International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 02 Issue: 03 | June-2015 www.irjet.net p-ISSN: 2395-0072

Modelling Pedestrian Overall Satisfaction Level at Signalised Intersection Crosswalks

Jitendra Singh Yadav[1], Anuj Jaiswal[2], Raman Nateriya[3]

[1]*M.tech Scholar, Department of Civil Engineering, Maulana Azad National Institute of Technology (MANIT), Bhopal, MP, India*
[2]*Asst. Professor, Department of Architecture and Planning, Maulana Azad National Institute of Technology (MANIT), Bhopal, MP, India*
[3]*Asst. Professor, Department of Civil Engineering, Maulana Azad National Institute of Technology (MANIT), Bhopal, MP, India*

Abstract -This study aims to find out the factors influencing pedestrian Level of service at crosswalks of signalized intersection and proposed a method to determine the pedestrian level of service at signalized intersection crosswalks by manipulating and quantifying the pedestrian perceived overall satisfaction level. A pedestrian survey was conducted to collect pedestrians overall satisfaction level in terms of safety, comfort and convenience for each crossing at signalised intersection based on pedestrian's experiences at the actual sites. The pedestrian overall satisfaction level was considered as the dependent variables for the regression analysis. Also a field survey was conducted to collect geometric, operational and traffic characteristics of each crosswalk at selected four signalised intersection. Crosswalk holding area , crosswalk marking, motorist behaviour, left turning vehicles volume, left turning vehicles speed, red timing for pedestrian, were identified as the main factors affecting pedestrian LOS at intersections. Pedestrian overall satisfaction level model were developed by a stepwise multivariable regression analysis using SPSS software. Percentage of pedestrian overall satisfaction was then transformed to six levels of service categories. The resulting general model has a high correlation coefficient (R^2=0.931) with the average observations, and is applicable to most of the developing cities of India like Bhopal. This model provides traffic planners and others the ability of rating signalised intersection crosswalks according to pedestrians' overall satisfaction level. This model may be used for evaluating existing signalised intersection, designing new signalised intersection, or redesigning existing signalised intersection.

Key words: Signalised intersection crosswalks, Pedestrian overall satisfaction, LOS,

1. INTRODUCTION

With the increase in economic growth of the developing countries, urbanization and growth of urban traffic also increases. This results in increase in urban spread out and further resulted in increase in the use of public transportation trips. Public transportation trips are usually connected to walk trips either origin or destination or both and sometimes at mode transfer points. A pedestrian may need to cross the road for many reasons. Due to their urgency or value of time, pedestrian follow non- complaint behaviour while crossing the road [8].
For some time, transportation engineers and planners have paid attention primarily to the motorized transportation system. Even today, the motorized transportation system receives an overwhelming priority over systems that serve the needs of non motorized users such as pedestrians and bicyclists. Due to increase in motor vehicle growth, mostly attention is given for regulation of motor vehicles only and the pedestrian regulation is completely neglected.

Intersections are the most critical elements in any transportation network. Road users of different types in different masses, from different directions and moving at different speeds have to use the same space, resulting in a large number of potential conflicts. Whereas intersections constitute a very small part of the entire transportation network, more than 50% of all motor vehicle accidents occur at intersections.

The latter, created the necessity of measuring the performance of the facilities that serve pedestrian traffic in order to determine quality of operations, existing deficiencies, needs for improvements and priority setting. Many of the walking trips are in urban areas and require many street crossings, mostly at mid-block or intersections. Though generally viewed as the preferred place to cross the street for safety reasons, intersections can be a deterrent for walking if design and operation heavily favour motor vehicles under mixed traffic condition.
Since the pedestrian environment is multi-dimensional, the pedestrian in the roadside environment is subjected to a set of several factors significantly affecting his or her perception of safety, comfort, and convenience. Measurement of these factors is necessary to evaluate the pedestrian facilities and evaluation methods are needed to understand how well a particular intersection accommodates pedestrian travel.

That's why there is a need to analysis of pedestrian crossing at signalised intersections and to develop a new LOS model by considering prevailing traffic conditions and pedestrian behaviour in developing cities in India.

2. BACKGROUND

There have been various studies carried out to estimate the pedestrian LOS which are influenced by different factors such as Road and traffic operation factors, Pedestrians factors, Vehicles factors, Road markings and signs factors, Traffic signal factors, etc. In general, the demand for the improvement of pedestrian facilities is raised due to the reasons such as difficulties in crossing heavily trafficked intersections, turning vehicles across their paths during the green signal, conflicts among pedestrians and cyclists, physical barriers, low visibility, improper design of handicapped accessible ramps and so on. Road designers have to investigate what kind of mechanism is necessary in order to promote walking. They need to analyze how to make walkways safe and comfortable so that pedestrians can travel with pleasant feeling [10].

