Australian Journal of Basic and Applied Sciences, 5(5): 590-598, 2011
ISSN 1991-8178

Predicting Speed Model of Horizontal Curves on Exclusive Motorcycle Lane

Seyed Farzin Faezi, Hussain Hamid, Seyed Rasool Davoodi.

Dept. of Civil Engineering, University Putra Malaysia, 43400, UPM Serdang, Selangor
Darul Ehsan Malaysia.

Abstract: The prediction and estimation of operating speeds on highways are of great significance to planners and designers. A variety of physical factors may influence speeds on highways. Horizontal curvature has the greatest impact on speed. The objective of this study was to develop speed prediction equation on horizontal curve using the geometric characteristics of the curve at 11 sites in exclusive motorcycle lane. To achieve this objective, the speed of motorcyclist was measured in exclusive motorcycle lanes in Malaysia. The multiple linear regression analysis was conducted to evaluate the effect of horizontal curve variables on the speed reduction, expressed as 85^{th} percentile speed reduction, as a dependent variable. The main independent variables entry in the regression analyses were radius of the curve (R), length of tangent (T) and deflection angle (Δ). Also the effect of curve radius on the predicted 85^{th} percentile curve speed was investigated. The findings from the efforts were guidelines in design for different curve types. These guidelines will help both designer and decision makers in evaluating different alignment alternatives.

Key words: Exclusive motorcycle lane, speed prediction, linear regression model, horizontal curve, operating speed

INTRODUCTION

The goal of transportation is generally stated as the safe and efficient movement of people and goods (Hashim *et al.* 2005). To achieve this goal, designers use many tools and techniques. One technique used to improve safety on roadways is to examine the geometric of the design. According to accident, fatality and safety issues, prediction and estimation of speeds on highway are of great significance to planners and designers. Also one of the fundamental elements of roadway design is the design speed, since it has the potential of affect almost every roadway design speed aspect (Faezi *et al.* 2010). Generally, drivers will make fewer errors handling geometric features that conform to their expectations. The weakness of the design speed concept is that it uses the design speed of the most restrictive geometric element the section. An inconsistency in design can be described as a geometric feature or combination of features with unusual or extreme characteristics that drivers may drive in an unsafe manner. This situation could lead to speed errors, inappropriate driving manoeuvres, and or an undesirable level of accidents (Davoodi *et al.* 2011, Faezi *et al.* 2011).

Predicting operating speed models is the more common method for evaluating the consistency of a roadway. These models estimate 85^{th} percentile operating speeds at points along a roadway by considering its horizontal and vertical alignment. These alerts the designer when there is an inconsistency in the roadway such as a large change in 85^{th} percentile operating speed between successive alignment elements.

Currently, most of the studies that have deal with safety and capable of predicting the speed of vehicles on highways, but no research is known about the speed prediction of motorcyclists on exclusive motorcycle lanes. There are also no statistical models to estimate operating speeds on horizontal curve on exclusive motorcycle lanes. The study's objectives were to develop motorcycle speed prediction equation of horizontal curves on exclusive motorcycle lanes in Malaysia. Regression models were developed to predict the 85^{th} percentile speed of motorcyclists on horizontal curves, based on the geometry of the curves.

Corresponding Author: Seyed Farzin Faezi, Dept. of Civil Engineering, University Putra Malaysia, 43400, UPM Serdang, Selangor Darul Ehsan Malaysia.
E-mail: farzin_faezi@yahoo.com

Background:

The majority of researchers propose determining the motorcycle operating speed using the geometric characteristics of the horizontal alignment. According to the American Association of State Highway and Transportation Officials (AASHTO) "operating speed is the speed at which drivers are observed operating their vehicles during free-flow conditions". The 85^{th} percentile of the distribution of observed speeds is the most frequently used measure of the operating speed associated with a particular location or geometric feature (AASHTO, 2004). Therefore, the 85^{th} percentile speed is used throughout this research as a measure of the operating speeds on exclusive motorcycle lanes.

