Indian Journal of Science and Technology Vol. 4 No. 4 (April 2011) ISSN: 0974- 6846

# Level of service model for exclusive motorcycle lane

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## Abstract

The concept of level-of-service (LOS) is meant to reflect the trip quality a traveler will experience on a roadway or other transportation facility. The present paper illustrates a statistical model for estimating motorcycle level-of-service (LOS) at exclusive motorcycle lanes in order to predict riders' perceptions about the service quality. 261 motorcycle riders contributed in a survey and rated the service quality of 500 m segments of exclusive motorcycle lane as it is shown on the scenes which are videotaped from the rider's perspective. Participants were asked to rate (using predefined scores) the service quality of clips on 6 point scale ranging from excellent to very poor after watching 10 video segments. The resulting linear regression model shows that the mean rider rating from motorcyclists' survey had statistically significant correlations with operational and design characteristics ($R^2$=0.62). This method is hoped to provide the means required in order to develop a procedure resulting in specific feedbacks to be effective for exclusive motorcycle lane level-of-service criteria and thresholds.

**Keywords**: Exclusive motorcycle lane, Malaysia, roadways, surface transport, two-wheeler safety.

## Introduction

On the roads which have high traffic levels, conflicts are likely to be created between the vehicles when heavy commercial vehicles and fast moving cars are required to share the same roadway facilities with motorcycles which are slower and less protected vehicles. Studies have proven that segregation is the best engineering method to safe motorcyclists (Umar *et al.,* 1995). The concept of segregating vulnerable road users from other traffic is not new in the field of safety management. Traffic segregation meaning segregation of pedestrians and bicyclists from the motorized traffic has long been accepted and implemented in many of the industrialized cities and it includes a part of the planning framework in the transport planning procedures. Similarly in developing countries there have been a number of studies conducted on the potential application of road marking installations for mixed flow conditions. Exclusive motorcycle lane used to improve motorcycle safety at roads due to reduced conflicts between vehicles and motorcyclists (Fig. 1). On such road sections, segregation of the motorcycle flows from the other traffic vehicles will not only help improve motorcycle safety due to reduced conflicts but also can improve the flow of traffic particularly when there is heavy motorcycle traffic. Moreover, providing exclusive lanes can make the riding safer and more comfortable for the motorcyclists. So understanding quality of motorcycle facilities will help policy makers find the most appropriate policies to enhance the safety and traffic performance on the roads. It may also help the industry to supply motorcycles with the right marketing strategy (Hsu & Ahmad Farhan, 2003).

*Fig.1. Exclusive motorcycle lanes, federal highway F02, Malaysia*

### *Motorcycle level-of-service (LOS)*

The methodology in the highway capacity manual (2000) defines standard calculation of level-of-service. HCM employs the level-of-service concept as a qualitative index of a traveller's trip quality under specified roadway, traffic and control conditions. Level-of-service in HCM (version 2000) is expressed as qualitative measures that characterize operational conditions within a traffic stream and their perception by motorists and passengers. The terms used in describing each LOS (designated as A through F, with LOS A being the most desirable) include travel time, freedom to manoeuvre, traffic interruptions, comfort, safety and convenience for the facility type (Transportation research board, 2000).

Estimation of motorcycle LOS is the most common approach in assessing the quality of motorcycle facilities. Measure of riding conditions would help in roadway cross-sectional design and would help in evaluating the existing motorcycle lanes. Studies on pedestrian, bicycle and vehicle has found that there are numerous literatures about level-of-service (LOS) and factors affecting it (Sorton & Walsh, 1994; Landis & Petritsch, 2005; Zhang & Prevedouros, 2005). Unluckily there is not much work and experiences available so far on the application of exclusive lanes for motorcycles. Lack of the proper commitment needed to plan safety strategies as well as the financial limitations usually integrate and lead to ignoring these measures. Malaysia is, perhaps, the first country to make use of such measure in order to improve motorcyclists' safety. Presently, there is relatively little research relating to motorcycle facilities and only a few articles considered relevant to this

Indian Journal of Science and Technology Vol. 4 No. 4 (April 2011) ISSN: 0974- 6846

study. Also there are no studies available on motorcycle LOS and measuring the relationship between prescribed level of service assessment methods and rider perceptions for exclusive motorcycle lanes. The objective of this study is to provide mean LOS rating as an index that combines the factors and indicates a mean value for the motorcycle LOS.

