QUALITATIVE AND QUANTITATIVE ESTIMATION OF PEDESTRIAN LEVEL OF SERVICE AT SIGNALIZED INTERSECTION

A Thesis

Submitted in partial fulfilment of the requirements

for the degree of

Master of Technology

In

Transportation Engineering

by

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ROURKELA-769008, 2015

NIT Rourkela

CERTIFICATE

I hereby certify that the work which is being presented in the thesis entitled **"Qualitative and Quantitative Estimation of Pedestrian Level of Service at Signalized Intersections"** in partial fulfilment of the requirements for the award of **Master of Technology** Degree in **Transportation Engineering** submitted in the department of **Civil Engineering** at **National Institute of Technology, Rourkela** is an authentic record of my own work carried out under the supervision of **Dr. Prasanta Kumar Bhuyan**, Assistant Professor, Civil Department.

The matter presented in this thesis has not been submitted for the award of any other degree of this or any other national or international level institute/university.

(Sangani Naga Raju)

This is to certify that the above statements made by the candidate are correct and true to best of my knowledge.

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This thesis is dedicated

To

my beloved Father and Mother,

May God bless them and elongate them live in his obedience.

ACKNOWLEDGMENTS

First and foremost, I am deeply obligated to **Dr. P.K Bhuyan** my advisor and guide, for the motivation, guidance, tutelage and patience throughout the research work. I appreciate his broad range of expertise and attention to detail, as well as the constant encouragement he has given me over the years. There is no need to mention that a big part of this thesis is the result of joint work with him, without which the completion of the work would have been impossible.

My sincere thanks to **Prof. M. Panda** former HOD of Civil Engineering Department, NIT Rourkela and **Dr. U. Chattaraj** for providing valuable co-operation and needed advice generously all along my M.Tech study.

I would like to extend my gratefulness to **Dr. S. K. Sarangi**, Director, NIT Rourkela and **Dr. S. K. Sahu**, HOD, Civil Engineering Department, NIT Rourkela for providing the indispensable facilities during my research work.

I also want to deliver sincere thanks to all my friends of the Transportation Engineering Specialization for their co-operation and indispensable belief which made this project work smooth. I apologize, if I have forgotten anyone.

Last but not the least, my parents and the one above all of us, the omnipresent God, for the blessing that has been bestowed upon me in all my endeavors.

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Abstract

Pedestrians form the largest single road user group and also are the most vulnerable road users. Pedestrian's movements are not restricted to lanes or specific routes however they are restricted by the physical boundaries around them such as the presence of walkways or pedestrian ways. The main objective of this study is to identify the various factors affecting pedestrian level of service (PLOS) at signalized intersections and to propose a suitable methodology for estimation of pedestrian level of service. The study carried out to develop a model for pedestrian level of service of signalized intersections in Vijayawada city and Bhubaneswar city based on pedestrian's perception on safety and comfort. The main factors considered for the development of the model were through traffic, left turning traffic, right turning traffic, number of pedestrians, number of lanes and pedestrian delay. Pedestrian delay was one of the key performance indicators for pedestrian level of service. Total twelve crosswalks from two cities were considered for study purpose. Video graphic method was used for collection of field data. Questionnaire survey was conducted to know the perceived level of service of pedestrians. The various factors required to develop the model extracted from video graphic data. Pearson correlation analysis was done to identify the various significant factors influencing pedestrian level of service. By considering perceived LOS as dependent variable and significant factors as independent variables stepwise regression analysis was done to develop a model which suitable for urban Indian conditions. The study revealed that various factors affecting level of service under heterogeneous traffic condition were turning traffic, through traffic, number of lanes, and number of pedestrian and pedestrian delay.

Contents

Chapter 1
Introduction

1.1 General

Walking is one of the most important travel modes in Indian urban and suburban areas. However, pedestrian concerns are nearly always neglected in transportation planning, construction, management. As efforts to make more environmental friendly facilities increasing, pedestrians are getting more and more attention.

Intersections are the most complex locations on any highway. This is because these are places where traffic moving in different directions wants to occupy the same space at the same time. At the same time pedestrians are also want some space to cross. So there is a high potential of conflict between the road users and vehicular traffic. In India traffic is mostly heterogeneous in nature comprising of vehicles of different characteristics. All categories of vehicles use the same space or any lateral position of the road based on the availability of the space at that instant without any discipline. Under these heterogeneous traffic conditions pedestrians are losing the space. The various pedestrian's facilities such as sidewalks, medians provide the segregation of pedestrian traffic from other vehicular traffic. These facilities provide increased safety from pedestrian point of view. The services provided by these facilities must be improved for better transportation planning.

In India, urban population increases exponentially as the thrust to live in cities and urban areas increasing. The urban population of India is 377 million, which is 31% of the total population. Urbanization is going on at an exponential rate, so better facilities are to be provided at the beginning stage.

The operational conditions of intersections have great influence on the performance of entire network. In many of intersections in India people are facing problems due to improper planning and no availability proper pedestrian facilities. The pedestrian volume at intersections larger in urban areas compared to rural areas in India so pedestrians have to take into considerations while designing the intersections. In India as there are no proper controlling measures at many of intersections which in turn causing irregular movement of vehicles and pedestrians increasing the conflicts and accidents. Proper safety measures to be taken to improve the quality and the safety of the roads.

1.2 Statement of the Problem

Pedestrians are one of the major commuters on Indian urban streets. In India mostly pedestrians are neglected in transportation planning and management. So as the pedestrians are increasing day by day so better facilities need to be provided. As there are no provisions for Indian conditions and the models developed for urban conditions in western countries are not a true representative as the conditions prevailing are different. Study on pedestrian need to be done to provide better facilities to pedestrian in India. Pedestrian Level of service is one of the indicative which represents quality of given intersection in terms of perceived safety, convenience and comfort in terms of pedestrian perspective. In India the number of persons prone to accidents and deaths are mainly pedestrians. The main commuters on roads who are prone to fatal injuries, deaths are mainly pedestrians. When it comes to signalized intersections, intersections are the places where two roads in different directions meet at the same level. So there is high possibility of conflicting traffic at intersections. At signalized intersections the vehicle movement is controlled and orderly movement of vehicles is allowed. Till now mostly in India pedestrians are neglected in the design of various road elements. As the number of pedestrians using the roads increasing day by day and in the case of urban roads it is increasing exponentially. As number of pedestrians on roads increasing and they are the main road users in urban environment so better facilities are needed to be provided for pedestrians.

