# PERFORMANCE ASSESSMENT OF URBAN STREETS ADRESSING IMPROVEMENT ISSUES FOR AUTOMOBILE MODE OF TRANSPORT

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**ABSTRACT**

The present study focusses on modelling automobile drivers' response pattern to assess the service quality provided by urban streets in developing countries. Several Quality of service attributes, affecting driver's riding quality were investigated from 102 urban street segments under widely varying geometric and traffic conditions. From Pearson's' correlation analysis, total nine variables are found out to be significantly affecting drivers' satisfaction level. Two novel Artificial Intelligence technique i.e. Artificial Neural Network (ANN) and Functionally Linked Artificial Neural Network (FLANN) are applied in this study to predict Automobile drivers' level of satisfaction score (*ALOS_score*). The prediction performance of developed models is assessed in terms various statistical parameters of a Modified Rank Index. Among the ANN models Bayesian Regularization Neural Network (BRNN) algorithm has given the best fitted model in both training and testing data sets. However, application of FLANN model shows better prediction performance in the present context. Because, there exists no hidden layer and all the input layer neurons are directly linked with output layer neurons with lesser number of connections. Hence, it's advantageous over ANN to reduce the accumulated error. The result shows that 73% of studied segments are offering inferior service quality. Sensitivity analyses have reported that Pavement condition is the most important variable with relative importance of 26.78% to influence the drivers' riding quality. Similarly, other parameters were also ranked in decreasing order of their relative importance, which will help the highway authorities to prioritize budgets for future investments to improve provided service quality.

## 1. Introduction

Land transport is the most important way of transportation because of coverage area. A proposed new LOS criteria based on user perceptions regarding individual contributing aspects of transportation facility would be more credible than those based on overall satisfaction for any mode of transport. In contrast, majority of the general population utilizes both private and public modes of transport as per their necessity. Design and construction of infrastructure for the sustenance of one mode may adversely affect the operational enactment of alternative modes. Researchers from developed countries like USA have contributed significantly for the development of methodology to assess LOS using perception data. But in India, researchers have contributed very little for such research. This research has taken into considerations of all the qualitative measures of road transport, inconsistency as well as complications of human perception from a multimodal perspective. Hence the objective of this study is to derive a suitable method which shows the combined effect of several attributes of a transportation facility (urban street) to estimate road user's satisfaction level from a multimodal perspective in developing countries.

To evaluate the road users' satisfaction level, this paper is structured into several parts. The first part consists of investigating prominent factors of the transportation system that affects the satisfaction level of the road users on urban street segment. Then an innovative questionnaire having two main sections was developed. In the first section demographic information of the participants were included, so that the diversity in respondent's opinion according to their age group, gender, educational level, income level etc. could be confirmed. The next part consists of preparing a questionnaire including thirty-three questions related to the investigated factors affecting road user's comfort level. The participants were requested to indicate the degree of satisfaction for different attributes and the Overall satisfaction for the respective segment on a scale starting from 1 to 7. These surveys either seize traveller's mid-trip by orally interviewing them or by giving them a questionnaire to rate the attributes at a convenient time after finishing their trip.

## 2. Review of literature

The literature review focuses on issues related to assessment of factors affecting user's opinions about service quality provided by urban road infrastructures, questionnaire design, and model development addressed in some of the previous studies. Ibrahim examined car owners' as well as non-car owners' remarks towards various modes of transport for shopping purposes [6]. Both subjective and quantitative parameters were considered in this estimation. The consequences from the subjective investigation found that shoppers' judgments on various modes of transport for the purpose of shopping are influenced by travelling aspects and financial condition of the person. In that survey the shoppers were requested to rate various modes of travel for shopping taking into account a few variables. The authors concluded that every mode has its particular attributes. Lee et al. displayed another LOS principle for signalized crosswalks in business/market regions at bi-directional flows of pedestrians [8]. An arrangement of five photos were displayed to each participant for a particular flow ratio. All the information gathered from that survey have been utilized to decide the different congestion bounds for various bi-directional flow. This study proved that comfort level of pedestrians is adversely affected by the bi-directional stream flows. Araujo and Braga assessed the crossings pattern of pedestrians at different road junctions [1]. Some specialized authorities have been taken part to select the performance measures i.e. comfort, safety and particular attributes of system continuity. Pedestrians were requested to rate the comfort level as per their perception. Paired Comparison and Constant Sum methods were used to evaluate

the perceptions of the participants. Rahaman et al. considered the pedestrian and shopkeepers' perceptions in judging the walking environment in a medium-sized city center in Portugal [14]. The analysis was carried out by applying the Analytical Hierarchy Process. To address the needs from a pedestrian and shopkeeper perspective the survey comprised of investigating five criteria i.e. Identity, Connectivity, Hindrances, Illegal inhabitance and Safety. This study revealed that both shopkeepers and pedestrians were using the sidewalk according to their necessities.

