A STUDY ON DEFINING PEDESTRIAN LEVEL OF SERVICE FOR ROAD LINKS IN URBAN INDIAN CONTEXT

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CERTIFICATE

This is to certify that project entitled, "**Defining pedestrian level of service for Road Links in Urban Indian context"** submitted by **ABHISHEK OJHA** in partial fulfillment of the requirement for the award of **Master of Technology** Degree in **Civil Engineering** with specialization in **Transportation Engineering** at National Institute of Technology, Rourkela is an authentic work carried out by her under my supervision and guidance. To the best of my knowledge, the matter embodied in this Project review report has not been submitted to any other university/ institute for award of any Degree.

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ABSTRACT

In countries like India pedestrians form a large percentage of traffic volume and they are the most vulnerable road users. Movement of pedestrian are not restricted to the lanes but pedestrians experience certain physical boundaries such as walkways or pedestrian ways which restrict their movement. Normally Indian roads experience inefficient facilities for pedestrians, which leads to a number of fatal accidents all over the country almost every day. To know the efficiency of roadways in aspect to accommodate the pedestrian travel or how effectively they are useful for pedestrians, walking conditions need to be assessed. This assessment helps further for the development of road geometry, road-side furniture and road network assets etc. Estimation of Pedestrian Level of Service (PLOS) is the most common approach to assess the quality of operations of pedestrian facilities. The main purpose of this study is to outline suitable methodology to evaluate Pedestrian Level of Service for both on-street and off-street aspect in Indian condition. All the existing models have certain limitations for which they are not applicable for Indian conditions. In order to assess the PLOS for India it is highly necessary to develop a new model. All the parameters affecting PLOS are considered and accordingly data was collected. Videography was found to be the most efficient method for the collection of traffic data. Video of traffic flow was taken during the peak hours of the day in 15 minutes segments at various locations in Bhubaneswar and Rourkela city. Video data were extracted in order to find the value of different parameters. The extracted data were used to develop a model and regression analysis was used as the main tool for the model development. Proposed model is quite significant as it gives the PLOS value as it is observed on the segment. It describes the traffic scenario very neatly and considers the effect of all parameters those affect pedestrian movement. Proposed model was also compared with the existing models and it was observed that the proposed model gives better result than the existing models. PLOS estimated using the proposed model shows that almost 70% of road segment gives level of service ‘C’ and ‘D’. 15% to 20% road segment comes under level of service ‘E’ and ‘F’. Only a few road segments come under level of service ‘A’ or ‘B’.

Key words: Pedestrian Level of service, Pedestrian Facilities, video data collection, average pedestrian space, flow rate, volume to capacity ratio, regression analysis.

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Abbreviations and Symboles

CAGR	Compound Annual Growth Rate
CFS	Contingent Field Survey
D_f	Disturbance Factor
GIS	Geographic Information System
HCM	Highway Capacity Manual
IPT	Intermediate Public Transit
L	Number of live-stocks found in 5 minutes
LOS	Level of Service
m	Meter
N_{ar}	Number of Assess road
N_{mc}	Number of median cutting
Ob	Number of obstructions present in the link
PCVS	Pedestrian Crossing Video Simulation

PLOS	Pedestrian Level of Service
sec	Second
V_f	Vehicle factor
Vol_{m5}	Average 5 minutes motor vehicle volume on the adjacent roadway
Vol_{n5}	Average 5 minutes non-motorized vehicle volume on the adjacent non-motorized lane
Vol_{p5}	Average 5 minutes pedestrian volume on the sidewalk
W_b	Width of buffer area, the maximum of street trees strip width and non-motorized vehicle parking strip width
W_{ls}	Width of landscaped strip between non-motorized vehicle lane and motorized vehicle lanes (m)
W_n	Width of non-motorized vehicle lane (road with exclusive non-motorized vehicle lane, m) or width of shoulder (road without exclusive non-motorized vehicle lane, m)
Ws	Width of sidewalk (m)
$\%HV$	% composition of heavy vehicle
$\%IPT$	%composition of intermediate public transit
$\%TW$	%composition of two-wheeler
$\%V_e$	% of vendor encroachment