*Study purpose & hypotheses*

This study addressed that question by asking motorcycle riders to rate the quality of segments of exclusive motorcycle lanes. Specific objectives were to: 1) To develop the model for motorcycle LOS to estimate the relationship between mean rider rating and some variables (motorcycle speed, motorcycle volume, total lane width, and surface pavement quality) of exclusive motorcycle lanes and 2) To define the LOS criteria.

**Methodology**

This study aimed to develop and assess a method used to collect the riders' perceptions of LOS for different roadway conditions. At present, there is no methodology which is widely accepted by engineers and planners allowing them to determine the levels of service index for exclusive motorcycles. Also, the highway capacity manual (HCM) does not define the level of service for exclusive motorcycle lanes (Highway capacity manual, 2000). The focus of the study was to predict mean rider perception of service quality on exclusive motorcycle lanes. To address these questions, it was necessary to present identical conditions repeatedly to different riders. An ideal research setting would likely be to obtain opinions directly from riders as they rode on real exclusive motorcycle lanes, but the costs and risks of on-road data collection was prohibitive. The researcher opted to use video presentation (video survey). The strengths of video presentation are that it approximates real-world stimuli, provides the ability to control the presentation of conditions, allows for repeated presentations to different groups, and provides a safe testing environment. The methodology of this study includes two constituents. The first one is the relationship between the motorcycle quality of service for exclusive motorcycle lanes and a set of geometric and operational conditions as its determinants. This relationship can be used to determine the motorcycle quality of service for any particular exclusive motorcycle ways. The other component is a mechanism to convert the determined quality of service to a particular level of service designation.

*Data collection method*

Data collection method involves moving camera (from eye level) riding on exclusive lanes (federal highway Route 2(F02) in the state Selengor, Malaysia, 30 KM) using a digital video recording camera and capturing short clips. The participants viewed the clips video from the actual exclusive motorcycle lanes and scored them. It has been found out that making use of videotape technology in order to obtain ratings can provide consistent results in previous studies about bicycles, pedestrians and vehicles (Dixon, 1996; Landis *et al.*, 1997; Harkey *et al.*, 1998; Flannery, 2008). In these research, participants evaluated geometric and operational road conditions on a 6 point (A to F) scale on how well they were served (how safe, comfortable, convenience, traffic interruptions, freedom to manoeuvre they felt) as they rode each segment. Level A was considered as the safest or most comfortable (or least hazardous); Level F was considered to be the most unsafe or most uncomfortable (or most hazardous). In this research an overall of 50 clips were prepared the length of which was 30 sec in 500 m segments. Each participant viewed 10 thirty second video clips of a test motorcyclist riding along an exclusive motorcycle lane. The video clips projected on a large screen and the participants were asked to rate motorcycle speed, motorcycle volume, total lane width, and surface pavement quality of each clip on a 6 point scale (from excellent to very poor) right after viewing it (Table 1). The participants viewed and rated (the mentioned 4 parameters) with respect to how comfortable, convenient and safe they would be riding there under the geometric and operational conditions shown. This method doesn't place its participants on actual exclusive motorcycle roadways and through traffic conditions. At last, participants were compensated for their time with a souvenir. The testing occurred in a college classroom. The participants were seated on chairs, watched the videos as they were projected onto a screen from a projector situated on a table (Fig. 2). A sound of the road noise recorded during the ride was played through a personal computer sound system (consisting of a subwoofer and stand-alone speakers).