A pedestrian LOS criterion for signalized intersection is defined in terms of time delay in the Highway Capacity Manual 2000 (HCM, 2000). Although HCM describes LOS criteria for pedestrian at intersections based on pedestrian delay, it does not include the other factors such as crossing facilities, turning vehicles, motorist's behaviour and pedestrian bicycle interactions at crosswalks, etc.

IRC-103-1988 specifies the provision of pedestrian crosswalks at all important intersections and at locations where substantial conflict exist between vehicular and pedestrian movements. It explains that wherever possible; crosswalks should be at right angles to the carriageway and properly marked so that pedestrians are subjected to minimum inconvenience. Also, at crosswalks walking distance should not be more for pedestrians. Proper visibility, free from obstructions and sufficient area for waiting are other important requirements provided in IRC for the location of crosswalks.

Sarkar [15] gives a qualitative method for computing pedestrian LOS based on six factors: safety, security, convenience and comfort, continuity, system coherence, and attractiveness [15]. In Sarkar's work qualitative attributes of pedestrian environments are described, but not quantified. Since his method is a qualitative method, the measurement of each factor is not easy in reality and also most of the factors are linked with each other. After this Khisty [7] build a quantitative method to determine the pedestrian LOS based on almost same criteria proposed by Sarkar [7]. Even though Khisty's method provides a quantitative measure of pedestrian LOS on a point scale, the results from this scale is not easy to interpret. A question remains as whether these scaling systems really address the pedestrian facilities, i.e. do pedestrians agree with these scaling systems.

Dixon [1] proposed a pedestrian LOS evaluation criterion which considers the provision of conflicts, basic facilities, amenities, motor vehicle LOS, travel demand management, and multimodal provisions. There was no qualitative environmental assessment describing to walkability. His method seems best suited to footpath assessments only and its applicability to intersections was uncertain.

Landis et al., [13] proposed a mathematical model based on five variables: lateral separation of pedestrians from motor vehicle traffic, presence of physical barriers and buffers, outside lane traffic volume, motor vehicle speed, and vehicle mix. This model evaluates a roadway segment, it does not include intersections. However, they believe that intersection conditions have a significant bearing on pedestrians and a measure must be developed that includes conditions at intersections. Also his model was limited to environmental factors only and it does not includes other factors such as path users flow rate, and holding area availability for pedestrians.

Petritsch et al. [13] provides a model which includes critical factors that determine pedestrians' perceptions of LOS at signalized intersection crossings. In his study it is found that right-turn-on-red volumes for the street being crossed, permissive left turns from the street parallel to the crosswalk, motor vehicle volumes on the street being crossed, midblock 85 percentile speed of the vehicles on the street being crossed, the number of lanes being crossed, the pedestrian's delay, and the presence or absence of right-turn channelization islands were primary factors for pedestrians' LOS at intersections.

Muraleetharan et al., [10] used conjoint technique to combine the factors affecting pedestrian LOS. Total utility from the conjoint analysis represents an overall value, which specifies how much a user puts on a product or service. Even though this study proposed a method to determine overall LOS, it does not include all the factors affecting pedestrian LOS.

Muraleetharan et al., [11] identified the factors affecting pedestrian level-of service at intersections and proposed a method for the estimation of pedestrian LOS at intersections. The study revealed that the factor turning vehicle has greater influence on pedestrian LOS than other factors. Furthermore, the factors delays at signals and pedestrian-bicycle interaction were also found to be significant factors in determining pedestrian LOS at intersections. Hubbard et al., [6] developed a signalized intersection model for pedestrian LOS based on the percentage of pedestrian crossings affected by turning vehicles.

Lee et al. [12] reviewed the existing criteria to evaluate the service quality of signalized intersections, and identified six criteria accordingly. Individual perceptions regarding the service qualities of signalized intersections were estimated using Fuzzy Weighted Average. A Consensus Analysis model was then used to measure the "weight" of individuals' opinions to

aggregate to the overall service quality of a signalized intersection. Lee et al. [12] also looked at crossing LOS using a stated preference survey. They found that the key determinants of LOS at signalized intersections were area occupancy, pedestrian flow, and walking speed.

Hubbard et al., [6] did a statistical analysis using a binary logit model that provides new insights into the factors that affect the likelihood that a pedestrian is compromised ,delayed, altered their travel path, or altered their travel speed, in response to traffic turning right on green during concurrent vehicle/pedestrian signal timing. Application of a binary logit model of pedestrian compromises shows that the probability of a pedestrian compromise increases with increasing right-turn vehicle flow rate, and is higher for crosswalks outside the CBD compared to crosswalks in the CBD for the same right-turn flow rate.