1.3 Objectives and Scope

The main objectives and scope of the study are as follows

- To identify the various factors influencing pedestrian LOS in urban Indian conditions at signalized intersections. The various factors that are influencing the level of service of pedestrian are weaving motorized and non-motorized traffic, through traffic, number of pedestrian, number of traffic lanes, presence of zebra crossing and pedestrian delay etc. Selecting the appropriate variables mainly influences pedestrian level of service in urban Indian road conditions.
- To identify the relation between various influencing factors and pedestrian LOS in urban Indian road conditions. The extent up to which the each variables influences pedestrian LOS.
- To identify the influence of pedestrian delay on pedestrian LOS under mixed traffic conditions at signalized intersections. Pedestrian delay is one of the major factor which

influences pedestrian delay. Mostly safety, comfort and convenience of pedestrians depend on the time that pedestrians spend on waiting at intersection to cross the given road.

- During the development of model the condition of the pavement surface and aesthetic conditions of the surrounding area are not taken into account.
- To identify the suitable methodology that is appropriate to develop pedestrian level of service model and to identify the relation between various variables and pedestrian LOS.
- To develop a model representing the pedestrian LOS of urban Indian roads with mixed traffic condition.
- To define the limits of different pedestrian LOS (A - F) for Indian road conditions under mixed traffic.

1.4 Organization of the Report

This report is organized into seven chapters. The first chapter introduces the topic, defines the problem and provides the objectives and scope of the present work. In the second chapter a discussion on urban street and level of services concepts have been presented. The third chapter presents the review of literature on pedestrian level of service analysis of urban streets of signalized intersections. The fourth chapter presents various methods that can be applied in analysis of data and delay data with proper validation measures and reliability analysis in defining pedestrian level of service criteria. The fifth chapter presents study area and data collection procedure for the present study. The sixth chapter presents the results of regression analysis and the various category limits of PLOS and validation of model and comparison with other models. The seventh chapter presents summary of the research work, limitations of model and future scope in this research area.

Chapter 2

Basic Concepts of Pedestrian Level of Service

2.1 Introduction

This chapter mainly deals with the things related to pedestrian level of service in urban areas at signalized intersections. Urban Street mainly refers to the arterial and collector roads present in urban areas. Pedestrian LOS is one the important factor which used to characterize quality of a given road in terms of travelers perspective. Signalized intersections are one of the complex places on road as chances of accidents are much more. Pedestrians are often want to cross these signalized intersections for many reasons. Pedestrian safety is one of the most concerned parts at signalized intersections as the chances of accidents are much more. Pedestrian LOS is one of measures used to define the quality of given intersection. The various quantitative measures which are used to define the pedestrian LOS are turning traffic, through traffic, number of pedestrians crossing the road, number of lanes crossed while traversing, presence of channelizing islands and pedestrian delay.

2.2 Signalized intersections

Signalized intersections are the places where vehicles movement is controlled and systematic movement of vehicles is allowed. There are chances of accidents and conflicts more as vehicles and pedestrians using the same space at the same time. Till now in India the concentration of design of roadway elements mostly on vehicles only as they are the main users of roads. But in urban areas at intersections considerable amount of pedestrians using roads. So as to design a given intersection as better transportation facility pedestrians has to be considered in the design of roadways. The main problems that are faced by pedestrians while crossing the road are as follows

Pedestrian delay

For signalized intersections, it was found that delay of pedestrian was one of the factors which influence perceived level-of-service of pedestrians. Delay is nothing but the time up to which pedestrian waits to cross the given road. Total delay that experienced by pedestrian classified into waiting time delay, crossing time delay and vehicle interaction delay. Waiting time delay is time up to which pedestrian waits for the gap to cross the road from arrival of him to given intersection. Crossing time delay is delay caused while crossing the road this mainly depends on the speed of pedestrian while crossing the road. Vehicle

interaction delay is delay caused due to interaction of pedestrian with vehicles this mainly depends on signal compliance.

Perceived vehicle conflicts

Pedestrians experience conflicts not only because of vehicles passing the crosswalk but also the vehicles moving so close to the pedestrian movement and makes they feel unsafe. The vehicle movements that cause problems to pedestrian are as follows

- Through traffic flow
- Left turning vehicles on red phase
- Right turning movements permitted
- Left turning traffic
- Right turning traffic

Perceived exposure

The perceived exposure of the pedestrian crossing road not only on depends on time but also on many other factors. Traffic control devices also influences the perceived exposure. The various factors influence perceived exposure of pedestrian are as follows

- Crossing distance
- Presence of zebra crossing
- Presence of channelizing islands
- Raised medians
- Presence of sidewalk

2.3 Pedestrian Level-of-service

Level-of-service is one of the best known criteria to express the performance of a road in terms of travels point of view. It is nothing but how well a transport facility can serve the road user. Pedestrians are one of the most vulnerable road users and as a transportation planner we have to take care of pedestrians in the design of various road elements. As per the recent accidental studies pedestrians are more prone to accidents than any other road users. So as to design better transport facility pedestrian level-of-service has to be taken into consideration.