Several studies (Leisch, 197; Shoueiri, 1987; Brenac, 1996; Krammes, 1992; Al-Masaeid, 1995) indicate that sudden changes in operating speed because of horizontal curves are a major cause of traffic accidents on two lane highways. For example, Lamm *et al*. (1986) reported that half of all accidents on two-lane rural highways may be indirectly attributed to inadequate speed adaptation. Also, they indicated that fatal or injury accidents accounted for more than 70% of the accidents on curves on two-lane rural highways. Numerous researchers have carried out studies on the driver speed, emphasizing the importance of defining analytical models that link driver speed and road characteristics. Moreover the majority of operating speed studies focuses on curved road sections, where high dangerous situations happen. These speed models are affected mainly by longitudinal elements of the horizontal alignment. Horizontal elements impact the speeds of cars on curves; therefore, because highway features change, so do the speeds. A review of vehicle speed models was conducted to identify previous research efforts into the specific issue of operating speed by roadway users. These models of speed can provide an insight to motorcycle speed model.

Speed Model on Horizontal Curves:

Speed prediction on highways has been researched extensively for horizontal curves on relatively flat terrain. Previous research indicates that curve radius is the most important element in determining speeds on horizontal curves. Superelevation and deflection angle are other variables that have been used in some regression equations to predict operating speeds on horizontal curves (Bennett, 1994).

Previous research has shown that linear regression can be used to predict operating speeds on horizontal curves. There are several models that predict the operating speed on circular curves. This may be the result of differences in driver behavior from one location to another, and it highlights the fact that no single model is universally accepted. The majority of researchers propose determining the operating speed using the geometric characteristics of the alignment. Most models use a single variable, which is usually the radius of circular curves (R) or the degree of curvature (DC). With the aim of making a comparative, the four models were explained: Lamm and Choueiri (1987) (Eq.1); Morrall and Talarico (1994) (Eq.2); Krammes *et al*. (1995) (Eq.3); and Castro *et al*. (2006) (Eq.4). They have shown that linear regression can be used to predict operating speeds on circular curves.

$$V_{85} = 94.39 - 3,189.24/R \qquad R^2 = 0.787 \qquad (1)$$
$$V_{85} = \exp(4.561 - 0.00586DC) \qquad R^2 = 0.631 \qquad (2)$$
$$V_{85} = 102.44 - 2,471.81/R + 0.012\, L_c - 0.10\, \Delta \qquad R^2 = 0.820 \qquad (3)$$
$$V_{85} = 120.16 - 5,596.72/R \qquad R^2 = 0.82 \qquad (4)$$

Where:

R=radius of circular curves; DC=degree of curvature; Δ=deflection angle; and L_c=horizontal curve length.

Also a project in Europe was reported by Cardoso *et al*. in NCHRP Report 502 (Wooldridge, 2003). Fifty curves in four countries were studied for their effects on speed. Unimpeded approach and curve speeds were examined using several different variables: curve radius, curve length, lane width, shoulder width, and longitudinal gradient. Of those variables, the only significant ones were curve radius and the 85^{th} percentile speed on the preceding tangent. Models were developed for each of the countries included in the data collection effort (France, Portugal, Greece, and Finland).

Table 1 lists the equations. A similar form was obtained for three of the countries, resulting in equations containing the reciprocal of $\sqrt{R}$; the equation for the remaining country (France) used the reciprocal of R^2. A common model for the complete database was developed using the reciprocal of $\sqrt{R}$, although it was decided that the models developed for the individual countries were superior. The models developed were as follows.

In another research Bennett investigated the effect of curvature on speed. The operating speed on horizontal curves and approach tangents at 58 sites located around New Zealand was studied (Bennett, 1994).

The resulting regression analysis model for predicting 85^{th} percentile curve speeds for passenger cars was:

$85^{th} = 61.58 + 0.4854\ Va - 4516/R$

Where,
85^{th} = 85th percentile curve speed in km/h;
Va = 85th percentile approach speed in km/h, $12.8 < Va < 173.4$ km/h
R= curve radius (m), $24 < R < 625$ (m).

In general, as the radius of the curve decreases or the degree of the curve increases, the operating speed decreases.

Table. 1: Regression Equations for Unimpeded Speeds on Curves in Europe ((M.D.Wooldridge *et.al*, 2003)

Country	Regression Equation	Num. Obser.	R^2	MSE
France	S_{85}= 49.22 292736/R ^{2} +0.454S85AT	28	0.8	4.02
Finland	S_{85}= 51.76 337.78/(R)+ 0.604S85AT	5	0.71	5.92
Greece	S_{85}= 41.363 294/(R)+ 0.699S85AT	9	0.92	5.91
Portugal	S_{85}= 25.01 271.5/(R)+ 0.877S85AT	35	0.9	6.1
Complete database	S_{85}= 33.08 289.99/(R) + 0.759S85AT +C	77	0.87	5.8

Where:
S_{85}= 85th percentile of the unimpeded speed distribution (km/h).
R = curve radius.
S85AT = 85th percentile of the unimpeded speed on the tangent immediately preceding the curve section (km/h).
c = constant used to adjust the Y intercept for each country, with
c = 0.000 Finland c =-3.665 France
c = -0.033 Greece c = 2.107 Portugal
1 km/h = 0.62 mph.