Petritsch et al. presented a pedestrian LOS model for urban arterial with sidewalks using the stepwise regression technique [12]. Density of conflict points along the facility and traffic flow on the adjacent roadways were considered as primary factors in this model. Around 500 members were requested to rate the facility related to the requirements from a pedestrian point of view. Papadimitriou et al. analysed the highway LOS with respect to drivers' individual characteristics and various conditions of traffic [10]. Drivers' characteristics include age, gender, driving knowledge, road familiarity whereas traffic conditions include capacity of vehicles and v/c ratio. Perception survey was carried out taking 264 participants to rate traffic conditions in a 10-point scale. A piecewise linear regression technique was used to develop a relationship among perceived LOS and traffic condition. Joewono and Kubota presented a survey to enhance driving quality about the prevailing paratransit system [7]. The authors have gathered around 980 users' perceived ratings with respect to level of satisfaction, service quality and loyalty while consuming the paratransit network. Eight factors have been extracted using factor analysis with thirty-five attributes. Musicant concentrated on measuring the abnormal behaviour, safety attitudes and safety climate perceptions of company car drivers [9]. The authors gathered car drivers' perception by arranging a 34-item perception survey. Six factors have been extracted using factor analysis on the gathered information. K-means clustering method was applied to subgroups the output in to three classes. The outcomes demonstrate that the qualities of the distinctive subclasses of car drivers will be helpful to understand the measures that will counter safety. Freeman et al. assessed the 4792 expert drivers' reaction and behaviour in an Australian fleet using Manchester driver's behaviour questionnaire [4]. The conclusion drawn from this study is that the number of kilometres travelled by the members provides a sign of forecasting the probabilities of crash. Popuri et al. focused to select the public transportation to their work place using attitudinal Survey of 23 statements measuring their daily travel demand [13]. This study has executed six factors by factor analysis of 23 statements. Binary logistic regression method was applied to decide the selection among private or public mode of transport for work trip. The above qualitative models are developed preferably for homogeneous traffic flow conditions in developed countries.

Bhuyan and Rao (2010) have applied Hierarchical Agglomerative clustering method on average travel speeds to define threshold values for six LOS categories (A-F) for mixed traffic flow conditions [2]. But, there was no representation of the actual need of drivers while defining LOS under mixed traffic flow conditions. To satisfy the above complications, a suitable LOS model is proposed in this study using step-wise multi variable regression technique to evaluate the service quality provided by the transportation infrastructure from road user's perspective.

## 3. Study location and Data collection
To develop an appropriate standard which fits for heterogeneous traffic circumstances, users' responses from three cities of India were gathered. Information gathered incorporates distinctive sorts of road conditions and drivers of light or heavy vehicles. Responses from road users regardless of their age and gender were gathered from Rourkela, Visakhapatnam, and