Pedestrian level-of-service concept was first introduced in Highway Capacity Manual (HCM) in 1985. It was one of the recent topics introduced in HCM. Quality and level-of-service describe the performance in a way that is designed to be favorable to decision

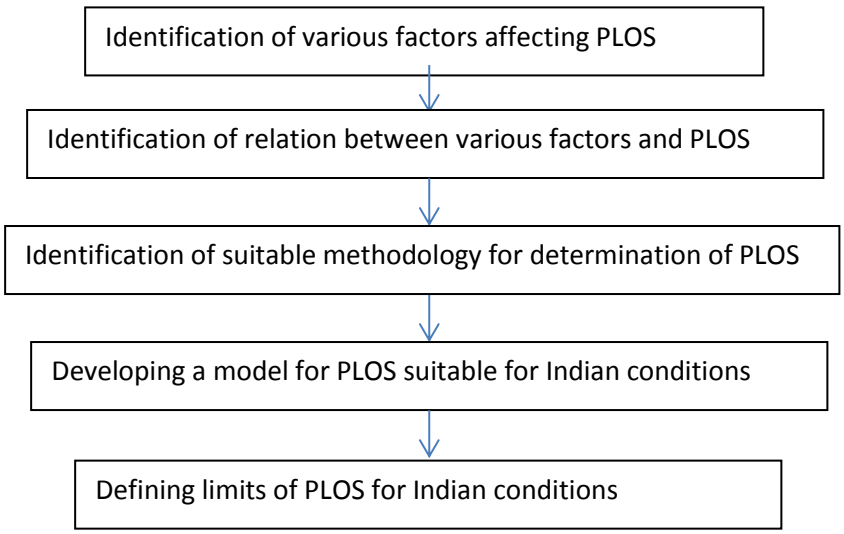
Factors affecting the perceived quality of service are

- Travel time, speed and delay
- Number of stops incurred
- Maneuverability
- Comfort
- Convenience
- Safety
- User cost
- Availability of services
- Facility aesthetics
- Information availability

These factors can be directly obtained in the field or can be interpreted from the field data. The quality of a given road or intersection or transport facility mainly depends on these factors.

2.4 Methodology

Methodology for determination of pedestrian LOS for signalized intersections as follows



2.5 Applications of pedestrian level-of-service

The study represents pedestrians of urban India. The intersections were similar to those present in urban and suburban areas of India. The intension of this research is to development of a reliable, statistical model which represents urban Indian roads.

Pedestrian level-of-service used to provide better facilities for pedestrians in terms of safety and comfort. PLOS used to define the operational efficiency of given intersection in terms of pedestrians perspective.

2.6 Summary

In this chapter brief introduction about pedestrian level of service and signalized intersections was presented. The methodology used to determine the pedestrian level of service was discussed. The various terms used in the level of service analysis also discussed. The various factors influencing pedestrian level of service also discussed. The classification of pedestrian level of service based on various factors also discussed.

Chapter 3
Review of Literature

3.1 General

Level of service is a quantitative stratification of a performance measure or measures that represent quality of service. Quality of service describes how well a transportation facility or service operates from a traveler's perspective. Research on the pedestrian level-of-service started on by Laustro, Murole. Level of service usually described in six classes varying from LOS A to LOS F where A represents excellent conditions and F represents worst possible conditions.

Level of service based on perceived safety and comfort by traveler's point of view. Also given Highway capacity manual (2000) given certain guidelines for calculating pedestrian level the different factors effecting the level of service such as traffic characteristics, geometric design, signal control and others. Vedagiri and Nagraj (2013) developed a model for pedestrian delay and pedestrian level of service at signalized intersection crosswalks in Mumbai under mixed traffic conditions by considering pedestrian perception on safety and comfort. This model based on factors such as turning traffic, through traffic, number of pedestrian and pedestrian delay. Video graphic technique and questionnaire survey are used for the collection of data and stepwise regression was done to develop the model.

Landis et al. (2005) developed a model for pedestrian level of service at signalized intersection based on perceived safety and comfort by considering perceived conflicts, perceived exposure and delay .Concluded that vehicles turning right on red mainly effects the level of service. Muraleetharan et al. (2005) developed a method to determine pedestrian level of service at urban intersection considering Space at corner, crossing facilities, turning vehicles, and delay, bicycle activities. It also revealed that turning vehicles has greater influence on pedestrian level of service. Jensen (2012) developed a model for pedestrian and bicycle level of service at intersection, roundabouts and other crossing facilities. Also revealed that presence of zebra crossing, sidewalk before intersection, shortest crossing distances improve the pedestrian level of service at intersection by considerable amount.

3.2 Pedestrian level of service

Dixon (1996) revealed various performance measures which effects pedestrian and bicycle level of service such as pedestrian facilities to be provided, conflicts, motorized vehicle LOS and amenities. Also set some standards for congestion management. Liping gao et al. (2012) developed a delay model at intersection based on pedestrian vehicle system and also stated that two stage grossing is more efficient for urban streets. Paraskevi and Magdalini (2012) presented a review of the methodologies available for the calculation pedestrian level of service and their scope and their applicability to different prevailing conditions.

Li Dan and Xiaofa Shi (2013) developed a pedestrian delay model based on multiple linear regression analysis and also given some restrictive conditions for setting exclusive right turn phase to improve intersection capacity and service level. Wang et al. (2005) proposed a Monte Carlo model for pedestrian delay at two phase intersection by calculating the delay of pedestrians arriving in different phases and overall delay. Alhajyaseen et al. (2012) presented a unique mechanism that can represent a realistic representation of left turning vehicle maneuvers to assess the safety of pedestrian when considering conflicts with left turning vehicles.

3.3 Methodology

Vedagiri and Marisamynathan (2013) developed a model for calculating pedestrian delay at signalized intersection for Indian conditions which can be used for calculation of pedestrian level of service. This study divided the total delay into waiting time delay, crossing time delay and pedestrian-vehicle interaction delay. Muraleetharan et al. (2005) presented different factors influencing pedestrian level of service along crosswalks and at intersection. The main factors are space at corner, crossing facilities, turning vehicles and delay and their extent of influence and also concluded that at intersection turning vehicle conflicts are the main influencing factor.

Yue li and Geoff Fernie (2010) revealed the influence inclement weather conditions on pedestrian behavior. The walking speed increases and pedestrian obeying signal decreases as the weather becomes cold. Pulugurtha and Sambhara (2011) stated that increase in population, the number of transit stops, the number approaches to an intersection and pedestrian volume will result in exponential increase of pedestrian crashes.

