RESEARCH ARTICLE OPEN ACCESS

Assessing Level of Service of Two Lane Highways Using User Perception and Its Relationship With Field Measurements

Minu S*, Rohini I**, Lija R L***
*(Department of Civil Engineering, SRR Engineering College, Chennai, India)
** ((Department of Civil Engineering, SRR Engineering College, Chennai, India)
*** (Department of Civil Engineering, SRR Engineering College, Chennai, India)

ABSTRACT
Level of Service (LOS) is an important measure of performance of highways. The primary measure of service quality for two lane highways based on highway capacity manual are percent time spent following and average travel speed which are not directly based on user perception. In addition to speed and delay the road users perceive other attributes in their subjective determination of LOS. A methodology based on fuzzy set approach and fuzzy clustering is presented to determine the LOS that explicitly accounts for user perception. Several attributes contributing to road user perceptions of LOS were identified using a questionnaire survey and composite level of service was obtained by combining all attributes together using fuzzy weighted average and fuzzy C means clustering techniques. The levels of service obtained were compared with that obtained using field procedure recommended in HCM 2000.

Keywords – Class II highways, Fuzzy clustering, Fuzzy weighted average, Level of service, HCM

I. INTRODUCTION

With increasing delay and congestion on our nation's streets and highways, finding effective ways to maintain acceptable levels of service is crucial for satisfying users as well as protecting the environment. Level of Service (LOS) is an important measure of performance in analysis of highways. It is used to evaluate the performance of a highway. LOS in Highway Capacity Manual (HCM 2000)was defined as "a qualitative measure describing operational conditions in a traffic stream, based on service measures such as speed and travel time, freedom to maneuver, traffic interruptions, comfort and convenience"[1]. This definition is applied in a six level scale levels of service from A to F. LOS A representing the best operating conditions and LOS F gives the worst condition.

Methodology adopted for this study is based on the user perception of road users. The need of fuzzy logic, based on fuzzy set approach and fuzzy clustering provides the foundation for approximate reasoning with imprecise properties

Fuzzy logic starts with the concept of a fuzzy set [2]. A fuzzy set is a set without a crisp, clearly defined boundary. The Fuzzy Logic Toolbox is highly impressive in all respects. It makes fuzzy logic an effective tool for the conception and design of intelligent systems. The Fuzzy Logic Toolbox is easy to master and convenient to use. It can contain elements with only a partial degree of membership.

Cluster analysis is the name of a group of multivariate technique whose primary purpose is to identify similar entities from the characteristic they posses [2]. The objectives of the cluster analysis are to

group data points into clusters so that the degree of association is strong between members of the same cluster (low variance within) and weak between members of different clusters (high variance between).

Fang Clara Fang et al. developed and implemented a methodology based on fuzzy clustering to define LOS boundaries based on user perception [3]. Speed, volume and acceleration noise were taken as the three criteria for the identification of LOS in a study conducted by K. Ramesh Kumar. This study was based on development of level of services for urban roads through user perception and fuzzy set approach [4]. Partha Chakroborty and Shinya Kikuchi studied applicability of fuzzy set theory to the analysis of capacity and level of service of highway facilities [5].Lin Zhang conducted a study at signalized intersection to determine the level of service that accounts for user perceptions. Fuzzy set approach was used for the determination of LOS [6].

In the present paper, an attempt has been made to conduct a questionnaire survey and identify the important attributes that affect road user perception on LOS of two lane highways of Trivandrum city in Kerala State, India and to develop a methodology based on fuzzy set theory and fuzzy clustering to define LOS on two lane highways. Level of Service was also determined by using field procedure recommended in HCM 2000.

II. DATA COLLECTION AND METHODOLOGY

The approach of this study was to select a diverse sample of road users and have these individuals to evaluate the three stretches of two lane highways of Trivandrum city in Kerala, India namely Karyavattom-Chavadimukku, Chavadimukku-Pongamoodu and Pongamoodu- Ulloor to gauge their perception of LOS.

