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Modelling Pedestrian Perspectives in Evaluating Satisfaction Levels of Urban Roadway Walking Facilities

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Abstract

Pedestrian Level of Service (PLOS) is a multifaceted expression which represents the working condition of walking facilities and satisfaction level of pedestrian experience while using these facilities. In this regard this study aimed at developing PLOS models for three pedestrian facilities such as sidewalk, signalized intersection and un-signalized intersection by using qualitative data sets. Total 2730 pedestrian's real time sense of satisfaction data were collected from ten cities of India. Behavioural responses were taken in order to assess variation with different age and gender from study areas having miscellaneous activities. Taking sets of questions, different variable scores were estimated to provide a wide variation of independent variable that will be more reliable for model fitting. Before model development degree of dependency has been examined with the help of discriminant factor analysis. Implementing ridge regression technique three different PLOS models have been developed for three pedestrian facilities. PLOS scores found by using the proposed models were classified by applying GA-Fuzzy clustering technique in order to get six PLOS ranges (A-F). At signalized intersection 3% of participants were extremely dissatisfied with the facility and they gave rating of >5 for PLOS score. This high score was because of pedestrian speed was severely restricted at some places due to the left and permissible right turning vehicles. Results also revealed that for un-signalized intersection nearly 23% of participants were having PLOS score of >4 as waiting time was more than expected and also pedestrian had to face conflict with vehicles while crossing.

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Keywords: Urban Roads; Pedestrian Facilities; Service Levels; Ridge Regression; GA-Fuzzy Clustering

1. Introduction

In recent years walking is taken as the intense topic for research in transportation planning as from last three decades people are accepting to walk rather than using public modes to reach at a near destination to avoid many problems like traffic congestion, air pollution, global warming, obesity and other health problems. For this, researchers, planners and policymakers are keenly looking for ways to improve pedestrian facilities to encourage pedestrian activity. The construction of new facility or the development of existing facilities can only be done after knowing the service levels of the sites. Level of Service (LOS) mainly explains about a qualitative measure describing

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operational condition within a traffic stream and its perception by the road users. Although the concept of LOS intended to reflect user perception but most of the research on pedestrian facility has been carried out based upon the operational aspect without considering the behavioural investigation and justification for choosing the facility. In addition to operational condition several other factors like safety, comfort, convenience, signal responsive, marking, aesthetics, clarity, usefulness of the road etc may effect to the road users. The effectiveness of the factors can only be observed from the views or perception of the road users in a scale of good or bad.

In this study analysis has been carried out for three different pedestrian facilities like sidewalk, signalized intersection and un-signalized intersection. Different factors affecting to the pedestrian service levels are investigated from the literatures and observing to the field and incorporating to those factors a convenient questionnaire has been prepared. User perception data has been collected for the different facilities from ten mid sized cities of India. The main goal of this study is to develop models for the evaluation of service levels of pedestrian facilities such as sidewalk, signalized intersection, and un-signalized intersection. In this regard different steps followed in this study are i. Identification of factors that are important to pedestrians while walking, ii. Formulation of proper questionnaire for the evaluation of service levels, iii. Development of ridge regression based models to be used for the estimation of PLOS score, iv. Classification of the PLOS score by applying Genetic Algorithms (GA) Fuzzy Clustering method to define ranges of PLOS categories,

2. Background

Highway Capacity Manual (HCM) 1965 first introduced level-of-service concept which was based on operational conditions within traffic stream, traffic interruption, comfort and convenience. Six LOS from A to F are defined for pedestrians in HCM 2000 in two phases like uninterrupted pedestrian facilities and interrupted pedestrian facilities in which LOS A stands for the best and LOS F stands for the worst condition. HCM 2010 described about PLOS based on the measure of effectiveness like flow, capacity density etc.

Video recording technique is the most common approach for pedestrian data collection (Al-Azzawi1 & Raeside, 2007) but in some studies questionnaire survey is used as the mode of data collection to analyse about attitudinal and psychological behaviour of the pedestrians. In order to develop models for pedestrian facilities to encourage walking as a viable alternate form of transportation careful attention has to be paid for pedestrian comfort, convenience, safety, security, continuity in addition to traditional volume and capacity factor (Sarkar, 1993; Khisty, 1994; Jaskiewicz, 2000). Incorporating perceived safety and comfort and route choice behaviour of road users different models are developed for examining the influence of overall LOS for pedestrians (Petritsch, Landis, Huang, & Dowling, 2005; Muraleetharan & Hagiwara, 2007). A new LOS model developed for different conditions found in Greece which was mainly based on questionnaire survey found that LOS varies significantly with the method selected and concluded that inclusion of both quantitative and qualitative parameters can secure the reflection of the actual conditions in the pedestrian movements at a satisfactory degree (Christopoulou & Pitsiava, 2012).

There are significant research outputs which gives better knowledge about the different measure of effectiveness for LOS. From the findings based on perceived safety and comfort for signalized intersection it is observed that vehicle turning right on red mainly affect service levels (Landis, Petritsch, Mcleod, & Huang, 2005). And also presence of zebra crossing, sidewalk before intersection, shortest crossing distances improve the PLOS at intersection by considerable amount (Jensen, 2012). Several studies have discussed about the evaluation of crossing behaviour at intersections and analyzed about pedestrian experience at actual site, geometric, operational and traffic characteristics adopting interview survey techniques (Lee, Goh, & Lam, 2005; Yang & Sun, 2013; Yadav, Jaiswal, & Nateriya, 2015). Investigation about pedestrian perception shows several issues like short term parking on walkways, illegal encroachment by the shopkeepers to attract buyers that affect the flow rate (Rahaman, Lourenco, & Viegas, 2012; Kang, Xiong, & Mannering, 2013; Choi, Min, & Kim, 2013).

For development of PLOS models several techniques have been adopted like point systems (Mozer, 1994); Dixon, 1996; Gallin, 2001), simulation (Miller, Bigelow, & Garber, 2000) and regression analysis (Petritsch et al., 2006; Landis, Vattikuti, Ottenberg, McLeod, & Guttenplan, 2001; Jensen, 2007). Developed models have shown the inter-relationship that does exist between pedestrian flow and vehicular flow (Dandan, Wei, Jian, & Yang, 2007; Petritsch, Landis, McLeod, Huang, Challa, & Guttenplan, 2005; Gangi &Velona, 2009). Some model frameworks also gave a clear picture to assess the performance of large-scale crowded pedestrian facilities during emergency evacuation in confined passageways (Abdelghany, Abdelghany, Mahmassani, Al-Ahmadi, &Alhalab, 2010; Chen, Ye, & Jian, 2010). Indeed, some researches on modelling pedestrian service measure have shown the variation with age, gender, weather condition etc. (Daamen, 2004), Coffin & Morrall, 1995; Morrall, Ratnayake, & Seneviratne, 1991). To assess pedestrian measure of effectiveness in China, PLOS models has been developed for sidewalk, signalized and unsignalized intersections with the consideration of both qualitative and quantitative data sets (Bian, Wang, Lu, & Ma, 2007; Bian, Ma, Rong, Wang, & Lu, 2009; Bian, Lu, & Zhao, 2013).

Many researchers have utilized Genetic Algorithm in optimizing the clustering problems. Lingras (2004) genetically designed a regression model utilizing Genetic Algorithm (GA) to estimate the missing traffic count. Later Fuzzy-C means (FCM) clustering was optimized using Genetic Algorithm to provide the optimal number of cluster (Alata, Molhim, & Ramini, 2008). Zhou & Khotanzad (2010) developed a Genetic Fuzzy Clustering Algorithm combining FCM clustering and GA in which a data point is not assigned to a single cluster rather each data points possess a membership function that indicates the strength of the data point.