Gang Ren et al. (2011) study stated that the rate of compliance with traffic rules for all pedestrians is 62.8% and also showed that women and middle aged are more likely to violate traffic rules. Also stated the major reason for violate rules is to save time and for convenience. Sisiopiku et al. (2006) compared the different methods for determination of pedestrian level of service such as the Highway Capacity Manual (2000) method, the Australian method, the trip quality method, the Landis model, and the conjoint analysis approach. It is revealed that no method captures all the quantitative and qualitative parameters influencing quality of pedestrian service in detail

3.3 Summary

A thorough literature review was discussed in this chapter related to pedestrian LOS analysis and various methods and techniques used in this study. From literature review it was found that very little work done till now on pedestrian level of service and there was no proper methods available for determination of PLOS in India. So there is lot of scope to carry out further research on the current PLOS methodology shown in HCM. Video graphic technique was found to be an efficient and accurate technique for collection of pedestrian data. Regression analysis was identified to be suitable for grouping data and to define PLOS categories. Chapter-4 discusses about the various methodologies available and the methodology applied for the estimation of pedestrian LOS

Chapter 4
Methodology

4.1. General

Determination of pedestrian level of service at a signalized intersection is complex phenomenon involving many factors. This is mainly because vehicles in different directions and pedestrians are to occupy the same area at the same time. The methodology for determining the pedestrian level of service mainly includes determining the various factors which influencing the pedestrians in terms of perceived safety and comfort. The factors such as pedestrian delay, number of pedestrians, number of lanes, through traffic, right turning vehicles, left turning vehicles, speed of vehicles at the intersection, corner area etc. are the main influencing factors.

Questionnaire survey

In Questionnaire survey pedestrian's crossing the intersection mainly surveyed to assess the pedestrian perception towards safety while crossing the road. For this purpose investigators stood on one side of the road and surveyed the pedestrians who are crossing the road.

Field survey

Field survey was conducted to explore the condition of traffic, crossing facilities and pedestrian delay at intersection. The characteristics such as corner area, side walk width, presence of road markings, length and width of crosswalk are measured during the field survey. Video graphic technique was used to determine the factors such as through traffic, number of pedestrians, left and right turning vehicles.

4.2. Factors effecting pedestrian level of service

The various factors influencing the pedestrian level of service are

Pedestrian delay:

Pedestrian delay is one of the most important factors influencing pedestrian level of service at signalized intersection. Pedestrian delay was total time the pedestrian waited while crossing the crosswalk. It mainly depends on pedestrian crossing behavior and traffic

conditions. The delay caused by waiting at the crosswalk, while crossing the road and due to conflicts with the vehicles

Corner area:

The corner area is the total area of the corner of road. It is divided into holding area and circulation area. Holding area is sufficient enough to provide space for pedestrian waiting at the corner. Circulation area is space required for the movement of pedestrian.

Pedestrian flow:

It is the total number of pedestrian crossing the given crosswalk divided by the analysis period

Vehicle flow rate:

The total number of vehicles crossing a given crosswalk during the analysis period

Mid-segment 85^{th} percentile speed:

The 85^{th} percentile speed is the speed of the vehicle which is exceeded by only 15% of vehicles. The speed measured at a distance from intersection that it should not be influenced by intersection.

Left turn on red vehicle flow rate:

The number of vehicles taking left turn on red phase during the analysis period.

Left turn vehicle flow rate:

The number of vehicles turning to left of the crosswalk during the analysis period.

Crosswalk length:

The length of road from outside edge to the other edge that is it is measured from curb to curb.

Width of crosswalk:

The width of the crosswalk is the width provided for the pedestrian to cross the crosswalk that is the width of the crosswalk.

Cycle length:

The time interval between successive red phases of signal on a given specific road. It mainly depends on the vehicular flow rate.

Presence of pedestrian head:

The green phase provided for pedestrian to cross the given crosswalk. It is used to indicate the pedestrian the time to cross the road and not cross the road.

4.3. Methods

The various methods available for the determination of the pedestrian level of service are given below

HCM (2010) method:

Highway capacity manual (2010) given the methodology to determine the pedestrian level of service at a signalized intersection based on two criteria one is based corner area available for pedestrians and another is based on delay and perceived safety and comfort.

Landis et al. model:

The research team developed a pedestrian LOS model that accurately represents pedestrian's perceptions of crossing at signalized intersections. Based on the findings of a study, conducted by the research team, the primary factors that are taken into consideration in the model are: (i) right-turn-on-red volumes for the street being crossed, (ii) midblock 85 percentile speed of traffic , (iii) motor vehicle volume on the street being crossed, (iv) permissive left turns from the street parallel to the crosswalk, (v) the number of lanes being crossed, (vi) the pedestrians delays and (vii) the absence or presence of right-turn channelization islands. The numerical result of the model is then cross referenced with a table in order to determine the pedestrian LOS. (Landis et al, 2005)

Muraleetharan et al. model:

This method was developed in Japan and considered as primary factors for assessing the pedestrian LOS on a crosswalk: (I) the level of space at corners, (ii) the crossing facilities, (iii) the turning vehicles and (iv) the pedestrian delay. It is based on the concept of total utility value, which comes from a conjoint analysis research.. (Muraleetharan et al, 2004)

Bian et al. model:

This method was developed in China and considered the following factors for assessing the pedestrian level of service at a signalized intersection (i) pedestrian delay (ii) crossing facilities (iii) traffic conflicts. The model was developed based on the actual perception of pedestrian comfort and safety. The LOS of a given intersection was estimated

by questionnaire survey that is the actual response of pedestrian and the model was developed to determine the LOS by identifying the various factors and their influence on the LOS by multiple linear regression analysis.

Vedagiri and Nagraj model:

Developed a model to determine pedestrian delay and for pedestrian LOS under mixed traffic conditions of urban areas in India. This model is developed mainly considering pedestrian safety and comfort as prime criteria. The model is developed based on the actual perception of pedestrian on intersection crosswalk. Questionnaire survey is conducted to estimate the LOS of given intersection. Field survey is conducted to identify the various factors influencing the LOS and their influence on LOS. The pedestrian model was developed based on the influencing factors by doing multiple linear regression analysis.

Methodology for determination of LOS:

Step1: Estimating the LOS of the given intersection by the actual perception of pedestrian that is by questionnaire survey

Step2: Video graphic survey to measure the various field conditions that effect the pedestrian LOS

Step3: Identifying the relation between various factors and pedestrian LOS by Pearson correlation

Step4: Developing a model to determine pedestrian delay

Step5: Defining the limits of various pedestrian level of service (A-F) for Indian conditions

4.4 Summary

In this chapter mainly the various available methodologies were described. Mostly the available methods were developed for developed countries. Suitability of different available methods to Indian roads was also studied. Chapter 5 describes about the study area and various data collection strategies.