2.1 Data Collection

A self administrated questionnaire survey was developed to test how road users perceive LOS of two lane highways. Survey questions related to:

- Factors important to users on highways
- Users opinion on average speed
- Users opinion on quality of the road
- Delay experienced on the road

Free flow speed, peak and off peak hour volume count were also collected for these road stretches.

2.2 Study Methodology

Fuzzy sets that represent the importance levels and the performance ratings of identified attributes are characterized by their membership functions. Triangular membership functions are used in this study.

The generation of membership functions for importance levels of the identified attributes involves the conversion of responses from the histogram to membership functions. Numbers from 1 to 6 were assigned to represent the following qualitative assessments.

- Important = 1
- very less important = 2
- less important = 3
- Moderately important = 4
- highly important = 5
- very high important = 6

Each performance rating class is assigned a linguistic term such as excellent, very good, good etc as well as a letter grade A to F. The fuzzy performance ratings are based on index numbers from 1 to 6, with 1 representing the worst and 6 representing the best.

- Excellent = A
- Very good = B
- Good = C
- Fair = D
- Bad = E
- Worse = F

2.3 Fuzzy Weighted Average (FWA)

The weight coefficients (or importance levels) and the performance ratings of identified attributes are treated as fuzzy numbers. The fuzzy weighted Average method is used to combine all the identified attributes to arrive at the LOS. Based on FWA, the fuzzy based overall LOS is defined in (1)

$$LOS\_R = \sum_{i=1}^{N} WiRi \Big/ \sum_{i=1}^{N} Wi \quad (1)$$

Where,

LOS_R = fuzzy overall LOS rating

Wi = fuzzy weight coefficient (or importance levels) of attribute i

Ri = fuzzy performance rating of attribute i

N = number of attributes that define LOS

2.4 Fuzzy C means (fcm) Clustering

Fuzzy C means Fuzzy C means (fcm) is a data clustering technique wherein each data point belongs to a cluster to some degree that is specified by a membership grade. The Fuzzy Logic Toolbox command line function fcm starts with an initial guess for the cluster centers. fcm assigns every data point a membership grade for each cluster. By iteratively updating the cluster centers and the membership grades for each data point, fcm iteratively moves the cluster centers to the right location within a data set. This iteration is based on minimizing an objective function that represents the distance from any given data point to a cluster center weighted by that data point's membership grade.

III. ANALYSIS

Data collected through questionnaire survey and through primary surveys from the three road stretches were analysed to get the level of service. The data analysed from the questionnaire survey was used to develop histograms, both for the importance level and performance level. Fig 1, 2, 3 shows the percentage of response of importance of speed, quality of the road and delay at the three road stretches respectively