*Fig. 2. Survey session.*

*Measure parameters & clip description*

The first step in the study is concerned with the establishment of data necessities. Determining the data requirements is essential in order to ensure that all selective information would be collected efficiently and accurately. Two video cameras, a portable laser speed detector, ruler distance measurer and a tri-pod were the equipments used during the field ride. One camera focused on the road from the rider perspective and another video camera recorded the speedometer. A professional Sony digital video camera (HDR-XR520E) was used to capture the roadway scenes from the rider perspective. In other word, the recorder assistant used moving camera from eye level of motorcycle rider position when riding along

*Table 1. Rating scale.*

| Rating | Description |
|---|---|
| 1 | Excellent |
| 2 | Very good |
| 3 | Good |
| 4 | Fair |
| 5 | Poor |
| 6 | Very poor |

Indian Journal of Science and Technology Vol. 4 No. 4 (April 2011) ISSN: 0974- 6846

the exclusive lanes. The video camera was mounted on the shoulder of the motorcycle recorder assistant and was used to provide a video and audio. Simultaneously, individual motorcycles spot speeds were measured 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. 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. Besides video recording technique, also measure total lane width (W). The total paved width of motorcycle lanes were measured in metres by using a ruler distance measurer. Surface pavement quality is the final parameter influencing on LOS. The riding surface smoothness influences on the comfort, safety and speed of motorcyclists. The irregularities on the pavement surface can do much more than causing an unpleasant ride. The pavement quality evaluation was based on pavement condition rating (PCR) standard (Chhote, 1998).

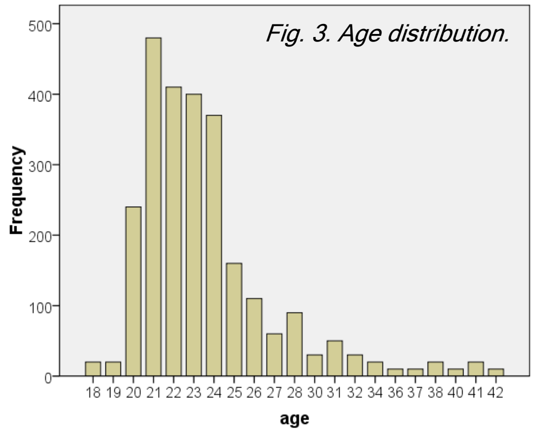


*Fig. 3. Age distribution.*

After the capturing and videotaping from eye level of motorcycle rider position, complete for each set of roadway segments, the video editing will be begin. Adobe premiere 6.5 was used to edit and create clip. Once all the clips were made, transitions were put in between each clip on the final media to help proctors and participants identify each clip (e.g. Clip #4) using the same software package. Then, the clips were merged with AVI or MPG. Finally the clips were replayed and the motorcycles volumes were counted. The manual tally-counter was used to count the number of motorcycles passing across the lane as observed on the computer screen. Time, date, and location information on the videotapes record during the experiment data collection. Each video clip illustrated a different scenario in terms of the impact of the volume of the motorcyclists, the total lane width, the pavement surface quality and the motorcyclists' speed. There were a myriad of volume, speed, total lane widths and pavement conditions present along the exclusive motorcycle lanes. The traffic volumes ranged from a low of 60 to a high of 1440 motorcycle per hour, with a mean of 451. 85% speeds ranged from 20 to 81 km/h with a mode of 64 km/hr. The total lanes width ranged from 1.50 to 3.85 m. All data were collected in exclusive motorcycle lanes in Malaysia.

*Sites selection & criteria*

The sites to be selected must be able to cater for the needs of the intended data analysis. On the other hand, in consideration that this is a basic study in motorcycle traffic sciences, the study initially focused on the ideal condition. This was done to help the survey participants focus on the geometric and operational conditions while minimizing their focus on additional physical discomfort or comfort that may be caused by noticeable uphill or downhill roadway segments. As such, the site selection criteria only considered the straight and level basic segments along the federal highway (F02) in state of Selangor-Malaysia. The other important criteria for the selection of study sites along the F02 motorcycle lane was the availability of high positions or concealed locations such as the pedestrian overhead bridges or high grounds. This is to ensure that the observed motorcyclists were not inhibited by any external factors such as the presence of study enumerators at the vicinity of the study site. Also for better definition, maps of the locations of the data collection sites found during the data collection. Except of federal highway (F02) many locations have been found and applied for capture the film. These sites include: 1- Subang Jaya airport; 2- Putrajaya-Cyberjaya expressway.