Current researches on pedestrian LOS show that there are also some other factors that affect pedestrian LOS more than delay. Therefore a method is needed to include the factors into the computation of pedestrian LOS at intersection. According to literature review, much of the works dealing with pedestrian is restricted to pedestrian facilities on uninterrupted sidewalks and there are a few studies dealing with pedestrian facility issues at intersections. Usually accidents in non-motorized transport modes occur when it is difficult for the user to cross an intersection [2]. This shows that a reliable measure is needed to describe the pedestrian environment at intersections. Therefore the endeavour of this research is to solve intersection LOS issues connected with pedestrians. The research will provide a method to assess the degree of difficulty a user will experience crossing an intersection. Development of pedestrian LOS measure for intersection is intended to indicate the level of difficulty in crossing intersections in terms of their satisfaction level.

3. METHODOLOGY

The major steps involved in this study are: (1) identify the factors affecting pedestrian level-of service (LOS) at intersections (2) selection of suitable site for field survey (3) The collection and extraction of data by visual surveys and field surveys. (4) Model development for pedestrian overall satisfaction score for pedestrian crossing at signalised intersection.

3.1. Identification of Parameters Affecting Pedestrian LOS at signalised Intersections

It is important that right factors should be included in the design process. In the selection of the parameters, the focus is solely on those factors which directly affect pedestrian crossings at signalized intersections in terms of pedestrian safety, comfort, convenience, system continuity and economy.

1. Road and traffic operation
   - Road width,
   - Visibility (being able to see vehicles and be seen),
   - Turning movements,
   - Gradient,
   - Lighting,
   - Channelling of pedestrian flow,
   - No. of lane
2. Pedestrians
   - Pedestrian volume,
   - Demand (in time and space),
   - Security,
   - Pedestrian speed,
   - Waiting time/delay
3. Vehicles
   - Vehicle Speed,
   - Vehicle density,
   - Vehicle volume,
   - Proportion of vehicle types
4. Road markings and signs
   - Zebra crossing
   - Stop line
   - Zebra crossing length
   - Zebra crossing maintenance
   - Signs warning of the presence of zebra crossing

5. Traffic lights
   - Pedestrian signal lights
   - Vehicle signal lights,
   - Timings for pedestrians,
   - Timings for vehicles,
   - Cycle length
   - Visibility of pedestrian lights

We select a set of some parameters that distinguish the facility under analysis of pedestrian by referring previous research works and field survey. These parameters are crosswalk holding area , crosswalk marking, crosswalk surface condition, crosswalk width, crosswalk length, motorist behaviour, left turning vehicles volume, left turning vehicles speed, pedestrian flow, red timing for pedestrian , green timing for pedestrian.

3.2. Study Area

This study was conducted in Bhopal. Bhopal is the capital city of Indian state of Madhya Pradesh. Bhopal is a fast growing city of India where urbanization occurred at very fast rate. There are many critical junctions due to its land use pattern. It is required a sincere study for pedestrian safety and comfort. for this crosswalks of four signalised intersections were chosen for the study area in Bhopal city. Each signalised intersection includes 4 crosswalks. Therefore we have studied 16 crosswalks at four signalised intersections in Bhopal. All locations have high pedestrian flow at peak hours. The selected locations have different roadway geometry conditions and roadway characteristics of intersections crosswalk.