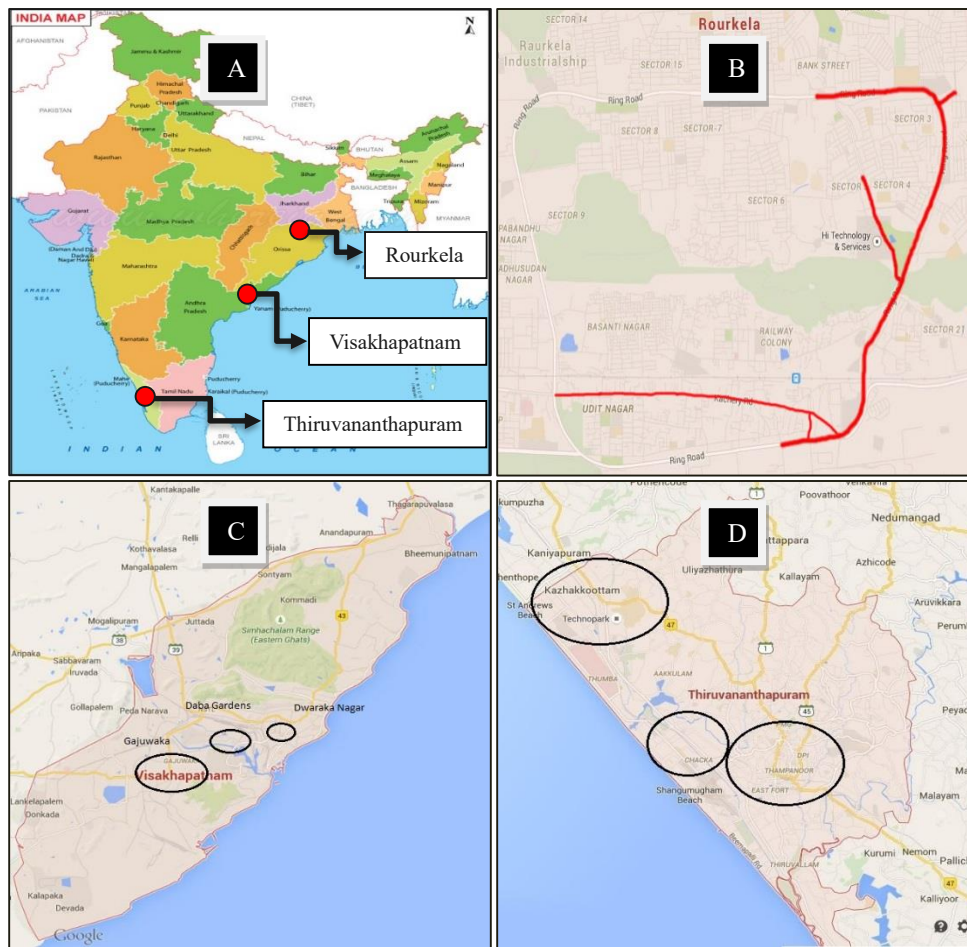Thiruvananthapuram of Odisha, Andhra Pradesh and Kerala state respectively.



Figure 1 A: Map showing the three data collection cities in India. B, C and D: Study sites of different locations in Rourkela, Visakhapatnam and Thiruvananthapuram respectively.

Various qualities of service (QOS) factors were affecting the road user's satisfaction levels on urban street segments as observed from a pilot survey conducted in this study. Based on the experience gained from the pilot survey, an innovative questionnaire was prepared containing 33 questions on QOS factors. Road users' perception data was collected by travellers' intercept surveys. The strength of this survey are better picture of extensive driving population, gathering of huge sample size and cost effectiveness with respect to the sample size. Study locations were chosen at residential as well as commercial zones in the urban communities. The survey has included personal information of the participant, such as: sex, age and driving experience. In the study around 450 participants were interviewed and requested to rate different QOS attributes on a rating scale ranging from 1= Strongly agree to 7= Strongly disagree. Finally, the overall satisfaction of each road user for the particular street portion was additionally noted down on the same rating scale.

*3.3 Demographic analysis*
In this study, responses were gathered from the drivers with a good cross section of sex, age and driving experience. Table 1 shows the demographic analysis of the road users took part in this

survey. Around 450 responses have been gathered from the above three cities and each city have minimum 30% of the total data.

Table 1 Demographic information of participants

| Variable | Category | Frequency | Percentage(%) |
|---|---|---|---|
| **Sex** | Male | 306 | 68 |
| | Female | 144 | 32 |
| **Age (in years)** | 20-30 | 320 | 71.2 |
| | 31-40 | 54 | 12 |
| | 41-50 | 43 | 9.6 |
| | 51-60 | 33 | 7.2 |
| **Driving experience (in years)** | <5 | 236 | 52.3 |
| | 6-15 | 185 | 41.4 |
| | >15 | 29 | 6.3 |

## 4. Study methodology

There are thirty-three statements used in the survey questionnaire to capture information regarding different features of transportation infrastructure. Yet, two causes are there behind not taking all the responses as input variables for the decision model. Firstly, there may be a high correlation among the individual statement. Secondly, utilizing all these variables is not suitable from model parsimony viewpoint. The information collected from the 33 statements were compressed into uncorrelated set of variables applying factor analysis.