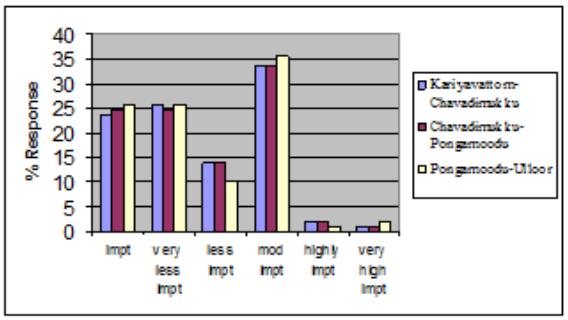

Figure 1.Percentage response of importance of speed

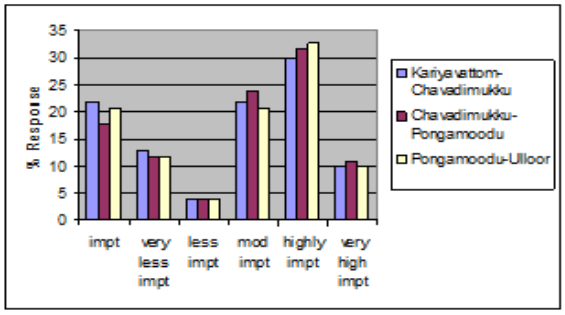

Figure 2. Percentage response of importance of quality of road

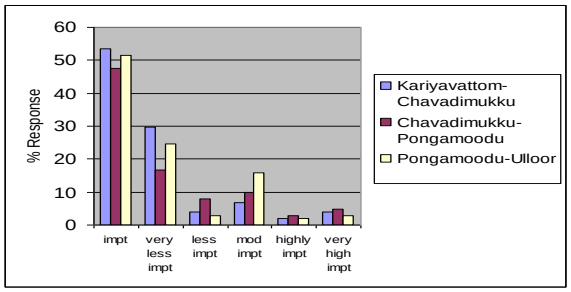

Figure 3. Percentage response of importance of delay

From Fig 1, it is clear that about 34% of the respondents consider speed as moderately important for the road stretches Kariyavattom- Chavadimukku and Chavadimukku- Pongamoodu. 36% of the respondents in Pongamoodu-Ulloor road stretch also consider speed as moderately important. From Fig 2, about 30, 31 and 32% of the respondents consider quality as highly important for the road stretches Kariyavattom- Chavadimukku, Chavadimukku-Pongamoodu and Pongamoodu-Ulloor road stretch. Around 54% of the respondents consider delay as moderately important for the road stretches Kariyavattom- Chavadimukku as from Fig 3.

The histograms for the performance level for the attributes were also developed. Fig 4, 5, 6 shows the percentage of response of performance of speed of the vehicles, quality of the road and delay for the three selected road stretches respectively.

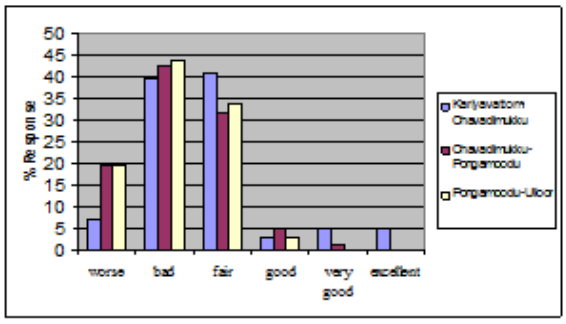

Figure 4. Percentage response of performance of speed

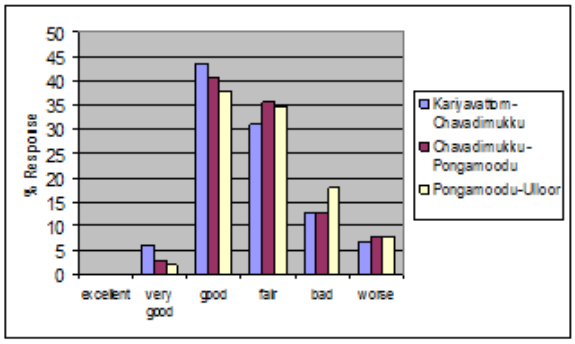

Figure 5. Percentage Response of Performance of Quality of Road

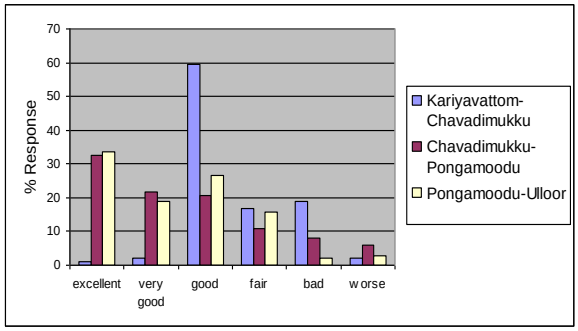

Figure 6. Percentage Response of Performance of delay

From Fig 4, around 44% of the respondents consider speed performance as bad for the road stretches Pongamoodu-Ulloor. However, for the Kariyavattom- Chavadimukku road stretch about 41% of the respondents rated the performance of the speed as fair. Fig 5 shows that around 44%, 42% and 38% of the respondents consider quality of the road as good for the road stretches Kariyavattom- Chavadimukku, Chavadimukku-Pongamoodu and Pongamoodu-Ulloor respectively. From Fig 6, it is clear that around 59% of the respondents consider the delay performance in that road is good that is this delay may cause not much congestion.