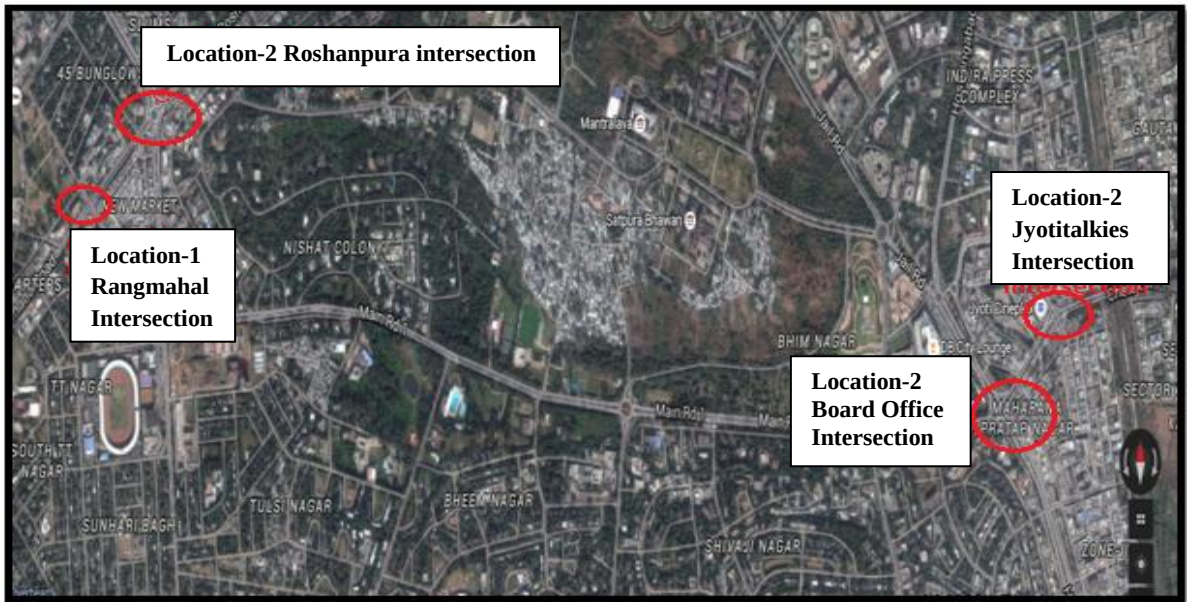


Figure3.1: Study area location map from Google earth

3.3. Data collection and extraction

A Pedestrian Intercept Survey and video graphic survey was conducted, in which individual pedestrian's overall satisfaction level percent in terms of safety and comfort, and geometric and traffic data were collected at crosswalks of signalised intersections four locations. At each crosswalk 25 pedestrian were interviewed which are much familiar with that crosswalk. In this Pedestrian Intercept Survey we ask the pedestrian to give their own perception on their overall satisfaction in percentage and factor importance rating out of 10 for each considered factors from literature which affects signalised intersections crosswalk LOS and according to which they respond for their overall satisfaction level at signalised intersections crosswalk. This survey also collects data about pedestrian perception on quality of pedestrian facilities available and motorist's behaviour at the same time. Since perceptions of individual pedestrian about various factors that affects LOS of particular signalised intersections cross walk is different from others due to variation in gender ,age, nature, etc, we take individual' perceptions over different pedestrian facilities and motorists behaviour. Each was asked to give their rating for different pedestrian facilities and motorists behaviour from 1 to 5.

Ratings of four factors crosswalk surface condition, crosswalk marking, crosswalk holding area and motorist's behaviour were asked to pedestrian to give their individual rating. Meaning and full explanation of these factors has given to each pedestrian which was already written on paper before asking their satisfaction level. It was emphasized to respondents

that this study needs their perception of the level of difficulty if they were to use the particular crosswalk. For better understanding of respondents the factors explanation paper was prepared in both English as well as local language (Hindi). Also respondents were given enough time to answer. The overall satisfaction levels in percentage given by the pedestrians were considered as the dependent variables for the analysis.

Traffic and Geometric data of particular signalised intersections crosswalk was collected video recording and field observation of signalised intersections crosswalk. Geometric data was collected during early morning hours when there is no much traffic at intersections. Both crosswalk length and crosswalk width was measured in meters.

Traffic volume and operational data was collected by video recording method. Traffic volume data includes no. left turning vehicle through each approach of intersection and no. of pedestrian crossing through crosswalk where as Traffic Operational Data includes red timing for pedestrian and green timing for pedestrian at each signalised intersection crosswalk which are considered for study. In this study we only considered red timing for pedestrian by excluding amber time because generally amber time was same for all signalised intersection and only red timing and green timing were changed for different signalised intersection. Speed of left turning vehicles through each approach of intersection were also calculated from these videos. One hour videos were taken at same time of pedestrian intercept survey in the evening peak hours i.e. between 5:30pm to 6:30pm. These videos were played in laboratory to count the pedestrian flow, vehicle flow and speed of left turning vehicles during green signal for pedestrian at signalised intersection crosswalks. We have taken average value speed of left turning vehicles due to large variation in an hour. Left turning vehicle through each approach of intersection is sum of left turning vehicles going from a particular approach and left turning vehicles coming from adjacent left turning lane to that approach.