Chapter 5

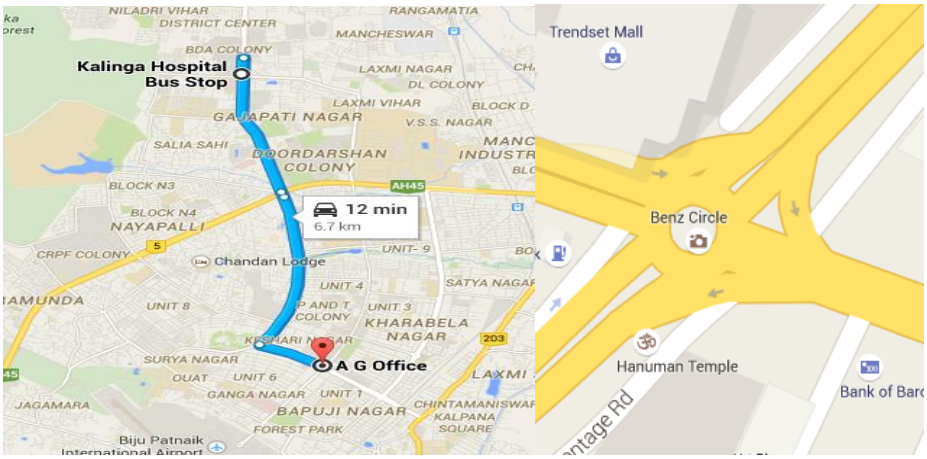
Study Area and Data Collection

5.1. General

The study area for this research work is taken as Bhubaneswar City of Odisha state, Vijayawada city of Andhra Pradesh India. The required data of the study area are obtained using video data cameras. Type and timing of data collection, data smoothing and data compilation are also discussed in detail. Observations of the characteristics and walking of pedestrians were collected on crosswalks. A survey was used to build a pedestrian database, to aid in understanding the relationship between pedestrian characteristics. Using a digital video camera, the data recorded crosswalks at various locations in 15-minute segments. The video clips were then used to observe pedestrian walking behavior, including pedestrian interactions with street furniture or with other pedestrians. Pedestrians were counted and traffic volume and relevant characteristics were recorded at different crosswalk locations. The survey data helped in finding out how pedestrian characteristics are affecting, and are affected by, the crosswalk environment.

5.2. Study area and Data collection

Two signalized intersections namely A.G. chowk and Kalinga hospital square were studied in Bhubaneswar city. A total of four crosswalks data had been collected. The various geometric features of the intersection also measured. Data of eight crosswalks from Vijayawada city also collected. The various geometric features of the road such as number of lanes, width of the roadway, width of sidewalk, presence of channelizing islands



Map showing the locations of study area

Snapshots of pedestrian crossing the road

Video graphic survey

Video graphic survey was conducted to explore the condition of traffic, crossing facilities and pedestrian delay at intersection. The characteristics such as corner area, side walk width, presence of road markings, length and width of crosswalk are measured during the field survey. Video graphic technique was used to determine the factors such as through traffic, number of pedestrians, pedestrian delay, left and right turning vehicles.

Questionnaire Data:

Questionnaire data is required for the perception based survey to establish a perception based model for PLOS. This includes several questions which are to be answered by the pedestrians. The answers were decoded to a quantifying measure and the parameters will be calibrated. Questions were asked to people of different age groups and to both male and female. An age wise and a gender wise distribution of the participants in perception survey are given below.

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5.3. Data extraction and Analysis