From the past researches it is evidenced that the concept of analysing service levels of pedestrian is quite convoluted. Qualitative walking values such as comfort, safety, security, attractiveness are having their importance in defining PLOS but most of the authors emphasized only on the functional values over quantitative aspect. However to provide a more pedestrian friendly environment it is essential to put equal importance on qualitative aspect as well as quantitative. In this research the prime focus is to analyse pedestrian perception and to develop models that would be useful in defining service quality of pedestrian facilities.

2. Methodological Approach

In the current study pedestrian perception data analysis for three walking facilities such as sidewalk, signalized intersection and un-signalized intersection has been carried out. Variables which are having effect on pedestrian service levels were selected and considering them a proper questionnaire was designed. Statistical significance of the variables has been examined with the help of determinant analysis and models are developed with the help of ridge regression technique. Model outputs are then classified to give six ranges of service categories using GA-Fuzzy clustering technique. Details of the methodology are described below.

2.1 Variable Selection and Variable Score Calculation

The very first step of this study was the selection of different important variables for each of three facilities, based on which questionnaire was finalized. In the beginning part of the questionnaire some socio-demographic attributes such as age, gender, education, occupation, purpose of trip etc. included that were common for all three facilities. Also users have been asked to know frequency of walk mode taken on daily, weekly or only for the first time on the same path as observed. Other influencing variables such as purpose of travel, main mode of travel, frequent mode of travel, alternate mode of travel, presence of transit near the site, reason of reluctance to follow walk mode and passing through area (i.e. heavily commercial, official, educational, residential or mixed type) affecting decision of participants are considered in this study. Pedestrians have been invited to review and rate their experiences by the adverse effect of traffic volume, traffic speed, presence of heavy vehicles and non-motorized vehicles. To measure the satisfaction levels of three different facilities participants were asked about five major parameters such as traffic influence, safety, comfort and convenience, road maintenance and aesthetics. All these parameters include number of similar but slightly different attributes for each pedestrian facility which has been shown in Table 1. Each attribute represents a question in the perception questionnaire about which participants were asked to answer.

One question was set aside in the questionnaires to ask about ‘overall satisfaction’ in a 6 point rating scale. Different notations used are: 1, 2, 3, 4, 5 and 6 for extremely satisfied, very satisfied, somewhat satisfied, somewhat dissatisfied, very dissatisfied and extremely dissatisfied. This ‘overall satisfaction’ rating has been used as the dependent variable and variables such as age, gender, platoon sized, traffic score, safety score, comfort score, maintenance score and aesthetic score are used as independent variables for the model development. After the pilot survey, the designed questionnaire has been checked to ascertain its consistency in accommodating all desirable variables and also useful in conducting the real survey on site at easy. This questionnaire was contained within four A4 sized pages from which page 1 contains common questions on demographic variables for all three pedestrian facilities. The remaining three pages contained 27, 31, 28 questions respectively for sidewalk, signalized and un-signalized intersection.

In this study five categories scaled has been used to provide clear statistical outcomes. The problem of using scaling format is that the collected data are discrete rather than continuous. However, a continuous data as a dependent variable works much better than discrete data in a regression analysis for which variable scores are calculated. For example, for a set of five questions the final variable score varies between five and twenty-five as a five likert scale was used for each variable. This provides a wider variation as the summation score of five questions were closer to continuous data and hence support to fit a better regression model. The variable scores for perceived data are converted in a 10 point scale using the following formula.

$$\text{Variable Score} = \{\sum \text{Answers}/(\text{no of questions} \times \text{No of options})\} \times 10 \quad (1)$$

Table 1. Attributes of Major Parameters Considered for Perception Survey

Major Parameters	Sidewalk	Signalized Intersection	Un-signalized Intersection
Traffic	Traffic speed	Traffic speed	Traffic speed
	Illegal turn of vehicles	Illegal turn of vehicles	Illegal turn of vehicles
	Non-motorized vehicles	Non-motorized vehicle	Non-motorized vehicle
	Heavy vehicles	Heavy vehicles	Heavy vehicles
	-	Waiting time to cross	Waiting time to cross
	-	Left & right turning vehicle	Left & right turning vehicle
	Vehicle swing over pedestrian path	Crossing time	Interaction with vehicle
	Illegal parking	Crossing during red phase	Continuous flow of traffic
Safety	Aggressiveness of drivers	Aggressiveness of drivers	Aggressiveness of drivers
	Walking is dangerous	Crossing is dangerous	Crossing is dangerous
	-	Attend calls while crossing	Attend calls while crossing
	-	Drivers stop to give space, so that pedestrians can cross safely	Drivers stop to give space, so that pedestrians can cross safely
	Driveway cars	Vehicle stops at red signal	-
	Presence of Barriers	Vehicles move even in red phase	-
Comfort	Lighting in night	Lighting in night	Lighting in night
	Facing problem in walking	-	problem during crossing
	Need of grade separator	Need of grade separator	Need of grade separator
	Comfort provided by sidewalk	Enough space to cross	Enough space to cross
	Feelings during walking	Enough time to cross	Enough time to cross
	Step out of the way to avoid other	Blockage zebra crossing	Blockage of zebra crossing
	Cars entering to driveways	-	-
	Obstruction due to over-crowd	-	-
	Streetscape feeling	-	-
Maintenance	Signals	Signals	Signals
	Pavement quality	Pavement quality	Pavement quality
	Road maintenance	Road maintenance	Road maintenance
	Road markings	Road markings	Road markings
	Visual cluster	Visual cluster	Visual cluster
	Advanced information sign	Advanced information sign	Advanced information sign
Aesthetics	Extreme weather	Extreme weather	Extreme weather
	Presence of medians	Presence of medians	Presence of medians
	Need of improvement	Need of improvement	Need of improvement
	Vending zone	-	-

2.2 Discriminant analysis

The parameters for three facilities are analysed using discriminant factor analysis as discriminant analysis is a multivariate statistical investigation that uses one or few linear combinations of several variables according to the multivariable observations in a sample of unknown matrix and then designate an individual to one of several known matrix owned. In discriminant analysis different tests for parameters such as Chi square test, Wilk's lambda criterion, Eigen-value evaluation etc are carried out. As the covariance matrix of the contrast was based on the statistic Chi square, the test is performed for the parameters. Wilk's lambda is used to statistically test hypothesis about group mean vector difference between the identified groups of subject on combination of dependent variables and it is basically used for multivariate analysis of variance (MANOVA). Parameters used in this study are multivariable, for which Wilk's lambda value for the parameters are checked. To measure the variance in all parameters, Eigen-value was taken into account. The ratio of Eigen value was the ratio of explanatory importance of the factors with respect to the variables. A canonical correlation analysis is used to investigate the linear relationship between the multidimensional variables extending the bivariate correlation, allowing multiple continuous independent variables and dependent variables. The dependent and independent variables considered in this study are discussed in the following section. The most important difference between canonical correlation analysis and other analysis is that here with respect to affine transformation of the factors they are invariant.