Table 1: Collecting Geometric and Operational Characteristics

Location	Cross walk	Avg facilities level			Motorists behaviour	CW length	CW width	Lft trng vhcl vol/hr	Lft trng vhcl spd	No of ped /hr	Rd tm for ped	Gr tm for ped
		CWSC	CWM	CWHA								
1	1	3	3	1	2	24.5	2.77	579.0	24.3	594	75	20
	2	3	3	1	2	20.3	2.97	634.0	21.4	638	75	20
	3	2	2	1	1	22.75	3.01	499.0	19.3	818	75	20.0
	4	3	3	1	1	29.3	2.64	554.0	19.7	632	75	20.0
2	1	4	3	4	2	29.65	2.73	1200.0	17.4	537	100	25.0
	2	4	3	4	3	26.34	3.00	946.0	21.6	660	95	30.0
	3	3	3	3	3	37.62	2.90	1130.0	18.2	736	100	25.0
	4	3	4	3	3	33.13	3.00	732.0	20.8	470	95	30.0
3	1	3	4	3	3	27.16	3.00	1585.0	10.1	633	95	20.0
	2	3	4	4	2	27.97	3.00	1221.0	9.26	689	85	20.0
	3	3	3	4	3	31.43	3.00	1501.0	7.41	835	85	30.0
	4	2	4	3	3	25.08	3.00	1137.0	12.0	672	85	30.0
4	1	2	1	2	3	21.97	-	910.0	25.8	447	78	33.0
	2	3	2	2	3	29.42	2.83	2093.0	33.6	842	96	15.0
	3	2	2	2	2	22.63	2.95	1580.0	29.4	570	78	33.0
	4	3	4	2	2	23.23	2.6	1423.0	25.0	783	96	15.0

Note: Averaged facilities rating are in round figures.

4. DATA ANALYSIS AND MODEL DEVELOPMENT

4.1. Averaged pedestrian overall satisfaction

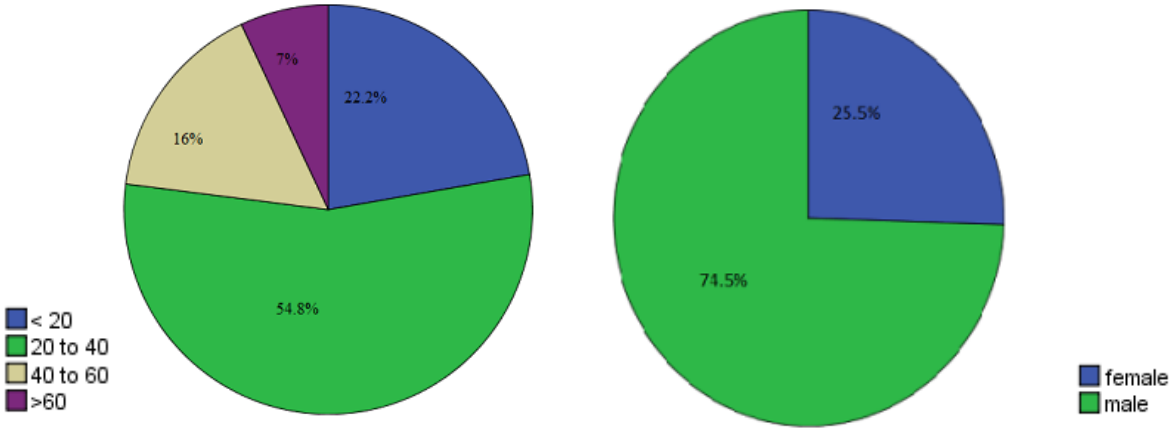
As shown in Table, the averages of pedestrian overall satisfaction were computed for each crosswalk using the answers of respondents. Responses from persons unfamiliar with the location and only using a few times per month or year were not considered. Responses from frequent users were only taken into the analysis. This question was asked to pedestrians before asking their satisfaction level.

Table 2 : Averaged pedestrian overall satisfaction

Location	Crosswalk	No. of pedestrian surveyed	Averaged pedestrian overall satisfaction (%)
1	1	25	49.49
	2	25	47.62
	3	25	43.73
	4	25	50.22
2	1	25	61.8
	2	25	60.20
	3	25	57.80
	4	25	64.81
3	1	25	57.55
	2	25	57.73
	3	25	62.04
	4	25	65.03
4	1	25	57.74
	2	25	40.03
	3	25	54.62
	4	25	44.90

4.2. Age Distribution and Gender of Respondents

A total of 400 participants responded to the survey, 298 males' and102 females. The result indicates that a wide range of respondents participated. Figure:2 shows the age and gender distribution of all respondents.



A: Age distribution B: Gender distribution

Figure 2: Overall Age and Gender distribution of pedestrian responses at all four locations.

4.2. Model Approach

4.2.1. *Regression analysis*

A stepwise multi-variable linear regression analysis was used to determine the overall satisfaction of the pedestrian about the LOS at signalised intersection crosswalk.