*Participants' demographics*

In this study, simple random sampling technique was used to select the participants. A simple random sample is a sample chosen using a method that ensures that every individual member of the population has the same chance of being selected. 261 motorcyclists completed the information regarding age, gender, education and experience in survey forms. The participants ranged in age from 18 to 42. Fig. 3 shows a histogram of the ages of the motorcyclists participating in the study.

*Table 2. Correlations between participant scores & field data.*

| | | Speed | Lane width | Volume | Pavement quality |
|---|---|---|---|---|---|
| Score speed | Pearson correlation | -.658** | -.566** | -.084** | .459** |
| | Sig. (2-tailed) | .000 | .000 | .000 | .000 |
| | N | 2610 | 2610 | 2610 | 2610 |
| Score width | Pearson correlation | -.800** | -.847** | -.149** | .346** |
| | Sig. (2-tailed) | .000 | .000 | .000 | .000 |
| | N | 2610 | 2610 | 2610 | 2610 |
| Score volume | Pearson correlation | .022 | .124** | .789** | -.079** |
| | Sig. (2-tailed) | .259 | .000 | .000 | .000 |
| | N | 2610 | 2610 | 2610 | 2610 |
| Score pavement | Pearson correlation | -.608** | -.331** | -.180** | .808** |
| | Sig. (2-tailed) | .000 | .000 | .000 | .000 |
| | N | 2610 | 2610 | 2610 | 2610 |

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

Indian Journal of Science and Technology Vol. 4 No. 4 (April 2011) ISSN: 0974- 6846

*Table 3. Model summary.*

| Model | R | R square | Adjusted R square | Std. error of the estimate |
|---|---|---|---|---|
| 1 | .707[a] | .500 | .500 | .79319 |
| 2 | .761[b] | .580 | .579 | .72733 |
| 3 | .783[c] | .613 | .612 | .69817 |
| 4 | .791[d] | .625 | .625 | .68716 |

*a. predictors: (constant), speed; b. predictors: (constant), speed, volume; c. predictors: (constant), speed, volume, pavement quality; d. predictors: (constant), speed, volume, pavement quality, lane width.*

## Results

*Comparison between participant scores and field data*

One of importance of the test demonstrates that there are relationships between field data and motorcyclists' perceptions scores. The most common statistic to measure the degree of relationship between two variables is the Pearson correlation. In fact, a correlation expresses whether two variables tend to increase or decrease together. Pearson correlation value varies between -1.00 (perfect negative relationship) and +1.00 (perfect positive correlation). In this case, a correlation analysis was performed to determine what relationships may exist between the dependent variable and independent variables. Table 2 shows that p-value is less than 0.05 and concludes no difference between participants' scores and amount of field data of that. Also, high correlations (-0.658, -0.847, 0.789 & 0.808) that comparing data using the video simulation and during the field event indicated no significant difference. That means data collected using this methodology would correlate closely with data collected using a real field data collection effort. Therefore, it can present the motorcyclists view of riding environments without exposing them to potentially hazardous traffic and roadway conditions.

*Development of the model*

When equations are used, the most important issue is selecting a statistical model which is the most appropriate for the nature of the data collected. A linear regression model was chosen for the statistical analysis approach. This model is well suited to the analysis of continuous data and ordinal (or ranking). The raw operational data were analyzed for two purposes: to develop the best model for LOS and defined LOS criteria. The participants should be asked for their perceived quality of service for exclusive motorcycle lanes. This model is viewed as the measure of effectiveness and can be used in designating qualitative levels of service.