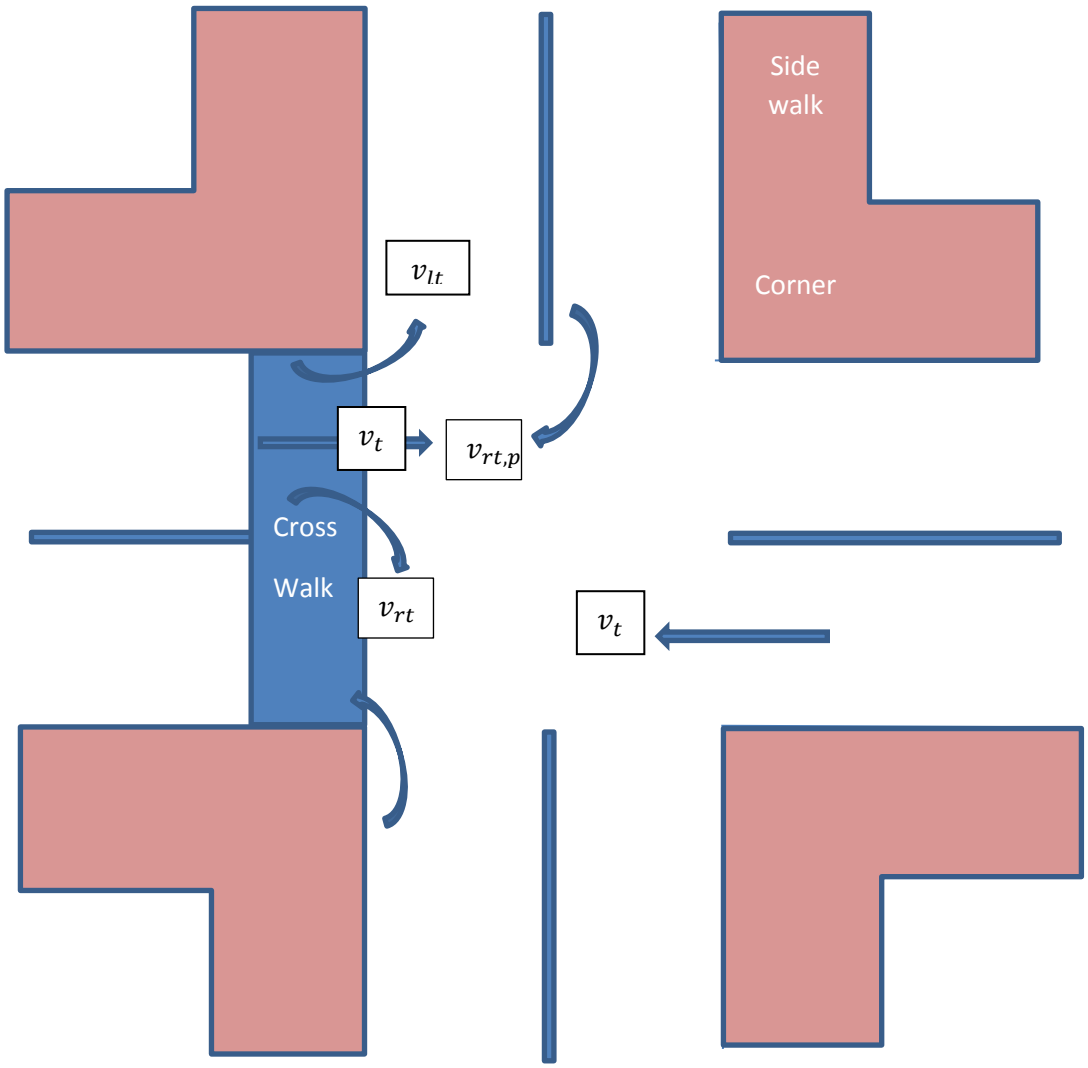


Figure showing various movements of traffic through a crosswalk

The above figure shows the various movements traffic that is possible through a particular crosswalk

Where v_t = through traffic flow

v_{rt} = right turning traffic

v_{lt} = left turning traffic

$v_{rt,per}$ = right turn permitted on red

v_{ltor} = left turn on red

Data extraction:

Bhubaneswar city

Site **Parameter**	A.G chowk 1	A.G chowk 2	Kalinga 1	Kalinga 2
Cycle length in sec	225	225	130	130
Green time in sec	60	40	35	30
Number of lanes	6	6	8	6
Left turning lane	Yes	Yes	Yes	No
Width of median(m)	7	1.5	1.5	1.5

Table 5.1 Details of intersection crosswalks of Bhubaneswar

Site	**Left turning traffic** (pcu/15 min)	**Right turning traffic** (pcu/15min)	**Through traffic** (pcu/15min)	**Left turn on red**(pcu/ 15min)	**Permitted right turns** (pcu/15min)	**Number of pedestrian**	**Average delay** (sec)	**Total flow** (pcu/15min
A.G chowk 1	32	75	427.5	137.5	97.5	13	3.61	769.5
A.G chowk 2	27	139	208.5	55	82	35	2.89	511.5
Kalinga 1	27.5	22.5	771	41.5	19.5	17	7	882
Kalinga 2	61.5	214	56	88	27	15	3.4	446.5

Table 5.2 Traffic and pedestrian flows at different crosswalks of Bhubaneswar

Vijayawada city

Site Parameter	Benz circle	Nirmala convent	PVP square 1	PVP square2	DV manor1	DV manor2	Stadium1	Stadium2
Cycle length in sec	240	180	150	150	130	130	130	130
Green time in sec	60	40	30	35	30	30	30	30
Number of lanes	4	4	2	4	4	2	4	2
Left turning lane	Yes	No	No	No	Yes	No	Yes	No
Width of median(m)	3	1.5	1.5	1.5	1	1	1	1

Table 5.3 Details of signalized crosswalks of Vijayawada

Site	**Left turning traffic** (pcu/15 min)	**Right turning traffic** (pcu/15min)	**Through traffic** (pcu/15min)	**Left turn on red**(pcu/15min)	**Permitted right turns** (pcu/15min)	**Number of pedestrian**	**Average delay** (sec)	**Total flow** (pcu/15min
Benz circle	43	21	562	114.5	24	124	5.83	784.5
Nirmala convent	12.5	54	513.5	8.5	25.5	122	7.69	614
PVP square 1	12	21	142	59	19.5	92	2.6	356

PVP Square 2	9.5	69	753.5	23.5	28.5	72	5.68	973
DV manor 1	6.5	69.5	594.5	15	26.5	80	5.91	712
DV manor 2	8.5	24.5	163	36	46	85	3	241.5
Stadium1	3	91.5	729.5	18.5	94	78	6.4	873.5
Stadium2	26.5	50	244.5	139.5	62.5	81	5.32	523

Table 5.4 Traffic and pedestrian flows at different crosswalks of Vijayawada

5.4 Summary

In this chapter various methods used for data collection, the details of traffic flows in various crosswalks and geometric features of various crosswalks described. The data from this chapter was used for the analysis to find out pedestrian level of service at signalized intersections.

Chapter 6
Results and Analysis

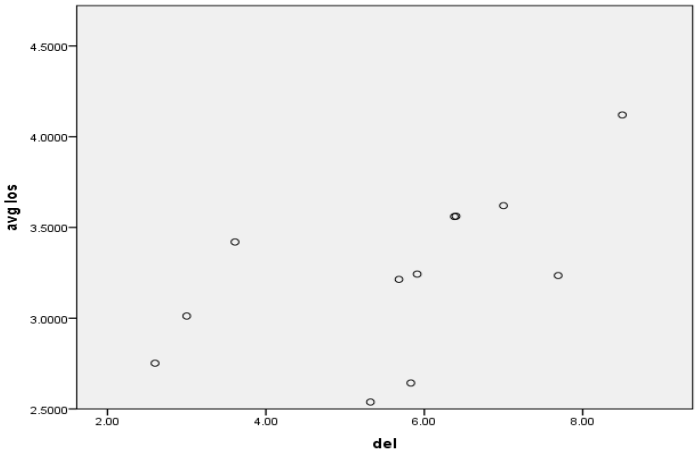
6.1 Introduction

Results of regression analysis are used to define PLOS scores of various roads discussed in this chapter. Stepwise regression analysis was carried out to identify which factors effecting PLOS considerably and the model was developed with those influencing factors. Based on PLOS score intersections are classified into six different categories. The model developed by using 12 crosswalks data and validated by 3 crosswalks data.