Data Collection:

In order to examine the relationship between speed and curve, it was necessary to find a set of road segments in which data on the horizontal alignment were available. This section describes the site selection and data collection methodology used. The speeds predicted using linear regression equation represent the speeds measured at the midpoint of the curve. The speeds measured at a specific location are generally accepted as a measure of the operating speeds at that location.

Data were obtained in Federal Highway (F02) and Putrajaya-Cyberjaya Expressway in Malaysia that has several different horizontal curve configurations and one way. A total of 11 curves with various geometric characteristics were chosen on 11 different segments. The data collection had two main components:
1- geometric data of the site; and 2- speed data.

Geometric Data:

Some researchers for speed prediction on highways indicate that there are several important elements in determining speed on horizontal curves. Curve radius, superelevation, deflection angle, degree of curvature, length of curve, and cross section are examples of variables that have been used in regression equations to predict operating speeds on horizontal curves. Also curve radius is considered to be the most important element in determining operating speed on horizontal curves; therefore, most researchers have used it as the dominant independent variable in their regression analyses. The geometric data collected for this study included information about horizontal curves such as: radius of curve (R), deflection angle (Δ), degree of curvature (DC), length of curve (L), length of tangent (T), total paved width (W), station of the beginning of the curve (PC) and the end of the curve (PT). The study was limited to simple horizontal curves on exclusive motorcycle lanes in Malaysia.

Operating speeds of different sites were observed under daylight and good pavement conditions (dry-weather conditions) with low traffic volume and no access points, because other roadside conditions might have adversely affected the operating speed of motorcyclist riding on the curves.

Speed Data:

Speed diminishes before the initiation of a circular curve, constant speed is maintained along it, and then speed increases again. A sufficient number of motorcyclist speeds were observed so as to limit the statistical sampling error. At least 100 observations were taken at each site. Previous research has suggested that 50 spot speed observations at each site in each direction would be adequate to estimate the operating speed at each location (Hashim, 2005; McLean, 1981).

Individual motorcycles spot speeds were collected using a portable laser speed detector and recorded on professional digital video camera (JVC model GP-KS1000). Both devices set up on the top of the pedestrian bridge nearby the study site or were located where they could see the speed measurement point. Furthermore, it was concealed as much as possible when taking speed readings to prevent motorcyclist from being influenced. A laser speed detector (Ultra Lyte 200 LR) developed by laser Technology Inc., USA was used to measure the individual motorcycle speed under the study. Speeds were measured at the half length of the horizontal curve (center of the horizontal curve). Motorcyclists that were not at free-flow speed were not included in the sample. Design methodology is based on a series of speed prediction models developed through regression analysis.

Data Analysis and Results:

The starting point of the analysis was the prediction of speeds on curves depending on the geometric characteristics of each curve. A total 11 horizontal curves belonging to 11 sites was carried out taking into consideration the data on speed. The geometric data from the data collection sheets were entered into a spreadsheet. Descriptive statistics were calculated using Statistical Package for Social Sciences (SPSS). These statistics included mean speed, 85th percentile speed, standard deviation, skewness, kurtosis, and coefficient of variation. Table 2 presents descriptive statistics for 11sites characteristics collected.

The speed data were tested for normality to determine whether the sample came from a normally distributed population by using the Kolmogorov-Smirnov test. The Kolmogorov-Smirnov test is suitable for analyzing speeds since speeds have a continuous distribution (Fitzpatrick, 2000). The normality test results indicated that speeds followed a normal distribution (Table 3). Therefore, the speeds were modelled using a normal distribution and standard statistical techniques. The normality test results indicated that at all of the sites, speeds did follow a normal distribution. As a result, the data were assumed to be normal.

Table. 2: Descriptive Statistics for Characteristics in Exclusive Motorcycle Lane.