2.3 Model Development for PLOS Scores

PLOS scores for different walking facilities depends on parameters like age, gender, platoon size, traffic score (TS), safety score (SS), comfort score (CS), maintenance score (MS) and aesthetic score (AS). To examine the collinearity among the parameters Variance Inflation Factor (VIF) was calculated using the following formula (Kutner, Wasserman, & Neter, 2004):

$$VIF = \frac{1}{1-R^2} \tag{2}$$

Here R^2 is the parameters of determination of the model. As VIF≥10 shows the multicollinearity, so to avoid that, ridge regression technique has been used to minimize the mean square error with the addition of penalty term. The solution of ridge regression can be found by:

$$\hat{a} = (X'X + \lambda I)^{-1} X'Y \tag{3}$$

when $\lambda = 0$, we get the linear regression estimate
when $\lambda = \infty$, we get $\hat{a}^{ridge}=0$
$\lambda \geq 0$ is a turning parameter, which controls the strength of the penalty term.
The amount of shrinkage is controlled by λ that multiplies the ridge penalty. Large λ means more shrinkage, and so we got different coefficient estimate for different values of λ.

2.4 Classification of PLOS Scores

PLOS scores that were found as the outputs of PLOS model were classified into six groups to define ranges of service levels (A-F). In this study GA-Fuzzy clustering, a combination of GA and FCM techniques is used to classify PLOS scores. FCM algorithm and the ability of GA in finding global minimum are utilized in this hybrid algorithm to get an optimal clustering result.
FCM clustering algorithm, as name suggests, the algorithm utilizes the concept of fuzzy set. Unlike the other algorithms FCM assign each data point with a membership function, which value ranges between 0 and 1. This membership function depicts belongingness of a particular data point with all the groups.

A $n \times c$ matrix $U = [\mu_{ik}]$ represents the fuzzy partitions, its conditions are given by:

$$\mu_{ik} \in [0,1], 1 \leq i \leq n,\ 1 \leq k \leq c, \tag{4}$$

$$\sum_{k=1}^{c} \mu_{ik} = 1,\ 1 \leq i \leq n, \tag{5}$$

$$0 < \sum_{i=1}^{N} \mu_{ik} < n\ , \tag{6}$$

The FCM clustering algorithm is based on the minimization of an objective function called C-means functional. It is defined by Dunn (1974) as:

$$J(X;U,V) = \sum_{i=1}^{c} \sum_{k=1}^{n} (\mu_{ik})^m \left\| X_k - V_i \right\|_A{}^2 \tag{7}$$

Where

$V = [V_1, V_2, V_3, ..., V_c], V_i \in R^n$ is a vector of cluster centres; X is the data set, U is the partition matrix; V_i is the mean of data points over cluster i; m is the weight exponent which determines the fuzziness of the clusters (default value is 2); n is the number of observations; c is the number of clusters.

Genetic Algorithm

The quality of cluster result is determined by the sum of distances from objects to the centres of clusters with the corresponding membership values: $J = \sum_{i=1}^{c}\sum_{k=1}^{n}(\mu_{ik})^m d(V_i, X_k)$

where $d(V_i, X_k)$ is the Euclidean distance between the objects. The local minimum obtained with the fuzzy c-means algorithm often differs from the global minimum. Due to large volume of calculation realizing the search of global minimum of function J is difficult. GA which uses the survival of fittest gives good results for optimization problem. GA does not guarantee if the global solution will be ever found, but they are efficient in finding a “Sufficiently good” solution within a “sufficient short” time.

3. Study Area and Data Collection

A comprehensive perception survey was carried out in order to assess views of pedestrians on satisfaction levels they perceived while using any of these three walking facilities. Ten mid-sized cities such as Bhubaneswar, Cuttack, Ranchi, Raipur, Jamshedpur, Vijayawada, Visakhapatnam, Vizianagaram, Tirupati and Rourkela located across India were selected for data collection purpose. Travel patterns, land use patterns, work cultures, commercial activities, economic background of pedestrians and motorists are somewhat different from large sized metropolitan cities and hence this study primarily focused on mid-sized cities. Locations of these selected ten cities of India are shown in Fig.1.

Number of sites of ten cities selected for each pedestrian facility type are listed and shown in Table 2. It has been noted that the population of these cities varies from 0.3 to 1.2 millions. These cities are favourably selected as diverse activities have been observed from residential, commercial, official, educational, recreational areas etc. with heterogeneous traffic flow to include data sets from varied class and community. Roadways are characterized by having access facilities, on-street parking provisions, nearby vending zones along 2 to 4 lane roads with grade separated footpaths in some cases. Intersections are connected with 3-5 approach legs, which are either major roads, secondary arterial roads or minor roads. Some intersections are well marked with zebra crossings and provided with advanced information signals and some are asset with poor condition of signals and markings. Data have been collected in five phases between July-December of 2015 during 9-11 AM in the morning and 4-6 PM in the afternoon from these ten cities.

Fig. 1. Location map of selected cities of India

Table 2 Number of sites selected for three facilities of each city

City	Sidewalk	Signalized Intersection	Un-signalized intersection
Bhubaneswar	15	7	3
Cuttack	15	4	9

Raipur	11	5	5
Ranchi	18	7	11
Jamshedpur	15	5	8
Vijayawada	7	-	-
Tirupati	8	8	-
Vishakhapatnam	3	7	3
Vizianagaram	3	2	3
Rourkela	4	2	3
Total sites	99	47	45

After pedestrians were well explained about purpose of this study, they were asked to answer on the full length of the prepared questionnaire so that a real time perceived data set would be collected. After extraction of data set it was observed that around 1425, 630 and 675 number of pedestrian's perception data collected from sidewalks, un-signalized and signalized intersections respectively are suitable for model fitting purpose. As perception on a single item varies from person to person, data had been collected from different age and sex group whether move alone or in a platoon. From a total 2730 participants, 56.2% male, 43.8% female, 38% young (15-35 yrs.), 37% middle age (35-55 yrs.) and 25% old (above 55 yrs.) were asked to answer. It was observed that 66% of the total participants walk alone whereas only 17% move in a group of minimum 2 pedestrians. 63% of participants had to walk daily to catch public transports like bus, auto rickshaw, taxi etc. for their work trips. Purposes of walk trips of 51% participants were official, educational or to go together with school going kids; which indicates that pedestrian facilities are being regularly utilized. It was observed that 55% of respondents were economically dependent (student/housewife/retire person/unemployed) member of the family. Whereas 20% of participant's annual income level was between 0.1 and 0.2 million Indian rupees and only 5% of participant's annual income level exceeds more than 0.2 million rupees. Higher income level people prefer to travel by their own private vehicles may be one of the reason for this low percentage of participants. From the total ten cities data sets, data of nine cities were used for model development and validation purpose and data for Rourkela city has been used to check model transferability.

4. Results

After data collection and extraction descriptive statistical analysis has been carried out in order to get the minimum, maximum mean and standard variations of the different variables. From the analysis it is observed that the mean value of platoon size is 1.48 which indicates that most of the participants were walking alone although often platoon size two or more are encountered at institutional and recreational areas. After following normalization procedure explained before, maximum and minimum score of traffic, safety, comfort, maintenance and aesthetics are obtained to be 10 and 2 respectively. Here the value '2' represents extreme satisfaction with the particular variable and vice versa. For sidewalk facilities traffic score and safety scores are varying within 2.33-8.67 and 2.5-9 respectively. Road segments where traffic flows in a normal speed and dispensed with some space for pedestrian movement were having minimum score values. For some sidewalks higher score of traffic and safety parameters are observed due to illegal movement of vehicles from opposite direction, conflict with non-motorized vehicles, illegal parking at the road side etc. It is found that mean score value for comfort is 5.5 and for maintenance is 5. Most of the participants have given moderate ratings for pavement quality, maintenance and markings of pavements. Pedestrians were quite dissatisfied due to vender's encroachment on the sidewalks and in most of the places roadside beautification is neglected. This may be the primary cause for which aesthetic scores of participants varies from moderately satisfied to extremely dissatisfied (4-9.5).