*4.1 Factor Analysis*

Factor analysis is applied to compress a large data set to smaller subsets of elements. This analysis is used for
(i) Understanding the arrangements of variables; (ii) Constructing a questionnaire which measures the underlying variable; (iii) Reducing the data set to a more adaptable size to retain more novel information as possible.

The factor analysis undertakes that the rankings of the variables are created by some unnoticed and underlying approaches. The basic formula of the factor analysis is explained by equation (1) as follows:

$$X_{ji} = \sum_{k=1}^{m} (\lambda_{jk} F_{ki}) + \varepsilon_{ji}, \quad \forall j = 1,2,.....,J, \quad \forall_t = 1,2,.....,N \tag{1}$$

Where, $X_{ji}$ symbolizes the score of statement $j$ for participant $i$; $F_{ki}$ implies the $k^{th}$ factor of participant $i$; $\lambda_{jk}$ (also known as loading) indicates the relation of $j^{th}$ variable with $k^{th}$ common factor; and $\varepsilon_{ji}$ signifies the associated error. The equation (1) undertakes $J$ statements, $N$ observations and $m$ factors considered in the model. It is required to be summon up that factor scores ($F_{ki}$) were not observed. This exploration calculates both factor scores and respective loadings to make best use of the information maintained from original statements.

KMO & Bartlett's Test of sphericity is the main aspect in Factor Analysis. The KMO statistic is used to quantity sampling adequacy for each variable. KMO values greater than 0.8 is measured as good, i.e. the factor analysis is suitable for the variables. The Bartlett's Test of Sphericity is related

to the implication of the study to show the validity and correctness of the collected responses to address the problem. The value of Bartlett's Test of Sphericity $< 0.05$ is recommended as a suitable value in factor analysis [3].

Another important aspect mentioned in this study is Rotated Component Matrix to decide the total number of factors that should be analysed, if a variable is linked to more than one factor. Rotation maximizes high item loadings and minimizes low item loadings to produce a simplified solution. In this study orthogonal varimax rotation technique is used, that produces uncorrelated factor structure. To measure the consistency of a questionnaire Reliability analysis (denoted by cronbach's alpha) is used.

*4.2 Multiple linear Regression Technique*
Eight factors have been extracted from the factor analysis. The overall scores under every factor are added together and an average value is taken for each individual. These mean average value of eight factors were considered as explanatory variables. OS scores of each participant are considered as output variable. The model was established applying multiple regression technique which tries to fetch the association among two or more independent variables and a dependent variable fitting a linear equation. The independent variables have a specific coefficient ($b_n$). The output is projected by combining each variable multiplied by their individual coefficients as well as the residual term.
Mathematically,

$$Y_i = b_0 + b_1 X_1 + b_2 X_2 + .... + b_n X_n + e_i \quad \text{for i} = 1,2,...\text{n} \tag{2}$$

Where, $Y_i$ = resulting variable i.e. OS, $b_1$ = coefficient of the first predictor ($X_1$), $b_n$ = coefficient of the $n^{th}$ predictor ($X_n$) and $e_i$ = standard error between the predicted and the observed value.

The eight independent variables extracted from factor analysis are: cross-section of Roadway Design (RD), Arterial Operations (AO), Intersection Operations (IO), Signs and Markings (SM), Maintenance (M), Aesthetics (A), Road user Behaviour (RB) and Other Facilities (OF). The dependent variable is the Overall Satisfaction (OS).

*4.3 K-means Clustering*
The output of the proposed model i.e. OS scores are categorized in to six LOS groups (A-F) using k-means clustering technique. This is a simple algorithm which resolves the classification problem. A $k$-means clustering technique groups the information grounded on $K$ points signifying group clusters. This $k$-means algorithm assigns each data point from a set of $N$ points, to one of the clusters $c$ to decrease the within-cluster sum of squares, provided that the number of clusters is $1 < c < N$.

$$D_{ik}^2 = (x_k - v_i)^T (x_k - v_i), \quad 1 \le i \le c, \quad 1 \le k \le N.$$
(3)

Where, $D^2{}_{ik}$ = distance matrix from data points to cluster centres, $x_k = k^{th}$ data point in cluster $i$, and $v_i$ = cluster centres (mean of the data points on cluster $i$).

$$v_i^{(l)} = \frac{\sum_{j=1}^{N_i} x_i}{N_i}$$

$$(4)$$

$$\max \left| v^{(l)} - v^{(l-1)} \right| \neq 0$$

$$(5)$$

Where $N_i$ = number of objects in the cluster $i$,
$j = j^{th}$ cluster; $1 \leq i \neq j \leq c$. $l$ = number of iterations.