	Mean Speed	85th Percentile Speed	Standard Deviation	Skewness	Kurtosis
Site 1	57	62	6.65	0.049	0.594
Site 2	56.6	62	6.03	-0.293	0.585
Site 3	56.4	61	5.96	-0.011	1.38
Site 4	54.4	59	4.37	-0.648	0.969
Site 5	49.7	54	4.91	-0.541	-0.474
Site 6	48.9	52	4.27	-0.519	0.932
Site 7	44.5	48	5.78	1.05	3.28
Site 8	37.5	42	6.2	-0.871	-0.193
Site 9	33.5	38	5.7	-0.309	-0.309
Site 10	24.85	27	3.55	1.704	3.338
Site 11	20.59	22	2.42	0.96	3.53

Table. 3: One-Sample Kolmogorov-Smirnov Test.

		Speed
N		11
Normal Parameters^{a}	Mean	48.09
	Std. Deviation	14.244
Most Extreme Differences	Absolute	.154
	Positive	.148
	Negative	-.154
Kolmogorov-Smirnov Z		.509
Asymp. Sig. (2-tailed)		.958

Correlation between Variables:

Correlation may exist between geometric characteristics and curve speeds associated with segments. Variables used in the correlation analysis of data for this study were: speed: 85^{th} percentile curve speed, Radius (R): radius of curve; Delta (Δ°): deflection angle; L: length of curve; T: length of tangent; C: length of chord and Width: total paved width. Table 4 shows Pearson correlation coefficients between pairs of the independent variables selected for analysis. The pairs of variables represented in the cells of the table, had statistically significant correlation at 95 percent confidence. The values indicate that there are significant correlations between most of the independent variables chosen for study.

Table. 4: Correlations between Geometric Characteristics and Curve Speeds

		Speed	Radius	Delta	T	C	Width
Speed	Pearson Correlation	1	.900**	-.939**	.913**	.919**	.707*
	Sig. (2-tailed)		.000	.000	.000	.000	.015
	N	11	11	11	11	11	11
Radius	Pearson Correlation	.900**	1	-.933**	.958**	.975**	.481
	Sig. (2-tailed)	.000		.000	.000	.000	.134
	N	11	11	11	11	11	11
Delta	Pearson Correlation	-.939**	-.933**	1	-.853**	-.879**	-.569
	Sig. (2-tailed)	.000	.000		.001	.000	.068
	N	11	11	11	11	11	11
L	Pearson Correlation	.933**	.838**	-.794**	.935**	.921**	.716*
	Sig. (2-tailed)	.000	.001	.004	.000	.000	.013
	N	11	11	11	11	11	11
T	Pearson Correlation	.913**	.958**	-.853**	1	.998**	.551
	Sig. (2-tailed)	.000	.000	.001		.000	.079
	N	11	11	11	11	11	11
C	Pearson Correlation	.919**	.975**	-.879**	.998**	1	.538
	Sig. (2-tailed)	.000	.000	.000	.000		.087
	N	11	11	11	11	11	11
Width	Pearson Correlation	.707*	.481	-.569	.551	.538	1
	Sig. (2-tailed)	.015	.134	.068	.079	.087	
	N	11	11	11	11	11	11

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Model Development:

In order to identify the most promising combinations of independent variables, a linear regression procedure was used. Linear regression analysis had been used to determine if any relationship exists and fits the data well between the parameters in order to develop a model. The linear regression selection procedure analyzes all possible combinations of variables presented. The purpose of this approach is to identify the best regression model according to specified criteria. After the best model was selected, more detailed tests were performed on this model. Table 5 displays R, R squared (R^2), adjusted R squared, and the standard error. R is the correlation between the observed and predicted values of the dependent variable. Its large value indicates a strong relationship.

The values of R range from -1 to 1. The sign of R indicates the direction of the relationship (positive or negative). The absolute value of R indicates the strength, with larger absolute values indicating stronger relationships. The values of R squared (R^2) range from 0 to 1. Use R^2 to help you determine which model is best. Small values indicate that the model does not fit the data well.

Table 5 indicated that three models have good R^2 values, and that the model three has the highest R^2 values of 0.99. This means that 99% of the observed variation in the dependent variable has been explained by the set of independent variable used in the regression equation. High values of R^2 are usually related to good regression models; but R^2 does not account for the number of parameters in the regression equation.