While analysing about signalized intersection it is observed that traffic scores ranges between 2 to 8. This minimum score is observed at some signalized intersections where police monitors vehicular movement, thus percentage of illegal turn of vehicles is less and walkers able to cross safely during pedestrian green time. It is noted that, at some major intersections pedestrians have to wait for a long time and also during crossing left and permissible right turning vehicles from adjacent approach leg hinders pedestrian movement. Since exclusive phase in signal cycle of some intersections is not provided for pedestrian crossings, this may be the possible cause of pedestrian's dissatisfaction. It is also observed that the minimum score of safety and aesthetic parameters are 4.33 and 4.67 respectively, which clearly indicate that participants are partially satisfied with these attributes. Study on un-signalized intersections revealed that score of traffic parameter varies from 2.25 to 9 and score of safety parameter ranges from 3 to 9.5. At these intersections some participants have faced difficulties to cross due to turning of vehicles from wrong directions and thus pedestrians are forced to reduce their speed to avoid collision. During peak hours continuous flow of traffic forms pedestrians waiting time longer than expected. At some zebra crossings unwanted blockages by vehicles raised score of comfort parameter to a high value of 9.2. A very high score of 9.67 by maintenance parameter at un-signalized intersections indicates that proper information signs and pavement markings are missing for a safe crossing of pedestrians.

4.1 Discriminant Analysis

In this study, eight different independent variables contributing to overall satisfaction ratings such as gender, age, platoon sized (PS), traffic score (TS), safety score (SS), comfort score (CS), maintenance score (MS) and aesthetic score (AS) were taken into consideration. From all these variables, discriminant function analysis helped to select only those variables that discriminate among the six satisfaction groups (extremely satisfied, very satisfied, somewhat satisfied, somewhat dissatisfied, very dissatisfied and extremely dissatisfied). This discriminant analysis with the help of Wilk's Lambda and significance test (p-value) has shown significance of each independent variables in these models developed for three pedestrian facilities are shown in Table 3. Wilks' lambda i.e. near to 1 for all eight parameters (variables) indicates that the observed variables have some contribution in the model fittings in all cases. To investigate further, contribution of all these eight parameters were checked through significance test result shown in this table 3. It has been observed from this table that coefficient of significance (Sig.) of two parameters such as 'gender' and 'age of participants' for all three facilities are greater than 0.05 (which is not desirable), which indicates that these two variables are not significantly contributing in the development of PLOS models. The smaller significance values (nearly equals to 0.000) and higher Wilks' lambda values of platoon size, traffic score, safety score, comfort score, maintenance score and aesthetic scores evidence the importance of these parameters.

Table 3. Test of Equality of Group Means of Independent Variables

	Sidewalk		Signalized intersection		Un-signalized intersection	
Parameters	Wilks' lambda	Sig.	Wilks' lambda	Sig.	Wilks' lambda	Sig.
Gender	.998	.778	.995	.626	.993	.578
Age	.999	.909	.991	.297	.974	.108
Platoon size (PS)	.995	.002	.991	.033	.979	.033
Traffic score (TS)	.955	.000	.952	.000	.945	.000
Safety score (SS)	.971	.000	.960	.000	.947	.000
Comfort score (CS)	.933	.000	.909	.000	.850	.000
Maintenance score (MS)	.993	.007	.676	.000	.935	.000
Aesthetic score (AS)	.983	.000	.983	.047	.971	.004

Further, investigation was carried out in the selection of six parameters (variables) in this study for which a canonical correlation analysis has been carried out and the result is shown in the Table 4. This analysis helped in determining some optimal combination of eight parameters (gender, age, PS, TS, SS, CS, MS and AS) so that the first function (represented by 1) provides the most overall discrimination among satisfaction groups, the second (represented by 2) provides the second most and so on. According to discriminant analysis, the number of functions is equal to the number of discriminating variables, if there are more groups than variables or 1 less than the number of levels in the group variables. As perceived satisfaction scores in this study are classified into six groups (PLOS A-F) so five functions (1,2,3,4,5) are considered. Here, in this study 1, 2,3,4 and 5 function corresponds to combination of group of variables of six, five, four, three and two members. Here the first function (represented by 1) represents the successful function of a six member group as this function is having highest eigenvalues (canonical roots) as 0.114, 0.510 and 0.227, percentage of variance as 71.8, 71.3 and 47.4 and canonical correlation as 0.319, 0.581 and 0.430 for sidewalk, signalized intersection and un-signalized intersection respectively. Hence, the selection of six parameters (variables) is well supported to the previous findings by significance test in the development of PLOS models.

The test of functional output shown in the Table 5 represents, those are included in a given test with the null hypothesis that the canonical correlations associated within the functions are all zero. Here the 1st test for all the three pedestrian facilities presented tests of all 5 canonical correlation (1 through 5) where as the last test is for 5th correlation alone. Wilks' lambda values are estimated by (1- canonical correlation^2) and chi-square gives the canonical correlation where the function is equal to zero. The small significance value 0.000 indicates that discriminate function separated the variables from one another moderately.

Table 4. Eigen values for discriminant functions

Function	Eigen value	% of Variance	Cumulative %	Canonical correlation
Sidewalk				
1	.114[a]	71.8	71.8	.319
2	.033[a]	20.8	92.5	.178
3	.007[a]	4.4	96.9	.083
4	.004[a]	2.5	99.4	.063
5	.001[a]	.6	100.0	.032
Signalized intersection				
1	.510[a]	71.3	71.3	.581
2	.141[a]	19.7	90.9	.351
3	.038[a]	5.3	96.2	.191
4	.022[a]	3.1	99.3	.146
5	.005[a]	.7	100.0	.072
Un-signalized intersection				
1	.227[a]	47.4	47.4	.430
2	.140[a]	29.2	76.6	.350
3	.058[a]	12.1	88.7	.234
4	.035[a]	7.4	96.1	.185
5	.019[a]	3.9	100.0	.136

a-First 5 canonical discriminant functions were used in the analysis.

Table 5. Wilks' lambda test for discriminant function for temporal variation

	Sidewalk			Signalized intersection			Un-signalized intersection		
Test of function(s)	Wilks' lambda	Chi-square	Sig.	Wilks' lambda	Chi-square	Sig.	Wilks' lambda	Chi-square	Sig.
1 through 5	.859	215.033	.000	.545	403.778	.000	.641	256.358	.000
2 through 5	.957	62.535	.001	.822	129.965	.000	.786	138.539	.000
3 through 5	.988	16.725	.728	.938	42.417	.004	.896	63.161	.000
4 through 5	.995	6.985	.859	.973	17.847	.120	.948	30.808	.002
5	.999	1.435	.921	.995	3.466	.628	.982	10.739	.057

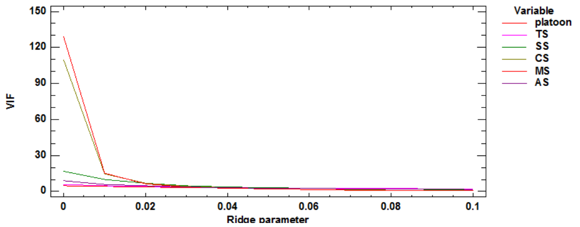
4.2 Models Development for Pedestrian Facilities