## 5. Result and Analysis

The proposed framework includes statistical model that can identify significant factors affecting the satisfaction. The collected data sets with respect to thirty-three questions pertaining to various QOS factors of transportation system were analysed. The apprehended data of 33 questions is summarised into convenient and uncorrelated set of variables using factor analysis.

### 5.1 Factor Analysis

Factor analysis was carried out on the thirty-three statements with varimax rotation (orthogonal). To determine the suitability of the correlational matrix for factor analysis, the computation involves the Kaiser-Meyer-Olkin (KMO) measure of suitability of sample. Table 2 represents the results of KMO and Bartlett's test. KMO statistic is found out to be 0.836 (i.e. >0.8). This value is adequate for factor analysis and indicates that the sample size is good enough to represent the model's appropriateness. The values of KMO > 0.5 represents a suitable limit. Bartlett's test is extremely significant with a significant test value of <0.05 means that R-matrix is not an identity matrix. This represents that there exist some kind of relationships among the variables involved in the exploration.

Table 2 Results of KMO and Bartlett's test

| Kaiser-Meyer-Olkin Measure | | 0.836 |
|---|---|---|
| Bartlett's Test of Sphericity | Approx. Chi-Square | 4686.75 |
| | Sig. | .000 |

Table 3 Summary of exploratory factor analysis results

| QOS Attribute Statement | Rotated Factor Loadings | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | RD | AO | IO | SM | M | A | RB | OF |
| Number of lanes and lane width are sufficient for traffic volume at peak hour | **.73** | -.03 | .06 | .04 | -.19 | .00 | .06 | .12 |
| Adding lanes in some places increasing | **.70** | .00 | -.01 | .09 | .01 | .03 | .17 | -.20 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| congestion in consecutive lane | | | | | | | |
| Separate bicycle lanes needed. | **.70** | .09 | -.11 | -.04 | .09 | .05 | .05 | .09 |
| Need for foot over bridge | **.69** | -.01 | .11 | -.05 | -.02 | .04 | -.10 | .08 |
| Wider footpath | **.67** | -.03 | .09 | -.10 | .06 | .00 | -.15 | .05 |
| Bus pullout lanes are present | **.61** | -.03 | -.04 | .08 | -.06 | .04 | .05 | -.10 |
| On-street parking space is sufficient | **.60** | -.01 | -.02 | -.04 | .07 | -.09 | -.13 | .05 |
| Better sight distance | **.57** | -.14 | -.15 | .05 | .09 | -.15 | .06 | -.21 |
| Traffic flow is continuous | -.04 | **.86** | .18 | .31 | .15 | -.01 | .00 | .00 |
| Satisfactory speed limit | -.03 | **.86** | .16 | .28 | .16 | .01 | .01 | .00 |
| Presence of heavy vehicles | -.03 | **.80** | .19 | .30 | .19 | .00 | -.01 | .02 |
| Delay at intersections | -.06 | **.80** | .22 | .33 | .11 | .03 | .01 | -.02 |
| Adequate Cycle length | -.02 | .18 | **.86** | .24 | .11 | -.03 | .03 | -.10 |
| Capacity of intersection | .01 | .20 | **.85** | .19 | .20 | .02 | .03 | .00 |
| Pedestrian facilities at intersections | -.02 | .07 | **.83** | .18 | .24 | .03 | .02 | .06 |
| Un-signalized intersections are better than signalized ones | -.01 | .28 | **.83** | .27 | .07 | -.01 | .04 | .01 |
| Pavement markings | .01 | .29 | .22 | **.86** | .07 | .02 | .02 | .01 |
| Slope of speed bump | .01 | .33 | .28 | **.81** | .09 | .05 | -.03 | -.08 |
| Road signs are better than overhead signs | -.01 | .34 | .25 | **.80** | .13 | .04 | -.06 | .00 |
| Street signs in advance of intersection | .01 | .36 | .26 | **.79** | .05 | .00 | .00 | -.02 |
| Rough roads and pot holes | .02 | .15 | .14 | .11 | **.84** | -.06 | .02 | -.03 |
| Congestion at road repairs | .01 | .04 | .05 | .02 | **.82** | .00 | .02 | .10 |
| Pavement quality at major roads | -.01 | .12 | .12 | .05 | **.81** | .01 | .02 | .01 |
| Pavement quality at minor roads | .04 | .17 | .23 | .10 | **.72** | -.05 | .11 | -.04 |
| Medians with trees | -.05 | .02 | .01 | -.01 | .00 | **.94** | .05 | .00 |
| Litter and dirt on road side | .06 | .05 | .04 | .08 | .02 | **.78** | .11 | .05 |
| Preferred driving in | .01 | -.21 | .03 | .13 | -.05 | **.67** | -.08 | -.11 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| residential areas than commercial areas | | | | | | | | |
| Unattractive roadside development | -.05 | .12 | -.06 | -.11 | -.04 | **.64** | -.11 | .01 |
| Driver courtesy | .13 | -.02 | .07 | -.03 | .09 | .02 | **.77** | .05 |
| Inefficient driving (illegal turns, not using indicators) | -.26 | .09 | .03 | -.07 | .02 | -.04 | **.67** | -.13 |
| Pedestrians stuck in middle of road | .03 | -.06 | -.02 | .07 | .04 | -.02 | **.60** | .37 |
| City well laid out to encourage transit use | .17 | .10 | .12 | -.16 | -.02 | .02 | .12 | **.74** |
| Need of Intelligent transport systems | -.18 | -.08 | -.13 | .09 | .07 | -.05 | .00 | **.71** |
| Eigen values | 7.85 | 3.67 | 2.60 | 2.26 | 1.84 | 1.63 | 1.27 | 1.12 |
| % variance | 23.78 | 11.12 | 7.87 | 6.83 | 5.57 | 4.93 | 3.86 | 3.38 |
| Cronbach's Alpha (α) | .82 | .95 | .93 | .95 | .85 | .76 | .70 | .69 |