3.1Fuzzy Set Approach

Fuzzy sets that represent the importance levels and performance rating of identified attributes such as speed, delay and quality of the road section were characterized by their membership functions. Triangular membership functions were assumed for this study. The membership functions were developed using MATLAB Fuzzy logic toolbox. The membership function for importance levels of identified attributes are based on the survey while the membership function for the performance rating were derived from the assumptions and currently used standards. Defuzzification was done for α value of 0, 0.5, and 1, for both importance and performance levels. The Level of Service of each road stretches was obtained by using Fuzzy Weighted Average

(FWA) method. The LOS obtained will have a maximum value and a minimum value, which is plotted on a standard fuzzy set to obtain the LOS of the selected two lane road stretches. The values of LOS obtained for the selected stretches are shown in the Table 1.

Table 1. Values obtained for level of service

Road Stretches	LOS Values
Karyavattom-Chavadimukku	(4.04,4.62)
Chavadimukku-Pongamoodu	(3.80,4.60)
Pongamoodu-Ulloor	(3.40,4.31)

The obtained value from the fuzzy set approach was plotted on a standard fuzzy set to obtain the LOS of the selected road stretches. Fig 7, 8, 9 shows the LOS plot for the selected road stretches respectively.

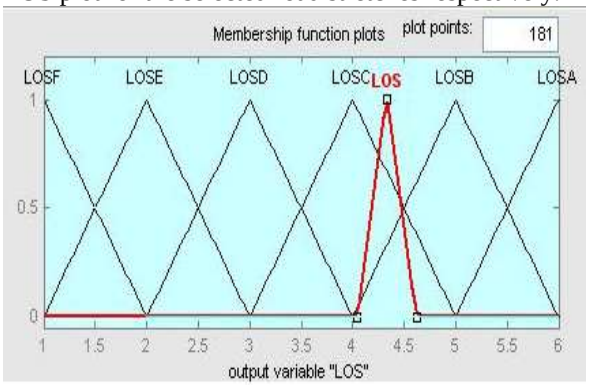

Figure 7. LOS of Karyavattom-Chavadimukku road stretch

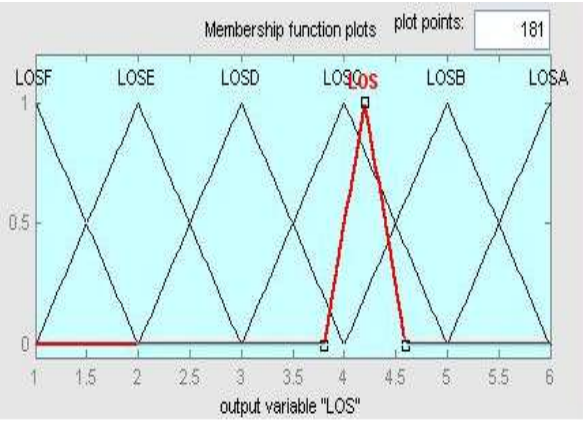

Figure 8. LOS of Chavadimukku-Pongamoodu road stretch

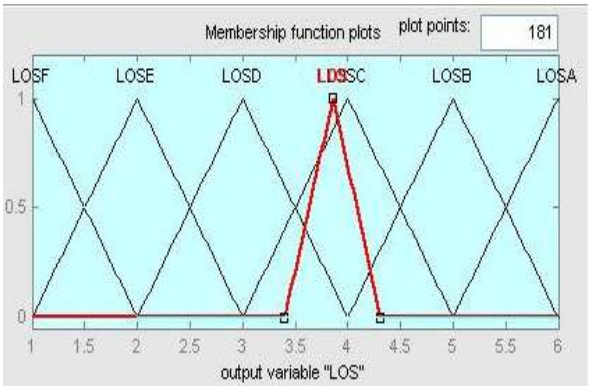

Figure 9. LOS of Pongamoodu-Ulloor road stretch

Levels of service of the three selected road stretches were obtained as 'C'.