After examining the significance of the variables influencing pedestrian satisfaction, it has been observed that except age and gender other variables such as platoon sized (PS), traffic score (TS), safety score (SS), comfort score (CS), maintenance score (MS) and aesthetic score (AS) are having significance in developing PLOS models for pedestrian facilities as the significance values were less than .05 (from Table 3). Also from sensitivity analysis it has been observed that, significant parameters of sidewalk, signalized intersection and un-signalized intersection are contributing to the prediction process by 98.25%, 99.32% and 96.04% respectively. Hence other parameters such as age and gender of participants together contributing 1.75%, 0.68% and 3.96% in the prediction process of these models are assumed to have limited role to play. Hence models are fitted with the major influencing variables. Taking 70% data of the total data sets proposed models for three pedestrian facilities are configured in a common format as follows:

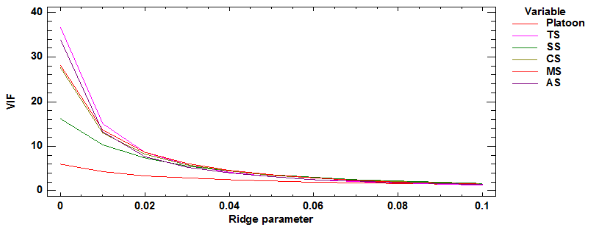
$$PLOSscore = \alpha_1 PS + \alpha_2 TS + \alpha_3 SS + \alpha_4 CS + \alpha_5 MS + \alpha_6 AS + \beta$$

(8)

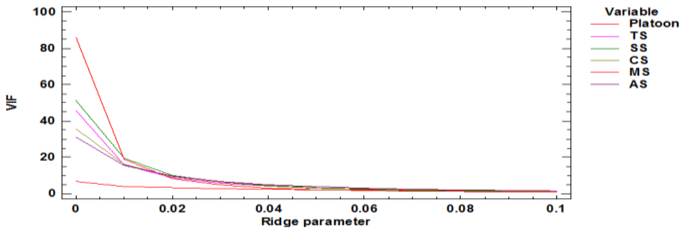
It has been observed from linear regression analysis that variance inflation factor (VIF) of different variables were greater than 10, which indicates serious multicollinearity were exist within the model variables. To avoid this, variables were analysed using ridge regression technique. As per ridge regression, large λ value indicates more shrinkage in the model development, hence in this study ridge parameter (λ) value has been closely observed to adjust its value closer to zero for better coefficient of estimation. It has been found that by fixing ridge parameters (λ) value at 0.05, 0.092 and 0.052 respectively for sidewalk, signalized intersection and un-signalized intersection, PLOS models provide least mean absolute errors and significant VIF value for each parameter. Plotting of various VIF values with respect to ridge parameters for different variables of three facilities are shown in Fig.2.



(a)VIF for sidewalk



(b)VIF for signalized intersection



(c)VIF for un-signalized intersection

Fig. 2. Variance Inflation Factors (VIF) and ridge parameters of different variables of three facilities

From the Fig. 2 it has been observed that at ridge parametric values of 0.05, 0.092 and 0.052 for the three facilities; VIF values are less than 5 for all six selected variables. As per the literatures, VIF value less than 5 proves the significance of each six variable in the PLOS models fitting. Coefficient and VIF values of each variable, and regression constant of three models are presented in Table 6. Significance of each variable in the model fitting is also checked by p-test, each value (sig.) is less than 0.05, which represents a good correlation exist between independent variables and overall satisfaction levels. Adjusted R^2 values of proposed models were estimated as 0.97, 0.96 and 0.96 with mean absolute errors of 0.089, 0.107 and 0.112 for sidewalk, signalized intersection and un-signalized intersection respectively.

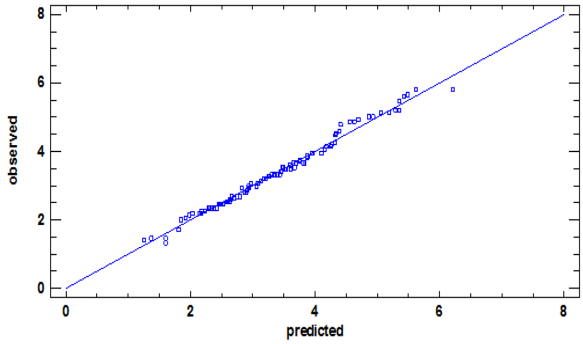
Table 6. Coefficients and VIF of parameters considered in three PLOS models

	Sidewalk			**Signalized Intersection**			**Un-signalized Intersection**		
Parameter	coefficients	VIF	Sig.	coefficients	VIF	Sig.	coefficients	VIF	Sig.
Constant	-2.97	-		-5.16	-		-2.32	-	
Platoon size (PS)	0.655	2.71535	0.000	0.65	1.56377	0.0000	0.217	2.20602	0.015
traffic score (TS)	0.146	3.18867	0.001	0.238	1.4563	0.0004	0.285	3.08687	0.056
safety score (SS)	0.311	3.20404	0.044	0.514	1.92074	0.036	0.074	2.89838	0.0018
comfort score (CS)	0.36	2.25516	0.0004	0.25	1.73892	0.005	0.21	3.20978	0.003
maintenance score (MS)	0.436	1.9427	0.001	0.23	1.68178	0.0194	0.345	2.06462	0.008
aesthetic score (AS)	-0.206	2.79453	0.004	0.113	1.58954	0.031	0.099	3.62994	0.004

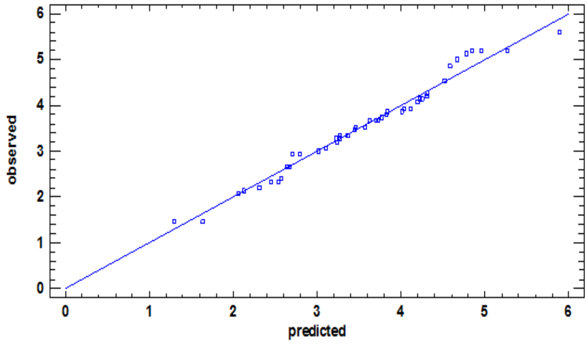
In this study, value of the dependent variable is always positive, ranging from 1 to 6 gives a positive mean value. The values of independent variables are also positive ranging from 2-10. Therefore the regression line crossed the x-axis somewhere between x=0 to x= 2 (depending on the minimum value of variable score) i.e. from the first quadrant to the fourth quadrant which results in negative values for the constant. Result in the Table 6, shows that all the parameters except aesthetic score of sidewalk are having positive coefficients. This implies that these parameters are directly proportional to the overall satisfaction i.e. the increase in the variable score explains about the dissatisfaction of the road user (overall score 6 represents the highest dissatisfaction). Aesthetic score for sidewalk facilities includes vending encroachment effects which leads to the inverse relationship with satisfaction level.

Three PLOS models for three pedestrian facilities have been developed using 70% of total datasets. The remaining

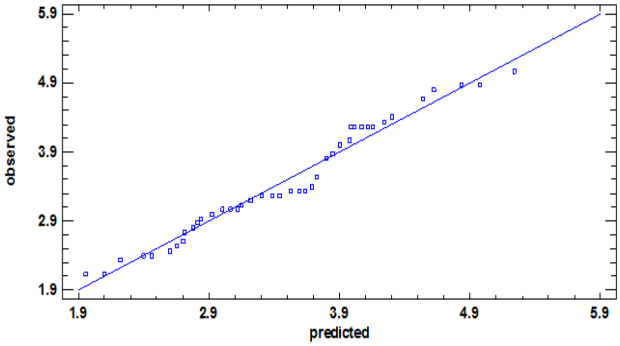
30% data were used for model validation purpose. Validation plot of three models are developed by taking prediction and observed data in X and Y axis respectively and the resulting plots are shown in the Fig.3. With R^2 of 0.978, 0.953 and 0.9531 for sidewalk, signalized intersection and un-signalized intersection respectively models for the three facilities are strongly validated.