Note: Factor Loadings > 0.50 are given the impression in bold.

After getting eigenvalues of each attributes in the collected data it is found out that 8 components have eigenvalues over the Kaiser's criteria of 1 and it clarified 67.34 percent of the variation in group. Reliability analysis (cronbach's alpha) is applied to quantify the consistency of a questionnaire or a distinct variable. The five variables i.e. RD, IO, AO, M and SM have the value of cronbach's alpha > 0.8, hence shows high reliabilities. However, remaining three variables A, RB and OF the value of cronbach's alpha is under 0.8, hence shows low reliability. The factor loadings after varimax rotation is tabulated in Table 3. From both factor analysis and professional judgement, there were 8 factors taken based upon the combination of percentage of total variance in original variables. Table 3 shows the cronbach's alpha values, eigenvalues and percentage of variance for each component.

The Scree Plot, which is shown in Figure 2 displays the percentage of total variance described by individual factor. As observed from this figure that beyond 8 factors the rate of decrease in % variance with increase in factor numbers is not significant. Therefore, the factors have been "rotated" using the varimax technique, so that individual variable can be loaded heavily beside a single factor for easy interpretation. This procedure supports the perfect documentation of variables those are found out under individual factor and also reduces the overlap among factors. The attribute statements with highest loadings were given the impression in bold for each factor.
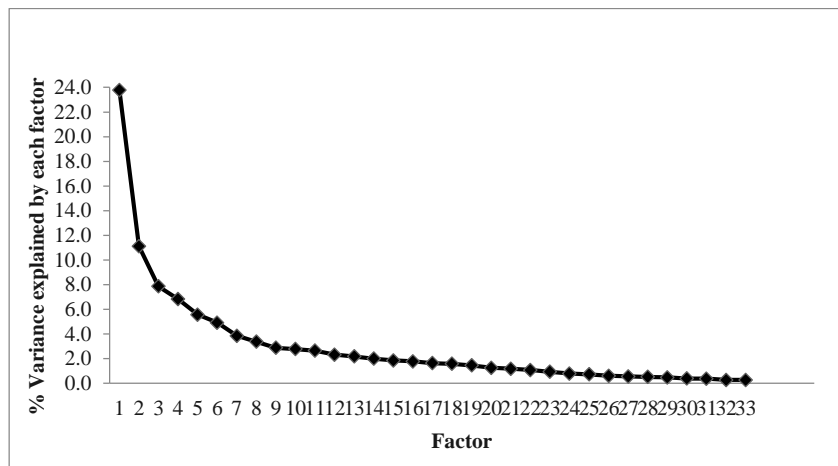
Figure 2 Scree plot after principal component analysis