A linear regression which is a general statistical tool to develop a relationship between dependent and independent variables, was the technique adopted for the development of the model. It includes modelling, analyzing several variables and describing the relationship between a dependent variable and one or more independent variables, thus regression analysis helps to understand how the values of dependent variable changes when any one of the independent variables is

varied Model should be selected to minimize the number of predictors which have maximum variance, in the other words; the most efficient model maximizes the value of the coefficient of the determination (R^2).
In this section of data analysis data is preparing for the model development, data are collected from the pedestrian intercept surveying. After extraction of all the satisfaction survey data in the excel sheet performed some mathematical analysis on the data for performing regression analysis using SPSS software.
SPSS statistical package is one of the most popular statistical packages which can perform highly complex data manipulation and analysis with simple instructions. SPSS is a Windows based program that can be used to perform data entry and analysis and to create tables and graphs. SPSS usually creates commonly used graphics in the fields of social science, such as histograms, scatter plots, and regression line, etc. For developing model for satisfaction level perform regression analysis on data using SPSS software.
In this study dependent variable is the overall satisfaction level of pedestrian at signalised intersection crosswalks. Regression models involve the following variables:

Table 3: Variable description for Multivariable Linear Regression model development

Independent Variables	Measure type	Description
Crosswalk Surface Condition,	Ordinal	5=very good ,4=good, 3=average, 2=poor, 1=very poor
Crosswalk Marking,	Ordinal	5=high visibility, 4=good visibility, 3= average visibility, 2=partially diminished, 5= fully diminished
Crosswalk Holding Area	Ordinal	5=more than enough space to accommodate pedestrian, 4=sufficient to accommodate pedestrian, 3=occasionally not sufficient to accommodate pedestrian ,2=mostly not sufficient to accommodate pedestrian , 1=holding area not available
Crosswalk Width,	Scale	Width in meter
Crosswalk Length,	Scale	Length in meter
Motorist Behaviour,	Ordinal	5=very good ,4=good, 3=average, 2=poor, 1=very poor
Left Turning Vehicles Volume,	Scale	No. of vehicles per hour
Left Turning Vehicles Speed,	Scale	Speed of vehicles in kmph
Pedestrian Flow,	Scale	No. of pedestrian per hour
Red Timing For Pedestrian ,	Scale	Red Time in sec
Green Timing For Pedestrian	Scale	Green Time in sec

4.3. Model development

Pearson correlation was used for identification of most appropriate factors influencing POS. Factors which have high correlation with the POS were considered in the model development. After various trials five factors i.e. crosswalk marking, crosswalk holding area, speed of left turning vehicles, behaviour of motorists and red time for pedestrian were found having high correlation with the pedestrian overall satisfaction level at crosswalk of signalised intersection.

Table 4: Correlation of Pedestrian overall satisfaction with the factors affecting POS by Pearson correlation analysis

S.No.	Factors affecting POS	Correlation value
1	Crosswalk surface condition(F_1)	.333
2	Visibility of crosswalk marking(F_2)	.499
3	Crosswalk holding area(F_3)	.732
4	Vol. of turning vehicles on green signal for pedestrian(F_4)	-.064
5	Speed of left turning vehicles on green signal for pedestrian(F_5)	-.643
6	Behaviour of motorists(F_6)	.573
7	No. of pedestrian(F_7)	-.378
8	Red time for pedestrian (F_8)	.708
9	Green time for pedestrian (F_9)	.256
10	Crosswalk width (F_{10})	-.154
11	Crosswalk length (F_{11})	.282

Multivariable regression analysis was used to develop the mathematical equation for pedestrian overall satisfaction at signalised intersection crosswalk. A multivariable linear regression model is develop which reflects the pedestrian overall satisfaction level of crosswalks at signalized intersections by combining five variables affecting pedestrians level of service at signalised intersection crosswalk with .931 R^2 value. This measure evaluates the conditions of crosswalks at signalised intersections. The pedestrian overall satisfaction level at signalised intersection crosswalk can be expressed in an equation format as shown below.

$$POS\ (\%) = 56.198 + 0.150CWM + 0.847CWHA - 0.040LTV\ Spd + 0.592Mt.Bhvr - 0.037RdTm$$

Where,
POS (%) =Pedestrian overall satisfaction in percentage
CWM = Visibility of crosswalk marking
(5=high visibility,4=good visibility, 3=average visibility2=partially diminished,5=fully diminished)
CWHA = Crosswalk holding area
(5=more than enough space to accommodate pedestrian, 4=sufficient to accommodate pedestrian, 3=occasionally not sufficient to accommodate pedestrian, 2=mostly not sufficient to accommodate pedestrian, 1=holding area not available)
LTV Spd = Average Speed of left turning vehicles on green signal for pedestrian
Mt.Bhvr = Behaviour of motorists (5=very good, 4=good,3=average,2=poor,1=very poor)
Rd.Tm = Red time for pedestrian in sec.