6.2 Correlation between PLOS and various factors

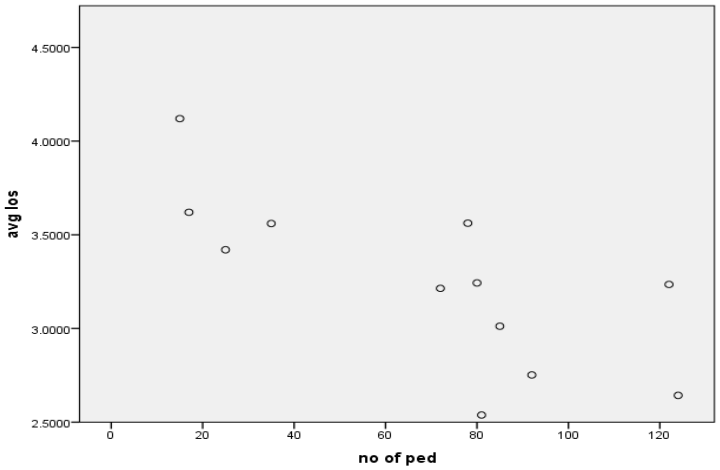
Correlation is done to identify the relation between various influencing factors and PLOS. This is mainly intended to identify that is the relation between independent variable and dependent variable is linear or exponential or logarithmic.

Correlation between average LOS and delay



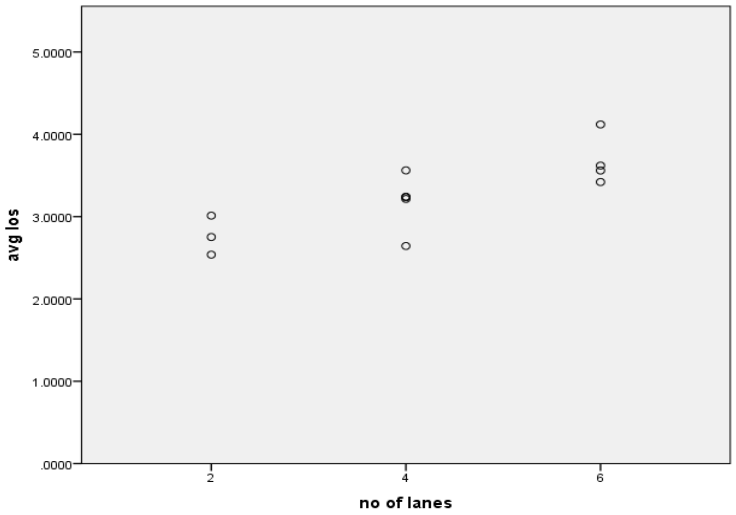
		Average LOS	Delay
Average LOS	Pearson Correlation	1	.588
	Sig. (2-tailed)		.045
	N	12	12
Delay	Pearson Correlation	.588	1
	Sig. (2-tailed)	.045	
	N	12	12

Correlation between average LOS and number of pedestrian



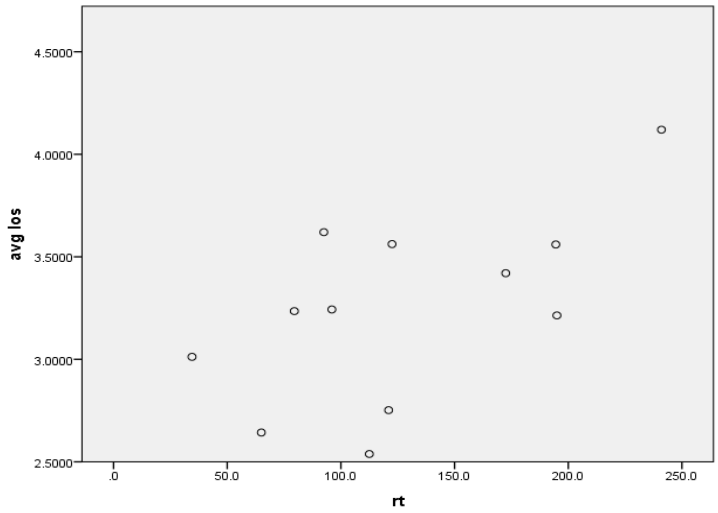
		Average LOS	No of pedestrian
Average LOS	Pearson Correlation	1	-.736
	Sig. (2-tailed)		.006
	N	12	12
No of pedestrian	Pearson Correlation	-.736	1
	Sig. (2-tailed)	.006	
	N	12	12

Correlation between average LOS and number of lanes



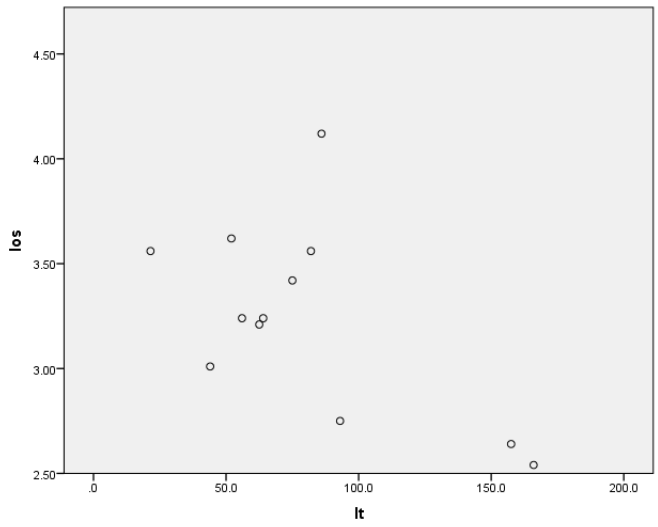
		Average LOS	No of lanes
Average LOS	Pearson Correlation	1	.796
	Sig. (2-tailed)		.002
	N	12	12
No of lanes	Pearson Correlation	.796	1
	Sig. (2-tailed)	.002	
	N	12	12

Correlation between average LOS and right turn traffic



		Right turn traffic	Average LOS
Right turn traffic	Pearson Correlation	1	.601
	Sig. (2-tailed)		.039
	N	12	12
Average LOS	Pearson Correlation	.601	1
	Sig. (2-tailed)	.039	
	N	12	12