(a)



(b)



(c)

Fig. 3. Validation of PLOS models for (a) sidewalk, (b) signalized intersection and (c) un-signalized intersection

Using these predicted models PLOS score values for each pedestrian were calculated. By taking the average score values of all participants for each site, PLOS score for different pedestrian facilities has been estimated and presented in Table 7.

Table 7. Predicted PLOS score obtained on each study site applying proposed models

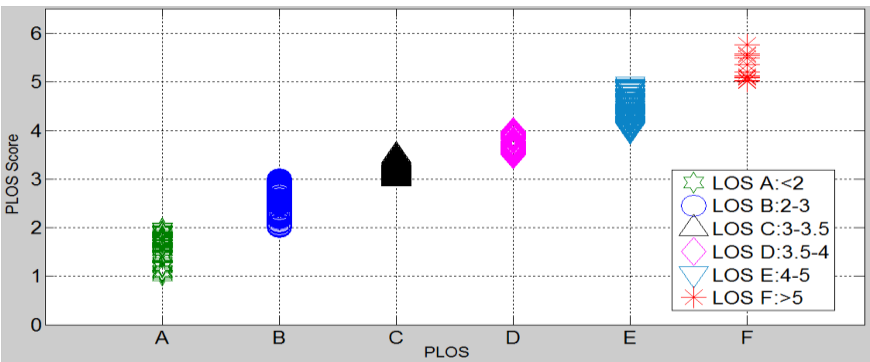
Sidewalk	Signalized Intersection	Un-signalized Intersection

Site	PLOS Score	Site	PLOS Score	Site	PLOS Score	Site	PLOS Score	Site	PLOS Score	Site	PLOS Score	Site	PLOS Score	Site	PLOS Score
Bbs1	2.33	Ctc10	3.37	Rn8	3.34	J14	3.66	Bbs1	2.36	J2	3.20	Bbs1	1.87	Rn8	3.41
Bbs2	3.37	Ctc11	3.39	Rn9	3.01	J15	3.47	Bbs2	5.09	J3	3.47	Bbs2	4.18	Rn9	3.92
Bbs3	2.89	Ctc12	3.71	Rn10	3.62	Vj1	3.71	Bbs3	3.50	J4	3.70	Bbs3	3.84	Rn10	4.17
Bbs4	3.86	Ctc13	3.70	Rn11	3.71	Vj2	3.19	Bbs4	4.06	J5	3.75	Ctc1	3.72	Rn11	3.53
Bbs5	3.50	Ctc14	2.25	Rn12	3.74	Vj3	2.87	Bbs5	4.20	Tp1	3.07	Ctc2	3.86	J1	4.07
Bbs6	3.86	Ctc15	3.68	Rn13	3.25	Vj4	3.63	Bbs6	4.27	Tp2	3.15	Ctc3	3.79	J2	3.54
Bbs7	3.58	Rp1	3.87	Rn14	3.27	Vj5	3.38	Bbs7	4.80	Tp3	3.88	Ctc4	3.18	J3	3.26
Bbs8	3.54	Rp2	3.67	Rn15	3.41	Vj6	3.33	Ctc1	3.43	Tp4	4.07	Ctc5	3.24	J4	3.37
Bbs9	3.50	Rp3	1.97	Rn16	3.43	Vj7	2.81	Ctc2	3.42	Tp5	2.95	Ctc6	3.70	J5	3.85
Bbs10	2.69	Rp4	2.86	Rn17	3.71	Tp1	2.86	Ctc3	2.48	Tp6	3.34	Ctc7	4.11	J6	3.94
Bbs11	3.54	Rp5	3.58	Rn18	2.85	Tp2	3.74	Ctc4	3.84	Tp7	3.92	Ctc8	2.16	J7	3.98
Bbs12	4.23	Rp6	3.42	J1	2.05	Tp3	3.52	Rp1	4.48	Tp8	4.94	Ctc9	3.70	J8	3.43
Bbs13	3.92	Rp7	3.73	J2	3.12	Tp4	3.58	Rp2	1.82	Vj1	3.81	Rp1	3.88	Vp1	4.16
Bbs14	3.63	Rp8	3.43	J3	3.77	Tp5	3.19	Rp3	3.03	Vj2	3.40	Rp2	2.59	Vp2	4.60
Bbs15	3.52	Rp9	3.62	J4	3.55	Tp6	3.53	Rp4	3.35	Vj3	2.75	Rp3	3.81	Vp3	2.62
Ctc1	4.07	Rp10	3.60	J5	3.79	Tp7	3.59	Rp5	3.69	Vj4	2.16	Rp4	3.82	Vz1	3.00
Ctc2	2.90	Rp11	1.82	J6	2.74	Tp8	3.48	Rn1	5.57	Vj5	3.08	Rp5	4.17	Vz2	2.79
Ctc3	3.86	Rn1	3.77	J7	3.03	Vp1	3.33	Rn2	2.25	Vj6	3.35	Rn1	4.18	Vz3	3.98
Ctc4	3.21	Rn2	3.90	J8	3.52	Vp2	3.73	Rn3	5.44	Vj7	3.60	Rn2	2.06	-	-
Ctc5	3.91	Rn3	2.77	J9	2.73	Vp3	3.21	Rn4	4.35	Vz1	3.89	Rn3	3.88	-	-
Ctc6	2.69	Rn4	3.70	J10	3.53	Vz1	3.03	Rn5	5.73	Vz2	3.29	Rn4	4.00	-	-
Ctc7	3.88	Rn5	3.51	J11	3.74	Vz2	3.45	Rn6	4.92	-	-	Rn5	3.87	-	-
Ctc8	2.58	Rn6	3.67	J12	3.73	Vz3	4.22	Rn7	3.50	-	-	Rn6	4.09	-	-
Ctc9	3.34	Rn7	3.14	J13	3.25	-	-	J1	1.27	-	-	Rn7	2.78	-	-

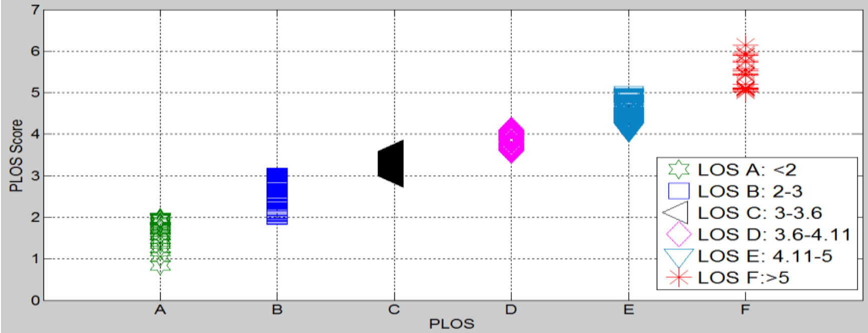
*Bbs-Bhubaneswar, Ctc-Cuttack, Rp-Raipur, Rn-Ranchi, J-Jamshedpur, Tp-Tirutati, Vj-Vijayawada, Vp-Vishakhapatnam, Vz-Vizianagaram