Now according to Khisty's proposal of relationship between LOS and satisfaction, we can find LOS of any signalised intersection crosswalk.

Table 2.1 Relationship between perceived user satisfaction and qualitative LOS

LOS	Level of satisfaction
LOS A	=>85% satisfaction
LOS B	=> 60% satisfaction
LOS C	=>45% satisfaction
LOS D	=>30% satisfaction
LOS E	=>15% satisfaction
LOS F	< 15% satisfaction

5. Discussions and Conclusions

From the developed model it is observed that among the pedestrian facilities crosswalk holding area has the highest influence on pedestrian satisfaction level over the other pedestrian facilities. Its positive coefficient value shows that pedestrian overall satisfaction is directly proportional to crosswalk holding area. From the developed model it is observed that as the holding area to accommodate pedestrian during waiting for green signal at the corner of pedestrian crossing increases their satisfaction level for that intersection also increases. It means there should be sufficient holding area for waiting and circulation area i.e. the space for moving at pedestrian crossing at signalised intersection for pedestrian safety and comfort. Furthermore, Crosswalk surface condition and crosswalk marking were also found to be significant factors which affect pedestrian satisfaction for determining pedestrian LOS at intersections. These two factors with positive coefficient value indicates direct proportional behaviour with pedestrian overall satisfaction level i.e. with increase in their quality, level of satisfaction increases hence LOS also increases. In this study an important factor i.e. motorist's behaviour at crosswalk of signalised intersection is identified which have high influence on pedestrian satisfaction level for determining LOS of crosswalk. This factor was excluded from most of the previous LOS researches. In present study it is observed that motorists' behaviour affects both safety and comfort of pedestrian which are using the crosswalk. Some times when motorists covers whole crosswalk path of the pedestrian then there is no space left for pedestrians and at that time pedestrian have to use the same space from where other vehicles passing. This type of motorist's behaviour causes pedestrian to follow non compliance behaviour which may results in severe accidents at intersection.

From the results it is found that left turning vehicles also has a significant influence on pedestrian satisfaction level. As the number of turning vehicles increases, the result shows a corresponding decrease in the perceived safety to the pedestrian. With number of left turning vehicles their speed causes inverse effect on pedestrian overall satisfaction. With higher speed of turning vehicles which crosses pedestrian crosswalk, chances of pedestrian – vehicles conflict increases. Pedestrian are unable to find acceptable gap to cross the left turning lane through high speed turning vehicles. Therefore it can be recommended that there should control on the speed of left turning vehicles which crosses the pedestrian crosswalk at signalised intersections because pedestrians feel unsafe and discomfort due to the conflicts with vehicles.. At Board office intersection and Roshanpura intersection even though there is large number of turning vehicles but there exists raised ramps for controlling the speed of turning vehicles which provides proper gap for crossing left turning lane.

One other interesting observation about signalised intersections is that pedestrian wants pedestrian-priority-crosswalks and they do not want long delays at signalized intersections crossing. Both HCM 2000 and other researches (Kaiser, 1994) indicates that pedestrians become irritated when they experience long delay, and they follow non compliance behaviours to cross the road. Risk taking behaviour of pedestrians is also shown when they have to cover longer path to cross the road. Satisfaction of pedestrian decreases as the length of crosswalk increases as it relates to the comfort of pedestrians.

5.1. Conclusion Summary

On the basis of above results we can summarise as following:

- Pedestrian overall satisfaction level model for crosswalk signalised intersections provides a measure of a crosswalk's performance with respect to pedestrians' safety and comfort.
- Using the value of pedestrian overall satisfaction at signalised intersection crosswalks, roadway designers can determine LOS at signalised intersection crosswalks and according to that they can find how well a particular intersection accommodates pedestrian travel.
- Pedestrian Level of service measures can provide an easy understanding about the condition of a crosswalk. These measures would help in evaluating and prioritizing the needs for pedestrians on existing intersections.
- Pedestrian LOS at signalised intersection crosswalk through overall satisfaction of pedestrian can be used to develop a minimum LOS standard which could prescribe the minimum acceptable LOS for the adequate accommodation of pedestrians.
- Crosswalks at signalised intersections should be targeted to maintain a minimum pedestrian LOS in order to provide a minimum level of accommodation for pedestrians.
- Pedestrian LOS models could also be used to support the development of pedestrian facility improvements. Roadway designers can use the pedestrian LOS model to test alternative intersection designs by iteratively changing the independent variables to find the best combination of factors to achieve the desired LOS.
- Proposed method in this study provides not only pedestrian LOS through pedestrian overall satisfaction level at signalised intersection crosswalks but it also provides the factors which contributing to low and high LOS.