3.2 Fuzzy Clustering

Coding of each variable involved assigning suitable weights to various levels of selected variables to achieve the desired result. For the easy analysis, all the variables obtained from the detailed questionnaire were coded in a standard manner. In this, the various factors were assigned the weights on a scale of 1-6. The membership values of labeled data were calculated using fuzzy cluster analysis.

Data entered as a matrix form, which contains m rows and n columns. Rows contain the number of data points and columns contain the characteristics of each variable. The data obtained from the questionnaire survey was used as input. All variables were coded and these labeled data were used for the analysis. The data from three road stretches were analysed using fcm function in MATLAB. The data were clustered into 6, which gave the six LOS. The position of the maximum membership grade gave the value of cluster in which the LOS of the desired road included. Table 2 gives the maximum membership grade and position of the cluster for the selected road stretch

Table 2. LOS of the selected road stretches by clustering methods

Road Stretches	Membership Grade	Obtained LOS
Karyavattom-Chavadimukku	0.1672	B
Chavadimukku-Pongamoodu	0.6419	C
Pongamoodu-Ulloor	0.4347	C

3.3 LOS Determination Using HCM method

In HCM, level of service is based on percent time spent following and average travel speed. Percent time spent following was estimated from (2).

$$PTSF=100(1-e^{-0.000879V_p})+f_{d/np} \quad (2)$$

Where

PTSF = percent time spent following $f_{d/np}$ = adjustments for the combined effect of the directional distribution of traffic and of the percentage of non-passing zones on percent time spent following

Percent time spent following were calculated for three road stretches and the obtained values are shown in Table 3.

Table 3. Percent time spent following for the selected road stretches

Road Stretches	**Percent Time Spent Following (PTSF)**
Karyavattom-Chavadimukku	52.8
Chavadimukku-Pongamoodu	54.54
Pongamoodu-Ulloor	56.06

On comparison with the values suggested by HCM for the percent time spent following, the level of service for the Kariyavattom- Chavadimukku, Chavadimukku-Pongamoodu and Pongamoodu-Ulloor road stretches were found to be B , B and C.

IV. SUMMARY AND CONCLUSION

The level of service is a qualitative measure which needs to reflect road user perception. Several attributes contributing to the perception of level of service were identified by conducting a questionnaire survey and LOS of the selected road stretches were assessed using fuzzy set approach and fuzzy clustering technique. Fuzzy set approach only the importance and performance levels of identified attributes such as speed, delay and quality of the road section can be considered. However, in fuzzy clustering technique, all the attributes such as age, gender, educational level, purpose of trip etc can be considered. Hence fuzzy clustering technique gave more accurate prediction.

The levels of service were also determined using field procedure recommended in HCM 2000. LOS obtained from the user perception methods was found to be lower level than that obtained from the field measurement. The user perception attributes influences the determination of LOS of two lane highways significantly. This may be the reason why the obtained LOS values are not in true match with that of HCM values.

REFERENCES

[1] Highway Capacity Manual, Transportation Research Board, National Research Council, Washington D.C,2000

[2] Timothy,J,Ross.,"Fuzzy Logic With Engineering Applications", University of Mexico, USA,2004

[3] Fang Clara Fang, and Lily Elefteriadou, "Using Fuzzy Clustering of User Perception to Define Levels of Service at Signalized Intersections", *Journal of Transportation Engineering*, *129*(6), 2003, 657-663

[4] K. Ramesh Kumar, *Level of Service Indices for Urban Roads Through User's Perception-Fuzzy Set Approach*, doctoral diss., Indian Institute of Technology, Madras,1993.

[5] Partha Chakroborty and Shinya Kikuchi, "Application of Fuzzy Set Theory to the Analysis of Capacity and Level of Service of Highways", *IEEE Journal*,1990.

[6] Lin Zhang and Panos D. Prevedouros,"Signalized Intersection Level of Service that Accounts for User Perception", Transportation Research Board, Washington D.C,2004,1-26.

[7] IRC 106:1990, "Guidelines for Capacity of Urban Roads in Plain Areas" , Indian Road Congress, New Delhi.