CHAPTER 1

INTRODUCTION

1.1. General

For a country township and cities are the heart of development and economic growth. Being one of the developing countries with a rapid growth rate India has experienced tremendous urbanization after independence and stepped accordingly with the global trend of economic growth. Cities have been developed significantly in term of physical, social and institutional infrastructures. Importance of transportation infrastructure is given importance in this particular context. India has experienced a rapid urban population growth and is estimated to grow to around 540 million by the year 2021. Expansion in the road network, a surge in motorization and the rising population in the country contribute toward the increasing numbers of road accidents, road accident injuries and road accident fatalities. The road network in India, the numbers of registered motor vehicles in the country and the country's population have increased at a compound annual growth rate (CAGR) of 3.4%, 9.9% and 1.6% respectively, during the decade 2001 to 2011. This results an increase in number as well as size in city. The main factor, transportation which plays a vital role in development does not have sufficient efficiency. Both inter-city and intra-city transportation systems are under estimated, ignored and neglected. Growth rate of motor vehicles in India clearly indicates the contribution of transportation system for urbanization and development. Another important fact is that every modal trip consists of significant percentage of walking which means the facilities required for the pedestrian should be given due consideration in the design of the urban environment and transportation facilities.

Certain facilities should be provided so that pedestrians experience safe, accessible and convenient mobility. Large percentages of people of a city walk every day, especially the poor who often do not have other alternatives. Walking also helps in supporting public transport facilities improving the overall livability of cities, providing accessibility within built areas, and providing an alternative to private vehicles for short-distance trips.

Walking is a regular and traditional practice of Indian cities and a major proportion of public depends upon sustainable travelling mode such as walking and cycling along with public mode of transport for their daily travel. However a noteworthy growth of motorization attracts the focus so that attention towards the pedestrian and public transport facilities is reduced. If the focus can be changed it will allow people to turn the urban environment a healthier one. Pedestrian fatalities and accidents have also been increased because of the growing motorization. The number of road accidents in the country increased at a CAGR of 2.1%. Similarly, the number of road accident fatalities and the number of persons injured in road accidents in the country between 2001 and 2011 increased by 5.8% and 2.4% respectively. In 44% to 51% of accident cases pedestrians are involved. Pedestrians are also suffering from high levels of air pollution during their walk to walk or access public transportation to reach their destination. Very less initiative has been taken to promote the improvement of walking in Indian cities. The few civil society organizations and nongovernment organizations working in this area can play key roles in promoting improvements on walkability and pedestrian facilities in their cities.

Being a developing country Indian urban street traffic comprises of different types of vehicles having different operational characteristics which makes the system heterogeneous. The existing guidelines for pedestrians need to be revised thoroughly and appropriate guidelines for

Indian cities should be developed as the existing guidelines are full of ambiguity, inequitable and rarely enforced in cities.

There is no proper methodology to evaluate Pedestrian Level of Service (PLOS) for urban streets in India. Development of suitable methodology is highly important to assess the facilities for pedestrians. Traffic scenarios like planning, design and operational aspects are affected by these methodologies. They also affect the transportation projects as well as allocation of limited financial resources among competing transportation projects. Taking above facts into consideration very suitable method should be adopted to define pedestrian level of service criteria of urban streets in Indian context. In this study an attempt has been made to define pedestrian level of service for heterogeneous traffic flow scenario experienced on Indian corridors.

The concept of Level of Service (LOS) was initiated from the concept of “practical capacity” presented in the 1950 HCM. LOS was started as “qualitative measure of the effect of numerous factors, which include speed and travel time, traffic interruptions, freedom to maneuver, safety, driving comfort and convenience, and operating cost” in the 1965 HCM. The statement of 1965 HCM was clarified in the 1985 HCM by taking into consideration two significant factors i.e. “Qualitative major of operational factors” and “Perception of motorist and passengers” however “Operation Cost” was dropped. In 1965 and 1985 HCM the LOS was described by the six classes from “A” to “F” defined, based on the combination of travel time and the ratio of traffic flow rate to the capacity, because travel time was recognized as a dominant factor of the service quality. However highway capacity is an ever-changing, dynamic and evolving phenomenon. The number of vehicles on the road, the amount of congestion, vehicle performance characteristics and geometric standards has significantly changed the environment in which a driver has to drive (Kittelson, 2000). Highway Capacity Manual (HCM, 2000) defined LOS as “a quality measure describing operational conditions within a traffic stream, generally in terms of such service measures as speed and travel time, freedom to maneuver, traffic interruptions, and comfort and convenience.”. The HCM designates six levels of service, A-F; describe operations from best to worst for each type of facility. In course of time the definition of LOS went in an evolution process and what is being followed is the LOS defined in 2010 HCM (HCM, 2010). The PLOS is highly affected by the heterogeneity in traffic flow on main carriageway such as poor enforcement of traffic laws, varying road geometry, unauthorized vendors activities, unwanted obstructions from utilities and illegal parking on footpaths etc. HCM 2010 describes numerous parameters which affect the PLOS significantly in various ways. Different researchers have studied the behavior of different parameters and their contribution towards PLOS. Regression analysis and cluster analysis have become the powerful exploratory tool to estimate the PLOS score and to define the PLOS ranges respectively.