*Linear regression analysis*

This is a collective name for the techniques used to analyze the relationship between two or more independent variables and a dependent variable. In the other words, regression will predict the dependent variable using information derived from an analysis of the independent variables. For each video clip, the value of speed, volume, total lane width, and pavement surface quality variables were collected in the field. Also for each video clip, the mean value of score rating (mean scores) of score speed, score volume, score total lane width, and score pavement surface quality were collected from the questionnaires. Using variables collected in the field as the independent variables and the mean rating score for each roadway segment as the response variable (derived from the questionnaires), regression model is developed to predict the comfort level of the motorcyclists. The model is developed for all the motorcyclists. This analysis approach determines all main effects, searches for significant square and the interaction terms and applies to the initial model development. The perceived quality of service (LOS) was first hypothesized as a function of a set of variables which takes the general form of linear regression:

Perceived quality of service (LOS) =F ($X_1$, $X_2$, $X_3$…) (1)

A comprehensive Pearson correlation analysis of the extensive array of roadway and traffic variables with respect to LOS was employed. As a result, the following variables were chosen to be considered in the second step of the model development process: the motorcycle volume, the motorcycle speed, the total lane width and the pavement surface condition. Accordingly eqn. 1 can be rewritten as:

Perceived quality of service (LOS) =F (V, S, W, P) (2)

Where, V = motorcycle volume (Mc/h); S = 85% of motorcycle speed (Km/h); W = total lane width (m); P = pavement surface condition (PCR); using a linear stepwise regression analysis technique, the model form would be:

Perceived quality of service (LOS) =b+$a_1$ (V) +$a_2$ (S) +$A_3$ (W) + $a_4$ (P) (3)

Table 3 displays R, R squared, adjusted R squared, and the standard error. In this case, the correlation coefficient for model 4 is relatively strong and statistically significant (R=0.62, p<.001). It shows that about 0.62 the variation in time is explained by the model. Thus, model 4 is selected to continue the analysis. Also, in all the model Sig value was less than 0.05 which means that all the models can be used. Besides R-squared, ANOVA (Analysis of variance) was used to check how well the model fits the data. ANOVA was used to test the hypothesis which relates to the significance of regression. A decision to reject null hypothesis ($H_0$) implies an acceptance of alternative hypothesis ($H_1$). The analysis of variance is summarized in Table 4. In Table 4, the computed F-statistic, F = 923.1, exceeds the critical value $F_{0.05,4,2609}$ = 2.37, therefore the null hypothesis, $H_0$: $\beta_1 = 0$, is rejected for a significance level of $\alpha = 0.05$. Rejecting null hypothesis implies that there is linear relationship between mean scores value and field data. Also the unstandardized beta coefficients give a measure of the contribution of each variable to the model. A large value indicates that a unit change in this predictor variable has

Indian Journal of Science and Technology Vol. 4 No. 4 (April 2011) ISSN: 0974- 6846

*Table 4. ANOVA (Analysis of variance).*

| Model | | Sum of squares | df | Mean square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 2463.863 | 1 | 2463.863 | 2373.667 | .000[a] |
| | Residual | 2707.101 | 2608 | 1.038 | | |
| | Total | 5170.964 | 2609 | | | |
| 2 | Regression | 2784.609 | 2 | 1392.305 | 1521.039 | .000[b] |
| | Residual | 2386.355 | 2607 | .915 | | |
| | Total | 5170.964 | 2609 | | | |
| 3 | Regression | 2992.068 | 3 | 997.356 | 1192.857 | .000[c] |
| | Residual | 2178.869 | 2606 | .836 | | |
| | Total | 5170.964 | 2609 | | | |
| 4 | Regression | 3031.949 | 4 | 757.987 | 923.115 | .000[d] |
| | Residual | 2139.015 | 2605 | .821 | | |
| | Total | 5170.964 | 2609 | | | |

*a. predictors: (constant), speed; b. predictors: (constant), speed, volume; c. predictors: (constant), speed, volume, pavement quality; d. predictors: (constant), speed, volume, pavement quality, lane width.*

a large effect on the criterion variable. The t and Sig (p) values give a rough indication of the impact of each predictor variable. Table 5 shows the coefficients of four models. In this case, coefficients of speed, volume, pavement quality, width in best model (model 4) are -0.025, 0.001, 0.324, -0.459 respectively. And significant of four parameters less than 0.05 that means all parameter contribute in model.