Also Adjusted R squared attempts to correct R squared to more closely reflect the goodness of fit of the model in the population. In this case R^2 and Adjusted R^2 are the same. Overall, Table 5 inferred that the three regression models describe the data "Well". But among them, model three qualifies as the best regression model that describes the independent variables. Thus select model three for continues analysis.

ANOVA was used to test the hypothesis which relates to the significance of regression. A decision to reject null hypothesis (Ho) implies an acceptance of alternative hypothesis (H_1). The analysis of variance is summarized in Table 6. Interpreting the F-statistic depends on the degrees of freedom that are related to the number of independent variables and sample size. The F-statistic must exceed the critical F-statistic to validate the regression model. A high F-ratio indicates a strong relationship between the dependent variable and the dependent variables. In Table 6, the computed F-statistic, F = 747.55, exceeds the critical value $F_{0.05\,,\,3\,,\,8}$ = 4.07, therefore the null hypothesis, Ho: $\beta_1 = 0$, is rejected for a significance level of $\alpha = 0.05$. Rejecting null hypothesis implies that there is linear relationship between operating speed (dependent variable) and independent variables.

Also if the significance value is small ($p < 0.05$) then reject the null hypothesis. In other word the independent variables do a good job explaining the variation in the dependent variable and model is significant. If the significance value is larger ($p > 0.05$) then the independent variables do not explain the variation in the dependent variable. This table shows three models are significant and useful for predicting the response.

The coefficients for the stepwise regression models for 85th percentile speed on horizontal curves and some of the analysis results are summarized in Table 7. The t and Sig (p) values give a rough indication of the impact of each predictor variable. A big absolute t value and small p value suggests that a predictor variable is having a large impact on the criterion variable. In this case t for model three equal 6.37, -3.513, 2.946 and

$t_{\frac{a}{2}}(d_f)$=

$t_{0.025}(10)$= 2.228. These three absolute t values is more than 2.228, so in this model, total lane width (W), deflection angle (Δ), and length of tangent (T) are significant and must be include the model. Also if p-value ≤ 0.05, we shall reject the null hypothesis (parameter is not a useful predictor) or can conclude that there exists enough evidence that the slope of the regression line is not zero and, hence, in this equation all regression parameters (βi) are statistically significant (P-

value < 0,05). That means three parameters are useful as a predictor in model. The equation for predicting 85th percentile curve speed, using the selected independent variables, is show below:

$$V_{85\ Curve} = 19.357\ W - 0.394\ \Delta + 0.654\ T \quad \text{(E.q 1)}$$

Where:

$V_{85,Curve}$ = 85th percentile motorcycle speed on horizontal curves, km/h
W= total lane width (W)
Δ= deflection angle (Δ)
T= length of tangent (T)

It can be concluding that, the operating speeds of the motorcycles were depending on the total lane width, deflection angle and radius. A positive sign of regression parameters indicates that the total lane width (W) and length of tangent (T) increases the 85th percentile curve speed. Also negative sign of regression parameters indicates that the deflection angle (Δ) decreases the 85th percentile curve speed.

Table. 5: Model Summary.

Model	R	R Square[b]	Adjusted R Square	Std. Error of the Estimate
1	.973[a]	.947	.941	12.103
2	.996[c]	.993	.991	4.756
3	.998[d]	.996	.995	3.494

a. Predictors: Width

b. For regression through the origin (the no-intercept model), R Square measures the proportion of the variability in the dependent variable about the origin explained by regression. This CANNOT be compared to R Square for models which include an intercept.

c. Predictors: Width, Delta

d. Predictors: Width, Delta, T

$\frac{a}{2}$

Table. 6: Analysis of Variance (ANOVA)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	26004.120	1	26004.120	177.517	.000[a]
	Residual	1464.880	10	146.488		
	Total	27469.000[b]	11			
2	Regression	27265.457	2	13632.728	602.793	.000[c]
	Residual	203.543	9	22.616		
	Total	27469.000[b]	11			
3	Regression	27371.361	3	9123.787	747.550	.000[d]
	Residual	97.639	8	12.205		
	Total	27469.000[b]	11			

a. Predictors: Width

b. This total sum of squares is not corrected for the constant because the constant is zero for regression through the origin.

c. Predictors: Width, Delta

d. Predictors: Width, Delta, T

Table. 7: Stepwise Regression Coefficients of Models

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	Width	14.581	1.094	.973	13.324	.000
2	Width	27.442	1.775	1.831	15.460	.000
	Delta	-.663	.089	-.885	-7.468	.000
3	Width	19.357	3.039	1.292	6.370	.000
	Delta	-.394	.112	-.526	-3.513	.008
	T	.654	.222	.219	2.946	.019

Table 8: Skewness and Kurtosis.

