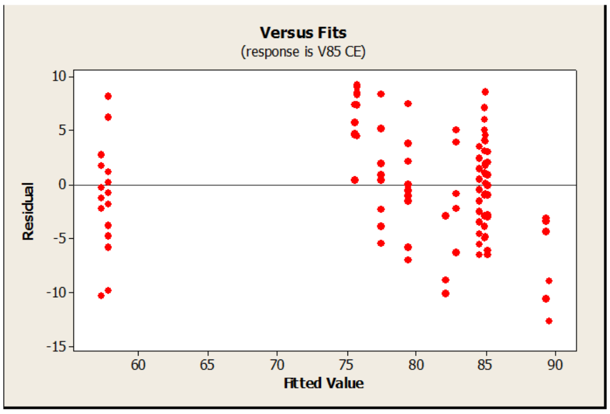

Fig. 3: Data pattern

4.3. Validity

In confirming the V85CE prediction model, The validity of the mode has been conducted by using Mean Absolute Percentage Error (MAPE), Root Mean Squared Error (RMSE) and Mean Absolute Error (MAE), the comparison between empirical data and predicted model was conducted and the result of the validity for RMSE (km/hour) is 6.32, MAE (km/hour) is 4.80 and MAPE (%) is 6.38. This is parallel with the other researches Aris (2010) and Adnan (2007) that required the number of RMSE and MAE not more than 30 and close result for the MAPE is between 5 to 10%. On the other hand, Fig. 4 below on goodness of fit for empirical vs. prediction indicates the empirical data and predication close to the R-sq is 0.9319.

4.4. Comparison with other models

The developed model was compared to other model.

$$V85 = 102.45 + 0.0037L - (2741.75 + 1.75L) / R \quad (2)$$

Equation (2) is the Design Guide for Canada Road for 2002. The selection of the model is the equation (2) is having minimum parameter for the model development (L is Curve Length and R is Curve Radius).

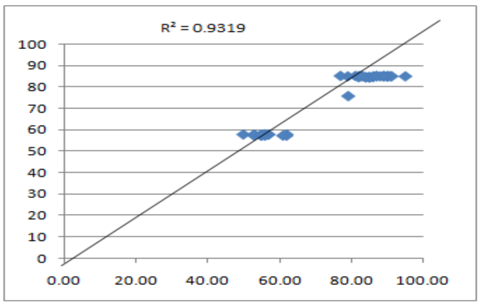

Fig. 4: Goodness of fit of empirical Vs prediction V85

4.5. Comparing empirical data and canadian prediction model

Where the R^2, RMSE, MAE MAPE show 0.93225,13.19.12.80 and 17.67 indicating that the equation (1) and (2) are similar in Fig. 5.

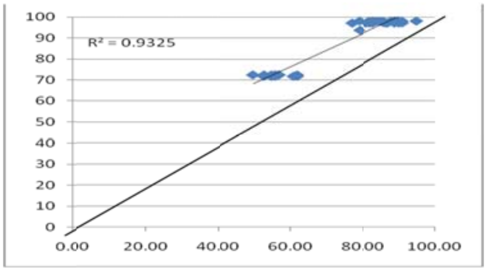

Fig. 5: Empirical Vs design guide for Canada road

The second model is the model mostly reviewed and compared by other researches which is by Voigt for his studies in the year of 1996;

V85 = 99.61-2951.37/r+0.014Lc-0.13Ω-71.82e (3)

Although Equation (3) was developed way back on 1996, it has exactly similar variable with equation (1) developed on this study. (r = radius, Lc = Length Curve, Ω = ideflation angle and; e = super elevation)

Where the R^2, RMSE, MAE MAPE show 0.93225, 6.55, 4.93 and 6.65 indicating the equation (1) and (3) are similar.

It can be seen that equation (1), (2) and (3) are similar in better in R^2, and in other hand ,RMSE,MAE and MAPE as demonstrated above indicates that equation (1) is better in Fig. 6. Overall result can be summarized as in Table 2.

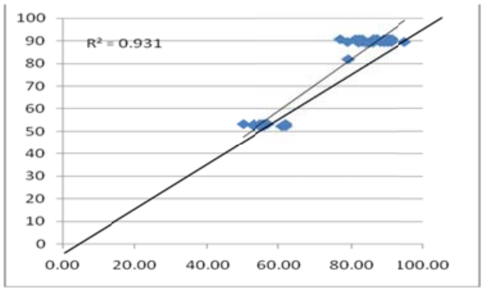

Fig. 6: Empirical Vs prediction model by voigt

Table 2: Result Summarization

Comparison	R^2	RMSE	MAE	MAPE
Prediction Model Vs Empirical Data	0.9319	6.32	4.8	6.38
Prediction Model Vs Canada Model	0.93225	13.19	12.8	17.67
Prediction Model Vs Voigt Model	0.93225	6.55	4.93	6.65

5. Conclusion

The number of prediction model for Malaysian local traffic model is growing with the existence of this paper. Although the paper concentrated only on Curve End, it managed to produce meaningful outcome with the support of validity test, goodness of fit and significant of P-Value which have been conducted for the model. As prediction model for Curve End has been successfully developed, it will fill the gap for the lack of prediction model for Malaysian traffic horizontal highway curve and achieve the aim to develop a prediction model focusing on local traffic condition. It directly has achieved the objective of the research. The prediction model has undergone a statistical test and has shown significant output and can be considered as a relevant prediction model to as a part of contribution to the local highway society. With the existence of the model, the highway engineer and highway planner or those who have interest on Malaysian Traffic and Prediction are able to refer to the model as a reference. This made the model as referable source either for the utilization or further improvisation.

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