*Reporting the results*

In the results section, the p value of the model by citing the R-square ($R^2$) is reported which indicates the strength of the model. Four models were estimated and the report is as follows:

Perceive quality of service (LOS)= 5.45- 0.047 speed (4)

$R^2$ =0.50 Model 1

Perceive quality of service (LOS) = 5.276-0.05 speed + 0.001 volume (5)

$R^2$ =0.58 Model 2

Perceive quality of service (LOS) = 4.224 - 0.041 Speed + 0.001 Volume + 0.232 Pavement (6)

$R^2$ =0.61 Model 3

Perceive quality of service (LOS) = 4.376 - 0.025 Speed + 0.001 Volume + 0.324 Pavement - 0.459 width (7)

$R^2$ =0.62 Model 4

The first model analysis explored how the quality of service perceptions of the survey participants correlated with just the measure of speed. The negative coefficient calculated for speed indicates that, as speed increases, the likelihood of a rider perceiving a worse LOS decreases. The high t-statistic (coefficient divided by its standard error) for speed indicates that it is certainly significant in the model. The $R^2$ value for model 1 equals 0.5 meaning 50% of the variation in mean participant rating can be estimated by the model. However volume, pavement and lane width do not contribute significantly to model. The second model analysis incorporated additional volume into the model to predict perceived LOS. The additional volume variable found to be significant has a positive coefficient sign. As expected, a low volume resulted in a better LOS ranking. The rationale given by the vast majority of the participants for this was because they felt they had more movement opportunities for any given traffic conditions and more “outs” in case something went wrong. While speed was still a significant variable, its t-statistic was considerably high in this model. Likewise, a decrease in speed, as weighted by high volume, resulted in a higher probability of a worse LOS ranking. This second model has R-square ($R^2$) value of 0.58, slightly superior to model 1.

The third model was attempted using speed, volume and pavement quality as the primary predictor of mean participant rating. Also lane width did not contribute significantly to the prediction power of the model. The positive coefficient calculated for pavement quality indicates that riders perceive a worse LOS, as pavement quality is worse. In this model the R-square ($R^2$) values were 0.61, meaning 61 percent of the variation in mean participant rating can be estimated by the model. The fourth model analysis incorporated total lane width into the model to predict perceived LOS. The total lane width variable found to be significant has a negative coefficient sign. The negative coefficient calculated for lane width indicates that, as lane width increases, the likelihood of a rider perceiving a worse LOS decreases. This model has R-square ($R^2$) value of 0.62, superior of model 1, 2 and 3. Also all four variables contributed in model.

*Distribution in linear regression analysis*

It was also necessary to examine the residuals (the

*Table 5. Coefficients.*

| Model | | Unstandardized coefficients B | Unstandardized coefficients Std. error | Standardized coefficients Beta | t | Sig. |
|---|---|---|---|---|---|---|
| 1 | (Constant) | 5.450 | .055 | | 98.783 | .000 |
| | Speed | -.047 | .001 | -.707 | -51.061 | .000 |
| 2 | (Constant) | 5.276 | .051 | | 103.064 | .000 |
| | Speed | -.050 | .001 | -.765 | -59.009 | .000 |
| | Volume | .001 | .000 | .288 | 22.242 | .000 |
| 3 | (Constant) | 4.224 | .086 | | 49.177 | .000 |
| | Speed | -.041 | .001 | -.628 | -40.709 | .000 |
| | Volume | .001 | .000 | .333 | 26.028 | .000 |
| | Pavement quality | .232 | .016 | .237 | 14.943 | .000 |
| 4 | (Constant) | 4.376 | .086 | | 50.807 | .000 |
| | Speed | -.025 | .002 | -.372 | -11.773 | .000 |
| | Volume | .001 | .000 | .372 | 28.008 | .000 |
| | Pavement quality | .324 | .018 | .331 | 17.757 | .000 |
| | Lane width | -.459 | .050 | -.246 | -9.228 | .000 |