5.2. Recommendations

From the model and the observations made, it can be recommended that in order to achieve high levels of service of crosswalks at signalized intersections, the following can be practiced in the planning and design of crosswalks at signalized intersections:

- Pedestrian crossing time can be shortened by reducing crosswalk length and increasing crosswalk width.
- Pedestrian flow can be increased by providing a longer pedestrian green time for pedestrian and by providing larger walking space i.e. more crosswalk width.
- Delay at signalised intersection for pedestrian can be reduced by shortening cycle length of the traffic signal system as much as possible.
- Crosswalk surface condition should be improved through routine checks and maintenance.
- Crosswalk markings at intersections should be proper visible to pedestrians at both day and night by routine checks and maintenance.
- Adequate crosswalk area should be provided for accommodating pedestrians while waiting to cross.
- Roadway width should be provided as minimum as required at the intersections to shorten crossing distance and crossing time.

References

1. Dixon, L. B. (1996), *"Bicycle and pedestrian level-of-service performance measures and standards for congestion management systems",* Transportation Research Record, 1538, pp 1-9.
2. Fugger,G. *Analysis of pedestrian gait and perception–reaction at signal-controlled crosswalk intersections.* Transportation Research Record 1705, *TRB, National Research Council*, Washington, D.C., 2000, pp. 20–25.
3. Gallin, N. "*Quantifying pedestrian friendliness: Guidelines for assessing pedestrian level of service"*, Proceedings from Australia: Walking the 21st Century Conference. 2001.
4. Guidelines for Pedestrian Facilities – IRC: 103 – (1998), *The Indian Roads Congress*, New Delhi.
5. Hummer, J. *"User Perceptions of the Quality of Service on Shared Paths."* Presented at the Transportation Research Board Annual Meeting, Washington, DC (2005).
6. Hubbard, S., R. Awwad, and D. Bullock. "*New Perspective on Assessing Impact of Turning Vehicles on Pedestrian Level of Service at Signalized Intersections*." Presented at the *Transportation Research Board Annual Meeting*, Washington, DC (2007).
7. Khisty, C. J. Evaluation of pedestrian facilities. Beyond the level-of-service concept. Transportation Research Record 1438, *TRB, National Research Council*, Washington, D.C., 1994, 45–50.
8. Kadali,R. Vedagiri,P. " Modelling pedestrian road crossing behaviour under mixed traffic condition", European Transport \ Trasporti Europei (2013) Issue 55, Paper n° 3, ISSN 1825-3997
9. Lee, J., P. Goh, and W. Lam. "*New Level-of-Service Standard for Signalized Crosswalks with Bi-Directional Pedestrian Flows.*" Journal of Transportation Engineering, Vol. 131, No. 12, pp. 957–960 (2005).
10. Muraleetharan, T. *"Method to Determine Overall Level of-Service of Pedestrians on Sidewalks and Crosswalks Based on Total Utility Value."* Presented at the Transportation Research Board Annual Meeting, Washington, DC (2004).
11. Muraleetharan, T., Adachi, T., Uchida, K., Hagiwara, T., Kagaya, S. A study on evaluation of pedestrian level of service along sidewalks and at crosswalks using conjoint analysis, *Journal of Infrastructure Planning, Japan Society of Civil Engineers*, Vol.21 No.3, 2004,pp 727-735.
12. Nagraj,R and Vedagiri,P, **"***Modeling Pedestrian Delay and Level of Service at Signalized Intersection Crosswalks Under Mixed Traffic Conditions", Transportation Research Record: Journal of the Transportation Research Board, No. 2394,* Transportation Research Board of the National Academies, Washington, D.C., 2013, pp. 70–76.
13. Petritsch, T. Landis, W. *"Level of Service Model for Signalized Intersections for Pedestrians."* Presented at the Transportation Research Board Annual Meeting, Washington, DC (2005).
14. Pecheux, K, M Pietrucha, and P. Jovanis. "*User Perception of Level of Service at Signalized Intersections: Methodological Issues,"* Transportation Research Circular *E-C018*, Fourth International Symposium on Highway Capacity, Transportatio Research Board, Washington, DC (June 2000).
15. Sarkar,S. *Determination of service levels for pedestrians, with European example.* Transportation Research Record 1405, *TRB, National Research Council*, Washington, D.C., 1993,pp 35–42.