4.3 Classification of PLOS Scores

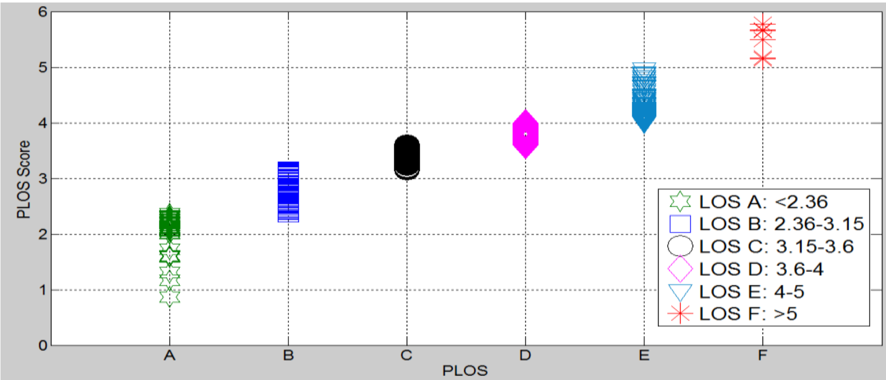
PLOS model outputs provides the predicted satisfaction scores for each participant and by applying GA-Fuzzy clustering technique these scores were classified in to six categories (A-F). Ranges of PLOS categories for three facilities obtained after clustering are shown in Fig.4.



(a) PLOS score ranges of service categories (A-F) of sidewalk



(b) PLOS score ranges of service categories (A-F) of signalized intersection



(c) PLOS score ranges of service categories (A-F) of un-signalized intersection

Fig.4. PLOS score ranges of service categories (A-F) of three facilities using GA-Fuzzy clustering technique
(*Here PLOS A: Excellent, PLOS B: Very Good, PLOS C: Good, PLOS D: Fair, PLOS E: Poor and PLOS F: Very Poor)

From the above figure the following observations has been noted for each facility type

Sidewalk: PLOS score ranges of service category ‘A’, ‘B’, ‘C’, ‘D’, ‘E’ and ‘F’ are < 2, 2-3, 3-3.5, 3.5-4, 4-5 and > 5 respectively. 6%, 24%, 23%, 24%, 21% and 2% of total sidewalk facilities are offering PLOS ‘A’, ‘B’, ‘C’, ‘D’, ‘E’ and ‘F’ respectively. It shows that only 6% of pedestrians were able to walk in their desired path and 2% of the total participant’s speed was severely restricted.

Signalized Intersection: PLOS score ranges of service category ‘A’, ‘B’, ‘C’, ‘D’, ‘E’ and ‘F’ are < 2, 2-3, 3-3.6, 3.6-4.11, 4.11-5 and > 5 respectively. 4%, 19%, 30%, 22%, 22% and 3% of total signalized intersections are offering PLOS ‘A’, ‘B’, ‘C’, ‘D’, ‘E’ and ‘F’ respectively. 4% of total participants can cross signalized intersection without any difficulties and 19% of participants occasionally have to alter their paths during crossing.

Un-signalized Intersection: PLOS score ranges of service category ‘A’, ‘B’, ‘C’, ‘D’, ‘E’ and ‘F’ are < 2.36, 2.36-3.15, 3.15-3.6, 3.6-4, 4-5 and > 5 respectively. 7%, 17%, 22%, 29%, 22% and 1% of total un-signalized intersections are offering PLOS ‘A’, ‘B’, ‘C’, ‘D’, ‘E’ and ‘F’ respectively. In these facilities 29% of slower participants have to face difficulties and speed of 22% of participants were restricted, where as 1% of pedestrians have face severe problems while crossing the intersections.

The PLOS ranges clustered using GA-Fuzzy clustering technique were compared with threshold values of PLOS ranges defined in some of the previous studies as shown in Table 8.

Table 8. Comparison of existing and proposed model score ranges of PLOS categories (A-F)

	Sidewalk			Signalized Intersection			Un-signalized Intersection		
PLOS	HCM	Yang Bian Model	Proposed Model	HCM	Yang Bian Model	Proposed Model	HCM (Control Delay, Sec.)	Yang Bian Model	Proposed Model
A	<2	<1.5	<2	<2	<1.5	<2	0-5	<1.5	<2.36
B	2-2.75	1.5-2.5	2-3	2-2.75	1.5-2.5	2-3	5-10	1.5-2.5	2.36-3.15
C	2.75-3.5	2.5-3.5	3-3.5	2.75-3.5	2.5-3.5	3-3.6	10-20	2.5-3.5	3.15-3.6
D	3.5-4.25	3.5-4.5	3.5-4	3.5-4.25	3.5-4.5	3.6-4.1	20-30	3.5-4.5	3.6-4
E	4.25-5	4.5-5.5	4-5	4.25-5	4.5-5.5	4.1-5	30-45	4.5-5.5	4-5
F	>5	>5.5	>5	5	5.5	>5	>45	5.5	>5

The results coming out from the proposed models were compared with the existing models (HCM and Yang Bian) by observing 10 sites from each facility type. Also these results were compared with the field observed satisfaction levels as shown in the Table 9.

Table 9. Comparison of observed PLOS categories with estimated PLOS categories of existing models and proposed model

Sidewalk				
Sites ID	Observed PLOS	HCM PLOS	Yang Bian PLOS	Proposed PLOS
1	D	C	D	D
2	B	A	E	B
3	B	B	F	B
4	F	E	D	C
5	A	A	C	B
6	C	C	F	C
7	C	B	D	C
8	A	B	C	A
9	C	B	F	C
10	C	D	D	C
% exact match to observed PLOS	100%	30%	10%	80%
Signalized Intersection				
Sites ID	Observed PLOS	HCM PLOS	Yang Bian PLOS	Proposed PLOS
1	C	B	F	C
2	A	B	E	A
3	C	C	F	C
4	B	B	D	B
5	D	E	F	D
6	F	E	F	E
7	A	A	D	A
8	E	D	E	E
9	B	B	F	B
10	A	B	D	A
% exact match to observed PLOS	100%	40%	20%	90%
Un-signalized Intersection				
Sites ID	Observed PLOS	HCM PLOS	Yang Bian PLOS	Proposed PLOS
1	A	B	A	A
2	D	E	E	D
3	C	B	B	B
4	B	C	A	B
5	C	D	F	C
6	F	E	F	E
7	A	A	E	A
8	E	E	E	E
9	D	C	A	D
10	A	C	D	A
% exact match to observed PLOS	100%	20%	30%	90%

From this table it is being noted that estimated PLOS categories by the application of proposed models give more harmonious results with field observed than existing model outputs. Outputs obtained using HCM and Yang Bian models have respectively shown only 30% and 10% matching with field observed service levels for sidewalks at these 10 selected sites. Applying these two models meant for signalized intersections, matching with field observed service levels are limited to 40% and 20%; similarly for un-signalized intersections matching are 20% and 30% respectively. Whereas, outputs of proposed models have shown more that 75% matching with the field observed service categories for all three facilities. Considering these results it has been inferred that proposed models in this study have more practical applications than the existing models.