Indian Journal of Science and Technology Vol. 4 No. 4 (April 2011) ISSN: 0974- 6846

differences between observed values & expected or "predicted" values) in the regression models to determine if their distribution was normal. In order for the linear regression to have valid results, the regression residuals must have a normal distribution. 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. In this case Skewness is equal -0.031 and Kurtosis equal 0.364 that both parameters are acceptable (Table 6). The normal probability plot (zresid normal p-p plot) is another test of normally distributed residual error, to check on whether the residuals are normally distributed. Under perfect normality, the plot will be a 45° line. For this study, it is close and indicated normality in the residuals (Fig. 4). Residuals can be tested by making a scatter plot of the standardized predicted value of the dependent variable and the standardised residuals. The Scatterplot should show that 95% of the residuals fall between -2 and +2, and only 1 in 1000 should fall outside plus or minus 3. The goal of a residual plot is to see a random scatter of residuals (Fig. 5). In this case is a good scatter. The indications are that mean scores is much more normally distributed, its Skewness and Kurtosis are good (which would be normal), the tests of p-p plot will be close a 45° line and Scatterplot are fall between acceptable areas.

*Table 6. Skewness & Kurtosis.*

| | | |
|---|---|---|
| N | Valid | 2610 |
| | Missing | 0 |
| Skewness | | -.031 |
| Std. error of Skewness | | .048 |
| Kurtosis | | .364 |
| Std. error of Kurtosis | | .096 |

*Level of service criteria*

When the model was developed, the motorcycle level of service (LOS) criteria was established based on the distribution of the participants' scores. To remain consistent with the highway capacity manual, six LOS designations (A through F) should be defined. Consequently, LOS designations were established for LOS A through LOS F. The 5th, 25th, 50th, 75th, and 95th percentiles of mean scores are used as the breakpoints to designate 6 levels of service. While the selection of these breakpoints is arbitrary (as are the breakpoints used in the highway capacity manual for other LOS designations), they have been chosen to represent the breakpoints between the various level-of-service designations. The 50th percentile of mean scores corresponds to overall rating of 3.25. Since there are 6 levels of service (A through F), the rating corresponding to the 50th percentile (3.25) was selected as the breakpoint in the middle of the scale between LOS C and LOS D. The breakpoints between the other levels were selected to reflect a slightly greater concentration of scores surrounding the 50th percentile and a very low concentration at the extremes. Extending 25% from either side of the 50th percentile, results in a 75th percentile corresponding to a mean rating of 4.375 and a 25th percentile corresponding to a value of 2.125. These values were selected as the breakpoints between LOS D and LOS E, and LOS C and LOS B, respectively. To define the breakpoint between LOS E and LOS F, the 95th percentile was selected. This percentile corresponds to the rating of 5.27. On the other end of the scale, the 5th percentile was selected as the breakpoint between LOS A and LOS B, equivalent to a mean overall rating of 1.225. LOS A (represented by an index <1.225) indicates that a roadway is extremely comfortable for motorcyclists while LOS F (represented by an index > 5.27) is an indicator that the roadway is extremely uncomfortable. Overall, Table 7 shows LOS criteria for exclusive motorcycle lanes.

*Table 7. LOS model output.*

| LOS letter grade | LOS model output |
|---|---|
| A | model ≤ 1.225 |
| B | 1.225<model≤2.125 |
| C | 2.125<model≤3.25 |
| D | 3.25<model≤4.375 |
| E | 4.375<model≤5.275 |
| F | model >5.275 |

**Discussion**

Motorcycle level of service (LOS) model predicts riders' perceptions of service quality using the four significant ($p < 0.05$) variables. The best model has an $R^2$ value of 0.62, indicating that 62% of the variance in the index or comfort level of the motorcyclist is explained by the four variables included in the model. In other words, the model is a reliable predictor of the expected comfort level of motorcyclist on the basis of these four variables describing the geometric and operational conditions of the roadway. The approach used in developing the motorcycle level of service was to obtain the perspectives of motorcycles by having them view numerous roadway segments captured on videotape and rate those segments with respect to how comfortable they would be riding on that segment under the geometric and traffic operations conditions shown. The survey of motorcycles was conducted using a video survey with 261 motorcycles successfully participating in the survey. The data collected were analyzed using an ordered linear regression. There were four model formulations explored in this research. The first model used only speed as a predictive factor. The negative coefficient calculated for speed indicates that, as speed increases, the likelihood of a rider perceiving a worse LOS decreases. The second focused on the speed and volume. The additional volume variable found to be significant has a positive coefficient sign. As expected, a low volume resulted in a better LOS ranking. In other