*5.2 Multiple linear Regression technique*

The 8 factors extracted from the factor analysis were taken as independent variables and the OS is taken as a dependent variable. R value of 0.842 signifies the multiple correlation coefficient between the explanatory variables and the resulting variable. $R^2$ value in this model is found out to be 0.709. This indicates that the 8 independent variables accounts for 70.9% of the variability of the total variability in overall satisfaction. Table 4 shows the Summary of the parameters of multiple regression model. Durbin- Watson value is found out to be 2.163 (nearly equal to 2), which shows that the residual expressions are not correlated.

Table 4 Model parameters of the multiple regression analysis

| R | R Square | Adjusted R Square | Std. Error of the Estimate | Durbin-Watson |
|---|---|---|---|---|
| 0.842 | 0.709 | 0.683 | 0.377 | 2.163 |

The ANOVA results shown in Table 5 examines whether the model is considerably superior to predict the resulting variable or not. The value of F ratio =106.798 represents that this regression model is much better than the inaccuracy within the model. The significance value is 0 indicates that the model has significantly developed the capability to calculate the resulting variable.

Table 5 Test Results of ANOVA table

| Model | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 31.549 | 8 | 3.944 | 106.798 | .000 |
| Residual | 12.961 | 351 | .037 | - | - |
| Total | 44.510 | 359 | - | - | - |

Table 6 shows the model estimates containing values of *b*-coefficient of predictors, the significance of each coefficient, and t- statistic. These values of *b*-coefficients represent contribution of each explanatory variable for the model output. After replacing the values of *b*-coefficients in equation (6) the model was re-written as:

OS = -0.93 + 0.29 RD + 0.19 AO + 0.26 IO + 0.1 SM + 0.11 M + 0.09 A + 0.09 RB + 0.1 OF
(6)

Table 6 Model parameters

| Model | Unstandardized Coefficients | | t-statistics | Sig. |
|---|---|---|---|---|
| | B | Std. Error | | |
| (Constant) | -0.932 | .362 | -2.573 | .012 |
| RD | 0.29 | .057 | 5.067 | .000 |
| AO | 0.19 | .053 | 3.541 | .001 |
| IO | 0.26 | .054 | 4.818 | .000 |
| SM | 0.1 | .050 | 1.981 | .051 |
| M | 0.11 | .052 | 2.181 | .032 |
| A | 0.09 | .049 | 1.967 | .052 |
| RB | 0.09 | .046 | 1.988 | .049 |
| OF | 0.1 | .045 | 2.278 | .025 |

In this model the values of predictors are found out to be positive specifying that there is a positive relationship among OS and the predictors. The standard error associated with the beta values indicating the extent to which these values may vary across various samples. The t-statistics related to respective *b*-values is significant (sig. <0.05) indicating the predictors are contributing significantly to the model. The greater the value of t-statistics, the larger the influence of that predictor.

*5.3 Classification of OS scores*
The LOS (OS scores) estimated from this model are grouped into six classes with the help of k-means clustering. The ranges of scores for six categories of LOS are shown in Figure 3.
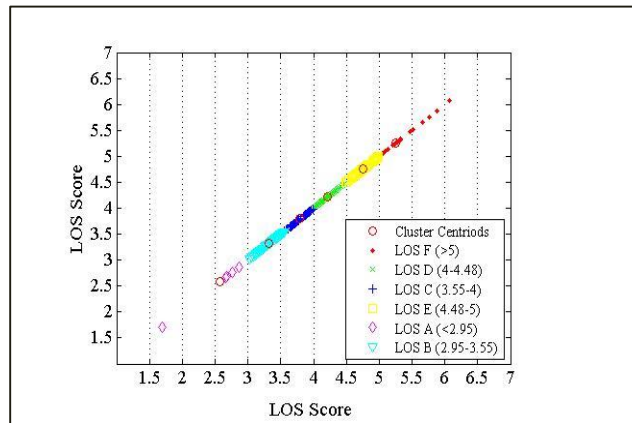