From the analysis of sidewalks of different cities it has been observed that for Cuttack city 75% of participants have given fair rating i.e. PLOS D, 22% rated as PLOS B and 3% rated as PLOS E. In Ranchi, Vishakhapatnam and Raipur cities nearly 15% of participants have given the ratings of PLOS E i.e. poor condition. This PLOS E is observed in those places where due to heavy traffic flow and absence of proper grade separated foot path pedestrians have to face difficulties while walking. For Vizianagaram city75%, 20% and 5% of participants have given ratings of PLOS C, E and F respectively.

Signalized intersection data analysis have shown that average 65% of pedestrian have given good rating i.e. PLOS C. Among all cities only for Raipur city highest 23% of pedestrian rated the signalized intersection as PLOS B where as in Vizianagaram city 14% participants rated the facilities as PLOS E. For Bhubaneswar, Ranchi and Jamshedpur cities nearly 3% of pedestrians have perceived the facilities as F quality of service which represents very poor condition.

In case of un-signalized intersection almost in all cities ratings were varying from fair to very good. In Cuttack and Ranchi city nearly 60% of user perception was come as PLOS D. This may be occurred due to the heavy traffic flow and the aggressive nature of drivers as they are reluctant to provide space for pedestrians' crossings. For Vishakhapatnam city, according to 31% of participants the un-signalized intersections were having service level of B. Observation shows that as enforcement of traffic rules are poor at un-signalized intersections, so pedestrians have to wait for longer time than expected to cross and also conflict with other road users at these facilities. It has been noted that none of these three facilities are able to offer service quality as 'A' in the prevailing conditions. This may be because of walkers are not fully satisfied with these facilities as they were excepted better pedestrian friendly environments. These are the condition of service categories for study areas taken in this research work. Similarly the proposed methodology, models and classification can be apply for other developing countries in order to achieve margins for service levels.

Model transferability is an important aspect to understand the characteristics at a place where detailed data is not available. To check model transferability, data of Rourkela city of India with mixed traffic conditions were analyzed. 4 sidewalks, 2 signalized intersections and 3 un-signalized intersections have been selected from Rourkela city to test transferability of PLOS models for the three facilities. From the observed and predicted investigation it was found that R^2 values were 0.86, 0.79 and 0.92 for sidewalk, signalized intersection and un-signalized intersection respectively. The probability of correct prediction of satisfaction level has been found to be 93%, 88% and 96% for the three facilities.

5. Discussion

Based on the perception of 2730 participants for pedestrian facilities such as sidewalk, signalized and un-signalized intersections, analysis has been carried out to develop models in order to measure satisfaction levels. Study shows that nearly 40% of pedestrians face difficulties due to turning of vehicles from wrong side. 5% of pedestrian often encountered difficulties due to heavy vehicles whereas 50% face difficulties because of non-motorized mode of transport (for example bicycle). Non-motorized modes were interfering to the walker as in most of the places there is no specific lane for bicycle and both pedestrian and bicyclist have to share the road side. 68% of walkers were feeling unsafe because of high traffic speed and nearly 20% of walkers have to change their path due to illegal parking on the sidewalks. 11% of participants perceived that drivers wait for pedestrians to cross first whereas according to 14% of pedestrians, aggressive drivers are troubling to the pedestrians always and it is more difficult to cross at un-signalized intersections. In order to avoid conflict in these cases facilities should be provided with better pedestrian signal system or alternate crossing facilities such as foot over bridge. Only 3% of participants were against putting barriers between sidewalk and main carriageway and 63% of participants have given their view that barriers will make walking safer.
In this study, both dependent and independent variables of the proposed PLOS models are measured under positive scales of values ranging between 1-6 and 2-10 respectively. The regression based model output values while plotted

against the input values shows that the regressed line crossed the X-axis somewhere between X=0 and X= 2 for each facility type; resulting in negative intercepting values on the Y-axis.

According to the PLOS classification proposed in this study, scores < 2, < 2 and <2.36 for sidewalk, signalized and un-signalized intersection pedestrian facilities represent service category ‘A’. Negative outcome of the model for any facility here can be assumed to belong to service category ‘A’. Investigations show that models proposed for these facilities have maximum chances of 2.55%, 1% and 1.62% that may give negative prediction values. Assuming these percentage values as percentage errors in the prediction precision of models, this study gives a new methodology to assess the perceived satisfaction level of pedestrians while using road facilities. A further investigation in this regard can be carried out in similar studies.

From these models it is examined that with the increase in platoon size i.e. when pedestrian moves in a group of more than 2 pedestrians they face more difficulties. High speed traffic leads to increase in the value of safety score and it directly effect to the pedestrian as the feel more unsafe while using sidewalks as well as during crossing intersections. When roadsides are shared by bicycle and pedestrian both then conflict increases. Therefore, it is more useful to provide separate lanes for bicycle and pedestrian. This will not only provide comfort for road users but also increase the use of green mode of transportation. Although in this research maintenance aspect is moderately satisfied by the participants, but if the facilities are not taken care properly after few years more than 55% of the pedestrian facilities will provide below average service. Therefore, facilities need to be developed and more advanced light and signals are to be provided in order to get safe and comfortable pedestrian environment.

5.1 Conclusion

From discriminant analysis higher Wilk’s lambda indicates that the group variability is larger than the total variability. Significance value of parameters like age and gender are greater than 0.05, which shows that these parameters are not having significant influence of PLOS measurement. Findings revealed that satisfaction levels of pedestrians mainly influenced by platoon size, traffic score, safety score, comfort score, maintenance score and aesthetic score. But variation in gender and age are not having major discrepancy while developing models for satisfaction level.

Variance inflation factors for different independent variables have proved the multicollinearity among variables. Implementation of ridge regression technique has given three PLOS models having R^2 values as 0.97, 0.96, 0.96 for sidewalk, signalized intersection and un-signalized intersection respectively. Developed models have given predicted PLOS score of each site of three facility types. The minimum and maximum PLOS score for each facility type is defined to be 1 and 6. PLOS score 1 signifies that the facility is offering the best service quality and 6 signifies the worst service quality.

With the application of GA-Fuzzy clustering technique ranges of service categories for pedestrian facilities shows that for PLOS ‘A’ service score for sidewalk, signalized intersection and un-signalized intersection are <2, <2 and <2.36 respectively. And PLOS scores are found to be >5 for ‘F’ service quality of all three facilities. Comparison of PLOS model based scores of six service categories (A-F) defined in this study shows that ranges differ from existing PLOS ranges of three facilities.

As the study used a wide range of data and validation shows the perfection of the models therefore these proposed models have remarkable potential for wide application in defining service levels for pedestrian facilities in developing countries. Model outputs indicates that PLOS categories estimated by applying the proposed model give more than 80% compatible results with field satisfaction level for the three pedestrian facilities. Proposed PLOS models for the three facilities can be used by roadway planners and designers to measure the performance of existing pedestrian facilities and to develop new improved facilities.

5.2 Limitation and Future Work

The present study developed a methodology for the evaluation of service level offered by three pedestrian facilities for mid-sized cities having population size less than or nearly a million. Many cities in developing courtiers are having population size more than a million. Pedestrian travel behaviour changes under such bigger cities as effect of public transportation system is more pronounced under busy working hours where people live in a more competitive environment with higher ambition to acquire more in life. So many parameters considered in this study perhaps will have different effect in the modelling approach. In this study, platooning effect has been considered from the perception survey. There is a need to thorough assess effect of pedestrian platooning on service quality offered by sidewalks and crosswalks under a mixed traffic flow in developing countries. Also, in this study only qualitative variables are considered, a different modelling approach can be given considering both quantitative and qualitative variables. A thorough investigation showing relationship between quantitative and qualitative variables can be accommodated in such models.

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