Correlation between left turning traffic and average LOS

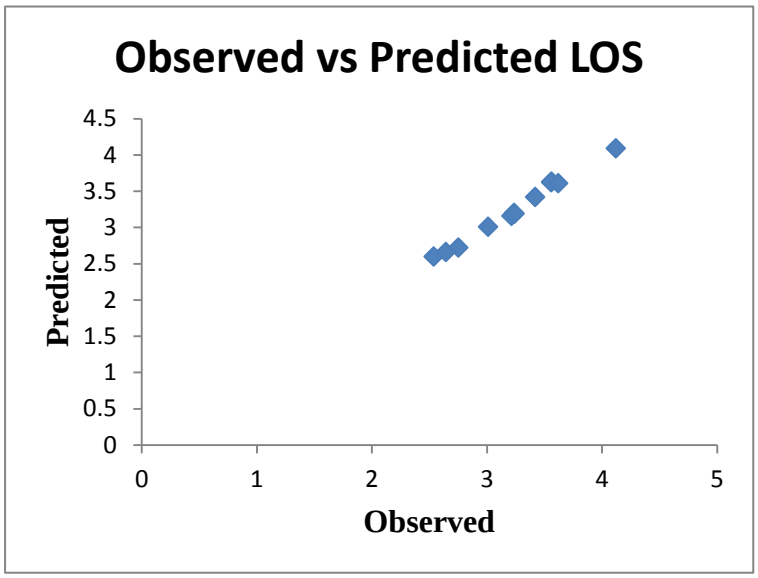


		Left turn traffic	Average LOS
Left turn traffic	Pearson Correlation	1	-.596
	Sig. (2-tailed)		.041
	N	12	12
Average LOS	Pearson Correlation	-.596	1
	Sig. (2-tailed)	.041	
	N	12	12

6.3 PLOS model for crosswalks, validation and comparison

The various factors influencing the pedestrian LOS are considered from the available literature and suitability of those factors in PLOS model in urban Indian conditions was observed. Using those influencing factors pedestrian LOS model was developed which represents mostly the conditions prevailing in urban Indian crosswalks. The developed model is as follows

Slope of the best fitting line was found to be 42.44^0. As the slope of the best fitting line is near to 45^0 the model is applicable and hence validated



6.4 Significance of PLOS score

Many of the literature show that a higher value of PLOS score indicates a low level of service. The developed model gives PLOS score in the range of 1 to 6. Level of service score of most of the cities lies between 2.5 and 4.5 which comes under PLOS C or D. So considering 3.5 as the mid value following level of service ranges can be defined.

LOS A: PLOS≤ 1.5

LOS B: 1.5< PLOS ≤ 2.5

LOS C: 2.5< PLOS ≤3.5

LOS D: 3.5< PLOS ≤ 4.5

LOS E: 4.5< PLOS ≤5.5

LOS F: PLOS >5.5

Pedestrian LOS score for Vijayawada city

By using the new model PLOS of various intersections of Vijayawada city was determined. The intersections are classified as follows

Site ID	PLOS score	LOS
Benz circle	2.643	C
Nirmala convent	3.235	C
PVP Square 1	2.752	C
PVP Square 2	3.214	C
DV Manor 1	3.243	D
DV Manor 2	3.012	C
Stadium 1	3.562	D
Stadium 2	2.538	C

Above table shows the pedestrian level of service of various signalized intersections of Vijayawada city. Most of the intersections fall under level of service category C and D.

Pedestrian LOS score for Bhubaneswar city

Site ID	PLOS score	LOS
A.G Square 1	3.42	C
A.G Square 2	3.56	D
Kalinga 1	3.62	D
Kalinga 2	4.12	D

The above table shows the pedestrian level of service of signalized intersections of Bhubaneswar city. The pedestrian level of service of intersections was varying between C and D.

6.5 Summary

Data collected by video graphic technique, perception and geometric means were used to develop a model for evaluating PLOS score in urban Indian context. Using the developed model PLOS score of different links of different cities was calculated. Based upon the score level of service of those intersections were determined.

Chapter 7
Summary, Conclusions and Future scope

7.1 Summary

In India most of the signalized intersections will have pedestrian crossing facilities like zebra crossings and pedestrian signals, but due to non-patience almost 90% are violating the signal and experiences to conflict with turning and through vehicles leading to more discomfort. The quality of the pedestrian environment has been measured for many years using the Level-of-Service approach. This study helps in assessing the factors affecting pedestrian level of service at intersections and thus evaluating a method to determine LOS of pedestrians at signalized intersections under mixed traffic conditions. The developed level-of-service model accurately represents the pedestrians' perceptions of crossings at signalized intersections. This model incorporates perceived safety and comfort and operations. Data for the model were obtained from field data collection. The data consist of (*a*) participants' perceptions of safety, comfort, and operations as they walk through selected signalized intersections and (*b*) the design and operational characteristics of these intersections. The resulting model provides a measure of the pedestrian's perspective on how well an intersection's geometric and operational characteristics meets his or her needs.

7.2 Conclusions

Following are the find outs from the research estimation of pedestrian level-of-service at signalized crosswalks in urban India.

- The study mainly helps in assessing the factors effecting pedestrian level-of-service at signalized intersections. The various factors influencing PLOS are through traffic, weaving traffic, number of pedestrian, pedestrian delay, number of lanes, presence of channelizing islands and speed of traffic flow etc.
- Developed a method to define the level-of-service of pedestrians at signalized intersections under mixed traffic conditions. In India mostly mixed traffic conditions will present due to the presence of different classes of vehicles.

- Level-of-service model was validated with field data of the two given cities. Studied the effect of various factors such as through traffic, weaving traffic, delay, number of pedestrian and number of lanes on level-of-service.
- There is a need to prioritize and evaluate the needs of pedestrian on existing urban Indian roads.

7.3 Future scope

There are opportunities for further improvement in defining level of service criteria for urban streets in Indian context. Some of them are given below:

The study area for the present study was confined to two cities in India. Similar study need to be carried out in number of cities in India, as India is a big country with large diversities among people and their walking behavior, physical features of roads and geometric conditions. In this study the factors considered are not the only factors effecting PLOS there are many other factors which influence the pedestrian LOS which needed to be considered to completely represent the mixed traffic conditions.

The model developed mainly based on perception of pedestrian on level-of-service. As the perception of pedestrian vary from person to person. Further research has to be done to exactly estimate pedestrian level-of-service. There are also some other factors which effect pedestrian level of service so further research has to be carried out to define the pedestrian LOS of various intersections.

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