N Valid	11
Missing	0
Skewness	.724
Std. Error of Skewness	.661
Kurtosis	-.484
Std. Error of Kurtosis	1.279

Evaluation of Speed Model:

The performance of the speed models was evaluated by analyzing the model residuals and the sensitivity of the parameter estimates. The residual analysis involved comparing the observed speeds with the speeds estimated by the prediction models. The residuals were calculated by subtracting the estimated model values from the observed values.

To test for the normality of residual distribution, stepwise regression analyses was performed. Two crucial measurements of residual distribution in the descriptive statistics procedure are the Skewness statistic and the Kurtosis statistic. Skewness measures the degree to which a variable's distribution (in this case, residual distribution) is pulled out in the positive or negative direction by outliers. The most desirable Skewness statistic would be zero, which would indicate a perfectly normal distribution.

However, Skewness statistics of between-1 and 1 are acceptable; with values less than two standard errors of Skewness being the most desirable. Also Kurtosis is a measurement which complements the Skewness statistic. It also has an acceptable value of -1 to 1 (Wimmer, 2005). In this case Skewness is equal 0.724 and Kurtosis equal -0.484 that both parameters are acceptable (Table 8). A residual analysis was performed to assess the goodness-of-fit of the equations developed to predict 85th percentile curve speed. From the values shown in the table 8, it can be found that there is no statistically significant difference between the observed and predicted 85^{th} percentile curve speed.

Effect of Curve Radius on the 85th Percentile Curve Speed:

To investigate the effect that curve radius alone had on 85^{th} percentile speeds, the 85^{th} percentile curve speeds calculated from the observations were plotted against the corresponding radius (R). These data points are shown in Figure 1. From the plot, it can be seen that as R increases, the 85^{th} percentile speed increases.

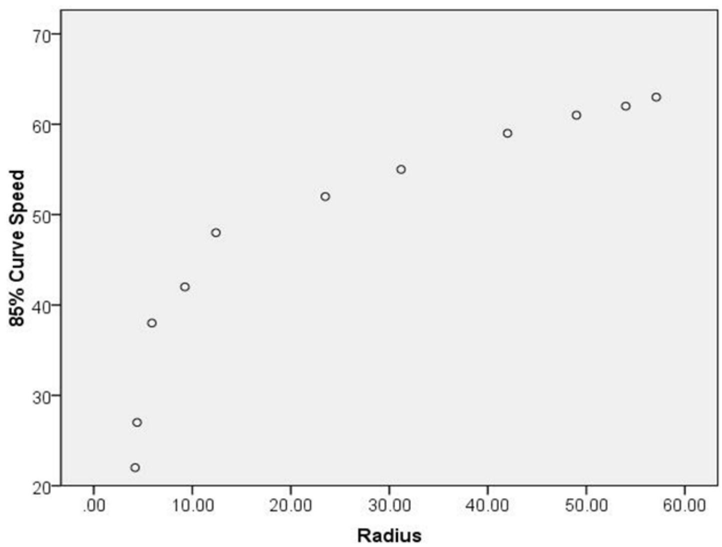

Fig. 1: Relationship between curve radius and 85th percentile speed.

Conclusion:

A primary objective of this research was to develop speed prediction equation of horizontal curves. The data analysis started with preparation for analysis and the checks for normality. It was followed by the identification of the independent variables that were correlated with 85th percentile speed. Then a series of statistical procedures were applied to the data to identify the best combination of variables to predict 85th percentile curve speed.

The variables selected in the initial analyses were used to refine and select the regression models for motorcyclist speeds on the different alignment combinations. Several parameters have relationship between them but there is no relationship exists for several others parameters. Regression models were developed for horizontal curves for different ranges of curves. These equations should be most accurate when used under conditions similar to those where the data were collected.

By using the residual analysis, it was determined that there was no statistically significant difference between the observed and the predicted 85th percentile curve speed.

These findings were based on speed and geometry data from 11 sites distributed in Malaysia. Predicting the 85th percentile speed on modernized sections would help designers in finding solutions that meet both the motorists' expectations and the current design standards to the possible extent.