Figure 3 Classifying OS score for LOS categories (A-F) applying *K*-means clustering

*5.4 Validating the proposed model*
From the total data 80% was used for model development and remaining 20% was used for validation purpose. While validating the proposed model the points are plotted between observed

OS scores and predicted OS scores as shown in Figure 4. The slope of trend line was found out to be 45 degrees by plotting a graph between predicted and observed OS scores. The reliability index ($R^2$ value) of 0.9 represents that the model is well validated for mixed traffic flow condition.
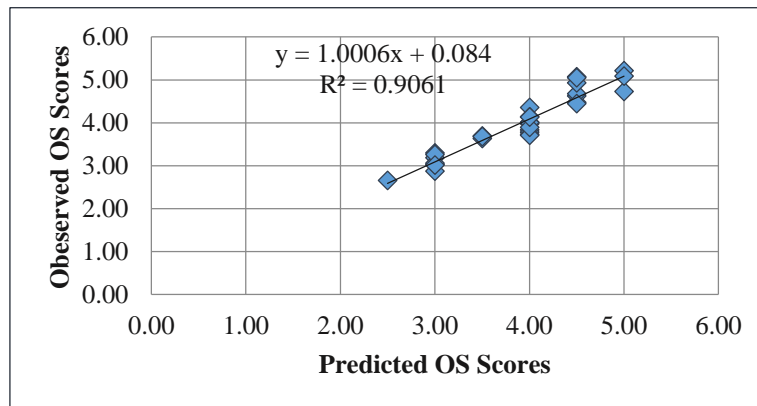


Figure 4 Scatter plot of observed vs. predicted OS scores

## 6. Conclusion

The highway capacity manual (HCM) has defined "Level of Service" as the service measures that both reflect the traveller's perspective and are useful to operating agencies. But LOS criteria in the current version of HCM are not grounded on the basis of travellers' perception survey about individual transportation facilities. In emerging countries like India, the mixed traffic flow condition comprises of diverse road and traffic operational features. Every user has different perspective and experience several difficulties while traveling along a particular roadway. There is no representation of variability and complexity of human perceptions in HCM for different modes of transport under mixed traffic flow conditions. Hence, HCM guidelines can't be applied directly to the highly heterogeneous traffic flow conditions. Therefore, the proposed LOS criteria based on user perceptions regarding individual contributing aspects of transportation facility would be more credible than the HCM guidelines, which is based on quantitative performance measures or capacity based outcomes.

This research includes a statistical model that can identify significant psychological factors affecting the satisfaction. The apprehended data of 33 questions is summarised into convenient and uncorrelated set of variables using factor analysis. The KMO statistic value of 0.836 indicates that the sample size is suitable for factor analysis. Five factors i.e. cross-section of roadway design (RD), intersection operations (IO), arterial operations (AO), maintenance (M), signs and markings (SM) have high reliability (Cronbach's alpha > 0.8) and remaining three factors i.e. aesthetics (A), road user behaviour (RB) and other facilities (OF) have comparatively low reliability (Cronbach's alpha is < 0.8). The proposed model using multiple regression analysis shows $R^2$ value is 0.709 shows that this model explains 70.9% of the variation in overall satisfaction. Durbin- Watson test result was found out to be 2.163 which is close to 2, shows that the residual terms are not correlated. The LOS scores are grouped into six clusters with the help of k-means clustering method. The findings from this study suggests that, the important attributes which mostly affect the comfort level of road users i.e. roadway design, intersection operations and arterial operations for the poor street segments (designated as LOS category D, E and F) requires improvement. The

proposed model was well validated with a reliability index of 0.9 and slope of the trend line 45 degree, while plotting a graph between observed OS scores and predicted OS scores. These kind of study is new to Indian traffic condition. Hence, this model is expected to serve as a guideline to improve the serviceability along the urban street infrastructure which will be easier for the Highway authorities to follow.

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