Indian Journal of Science and Technology Vol. 4 No. 4 (April 2011) ISSN: 0974- 6846

word, volume of motorcyclists will be correlated with an increase in the mean comfort level rating. The third examined the speed, volume and pavement quality. The positive coefficient calculated for pavement quality indicates that riders perceive a worse LOS, as pavement quality is worse. However the fourth took into account all the significant above mentioned factors as well as the lane width. If a lane width is present and all other variables in the model are held constant, the index is reduced by 0.459, indicating a higher level of comfort. The speed only in model 1 showed that speed is indeed a

*Fig. 4. Normal P-P plot of regression standardized residual.*

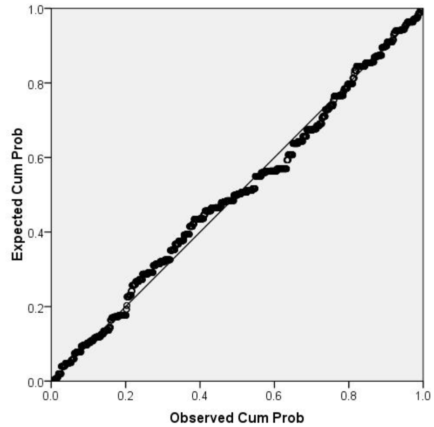
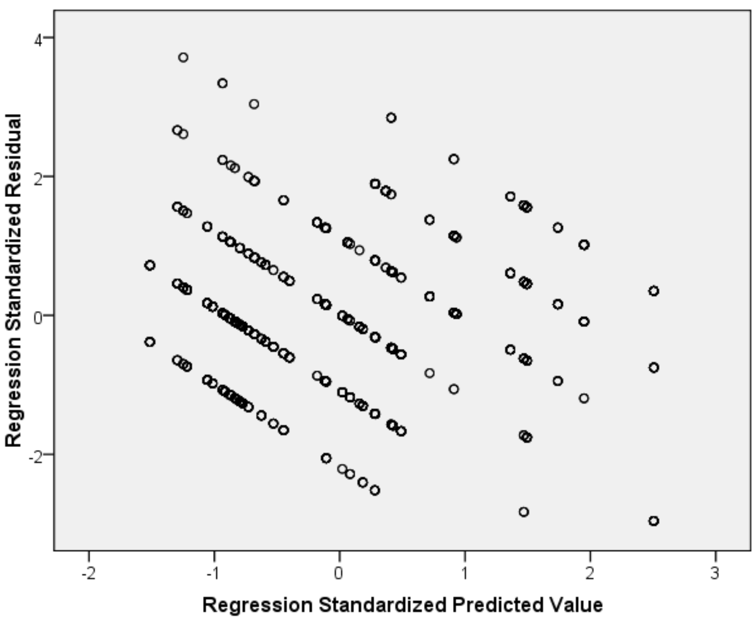



*Fig. 5. Residual plot of predicted & standardized residuals (scatter plot).*




strong indicator of riders' perceptions of trip quality. So speed is very significant to riders when they are judging the quality of service provided by exclusive motorcycle lanes. Based upon statistical analyses found no significant difference between the data collected using the real field data collection and the data collected from the video survey. So no calibration equation was needed to correct the data collected using video to data collected to the real-time field data.

This study is also seen as an initiative to full the knowledge gap that existed among the various types of land transportation facilities, which is the state-of-knowledge in motorcycle traffic sciences, the level of service (LOS) of motorcycle facilities. As such, it contributed new knowledge to the field of transportation engineering. The results of this research can help the traffic engineers assess the quality of service at exclusive motorcycle lanes. The data which are collected can be used to determine the level of service intervals for highway capacity manual.

## Acknowledgements

The work described in the article was fully supported by University of Putra Malaysia (UPM). The author is also indebted to the Road Safety Research Centre and Traffic Lab in UPM and Road Care Sdn.Bhd for their technical assistance.

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