ACKNOWLEDGMENTS

The writers would like to thank the Road Safety Research Centre and Traffic Lab in UPM and Road Care Sdn.Bhd for their technical assistance and the JKR (Public Work Department Malaysia) Administrations for the permission to collect the data along their roads.

REFERENCES

Al-Masaeid, H.R., M. Hamed, M. Aboul-Ela and A.G. Ghannan, 1995. Consistency of horizontal alignment for different vehicle classes. Transportation Research Record, Washington. D.C., 1500.

American Association of State Highway and Transportation Officials (AASHTO), 2004. A policy on geometric design of highway and streets. Washington. D.C.

Bennett, C.R., 1994. A Speed Prediction Model for Rural Two-Lane Highways. Ph.D. thesis, University of Auckland, New Zealand.

Brenac, T., 1996. Safety at curves and road geometry standards in some European Countries. Transportation Research Record, Washington, D.C., 1523.

Castro, M., L. Iglesias and R. Rodríguez-Solano, 2006. Desarrollo de un sistema para el análisis de la consistencia del trazado de carreteras. Internal Rep., Universidad Politécnica de Madrid (in Spanish).

Davoodi, S.R., H. Hussain, S. Arintono, M. Ratnasamy, S.F. Faezi, 2011. Motorcyclist Rear Brake Simple Perception-Response Times in Rear-End Collision Situations, Traffic Injury Prevention, 12(2): 174-179.

Faezi, S.F., H. Hussain, S.R. Davoodi, 2010.The Effect of Pavement Marking on Speed Reduction in Exclusive Motorcycle Lane in Malaysia, Contemporary Engineering Sciences, 3(3): 149-155.

Faezi, S.F., H. Hussain, S. Arintono, S.R. Davoodi, 2011. Level of service model for exclusive motorcycle lane, Indian Journal of Science and Technology, 4(4): 387-393.

Fitzpatrick, K., L. Elefteriadou, D.W. Harwood, J.M. Collins, J. McFadden, I.B. Anderson, R.A. Krammes, N. Irizarry, K.D. Parma, K. Passetti and K.M. Bauer, 2000. Speed Prediction for Two-Lane Rural Highways. Draft Final Report FHWA-RD-99-171.

Hashim, I.H. and R.N. Bird, 2005. Operating Speed Behaviour Models for Single Rural Carriageways-Case Study of North East of England, Proceedings of the 37th Annual Conference, Universities' Transport Study Group, University of Bristol, Bristol.

Homburger, W.S. and J.H. Kell, 1998. Fundamentals of Traffic Engineering, 12th Ed. Institute of Transportation Studies, University of California at Berkeley.

Krammes, R. and S.W. Glascock, 1992. Geometric inconsistencies and accident experience on two-lane rural highway. Transportation Research Record, Washington. D.C, 1356.

Krammes, R.A., *et al*. 1995. Horizontal alignment design consistency for rural two-lane highways. Rep. No. FHWA-RD-94-034, Federal Highway Administration, Washington. D.C.

Lamm, R., J. Hayward and J. Cargin, 1986. Comparison of different procedure for evaluating speed consistency, Transportation Research Record, Washington. D.C., 1100.

Lamm, R. and E.M. Choueiri, 1987. Recommendations for evaluating horizontal design consistency based on investigations in the State of New York. Transportation Research Record, Washington. D.C., 1122.

Leisch, J.E. and J.P. Leisch, 1977. New Concepts in Design Speed Application. Transportation Research Record, Washington. D.C., 631.

McLean, J., 1981. Driver speed behaviour and rural road alignment design. Traffic Eng. Control, 208-211.

Morrall, J.F. and R.J. Talarico, 1994. Side friction demanded and margins of safety on horizontal curves. Transportation Research Record, Washington. D.C., 1435.

Shoueiri, E.M., 1987. A Design Procedure to Determine Critical Dissimilarities in Horizontal Alignment and Enhance Traffic Safety by Appropriate Low-Cost and High Cost Projects. National Science Foundation, Washington. D.C.

Wimmer, R.D., J.R. Dominick, 2005. Mass Media Research: An Introduction. Wadsworth Publishing Company.

Wooldridge, M.D., K. Fitzpatrick, D.W. Harwood, I.B. Potts, L. Elefteriadou and D.J. Torbic, 2003. Geometric Design Consistency on High-Speed Rural Two-Lane Roads, NCHRP Report 502. Transportation Research Record, Washington. D.C.