1.2. Statement of the Problem

Increase in urbanization also shows the consequences by taking toll on the urban infrastructures. Urban pedestrian facilities are not spared from the ill effect of urbanization, which results the decrease of operating condition of road available for commuters day by day. In present scenario the urban roads are suffering from problems like decreasing speeds, increased congestion, increased travel time, and decreased level of service and increase in accident rates. Consideration for the needs of pedestrian should be mandatory in the design of the urban environment and transportation facilities like the needs of other road users such as motor vehicles and non-motorized vehicles. A national review has shown that nearly 60 per cent of deaths and injuries on national highways are among pedestrians and hospital-based studies indicate pedestrian deaths to vary from 22% to 35%, and population based studies reveal that 1/3rd to 1/4th of road deaths are among pedestrians. The precise number of pedestrians injured and killed is difficult to ascertain and could be approximately 40,000 deaths annually in India. Collision with heavy vehicles like buses/trucks and medium sized vehicles like cars/jeeps resulted in higher deaths.

The operating condition of a pedestrian can be defined by one of the most suitable concept i.e. PLOS concept. In order to apply the PLOS analysis concept we have to calculate the LOS of the facilities provided to the pedestrians in current condition or in the near or distance future. So for this growth rate should be taken care of. PLOS can give the clear idea about the operational frequency of urban roads. In India there is no proper methodology or suitable criterion to define Level of Service for pedestrians. Indian urban context is also quite different from other developed countries in terms of traffic, roadway and environmental characteristics. So a modified criterion to define PLOS is much needed for India.

1.3. Objective and Scope of Study

Based on the above problem statement, the objectives of this study are:

- To develop suitable methodology that can be applied with due modifications in defining PLOS criteria for the facilities of urban street segments in urban Indian context.
- To develop procedures for the collection of pedestrian data that is required in applications like defining pedestrian level of service criteria of urban off-streets.
- To identify the necessary variables those influence the models used in the methodology.

- To outline suitable criteria which will be most appropriate for Indian context to evaluate PLOS.

1.4. Organization of Report

This report has 7 chapters. The first chapter gives an introduction to the research work and gives brief idea about objective and scope of study. Second chapter provides the idea about Pedestrian Level of Service concept. It describes PLOS for both onstreet and off street condition. Detail discussion of various literatures is given in the third chapter. Chapter 4 describes the methods and proceedures used in this research. This chapter also gives idea about the regression analysis technique which is used in this research. Chapter 5 deals with the study area for collection of data and details of all data which are collected for this study. This chapter gives brief idea about the cities which are taken for data collection. Developed model is also described in this chapter. Result of all the research work is discussed in chapter 6. This chapter provides the validation of the model and it's comparison with other model. The PLOS score of different road segments for Rourkela and Bhubaneswar city and their level of service are also discussed in this chapter. Chapter 7 gives the conclusion of the study. It also discusses the drawbacks of the developed model and gives some idea about the future scope in this aspect.

Chapter-2

Pedestrian Level of Service Concepts

2.1 General

To determine Level of Service a level of service score is estimated. Many of the literatures define six levels of service which range from A to F, for the output from a mathematical model based on multiple performance measures or for each service measures. For traveller's perspective LOS A defines the best operating condition where as LOS F defines the worst. Generally roadways are not designed for LOS A conditions during peak periods for cost, environmental impact and other reasons. However design is done for a lower LOS that gives a balanced condition for travelers' desire, society's desire and financial resources. A balanced design may operate at LOS A during low-volume period.

Earlier according to HCM LOS was defined with respect to space for pedestrian, flow rates and speed individually. Speed was an important measure in this aspect as it was easy to measure and it reflects the user's perception on service condition directly. Another important aspect was space for individual pedestrian. It indicates the degree of comfort while walking. It plays a vital role during platoon movement and when two platoons cross each other as conflict is encountered in this type of movement. Ability to pass the slower pedestrian is also affected by the space for pedestrian.

Now-a-days many of the literature defines LOS based upon LOS score. LOS score is a mathematical function of different parameters which affect pedestrian movement. Broadly these parameters can be divided into 2 categories such as geometrical parameters and traffic parameters. Geometrical parameters may include the urban infrastructure or road furniture along with geometrical features of road such as length of segment, road width, lane width, sidewalk width etc. These parameters affect walking directly in terms of speed and comfort. It can affect the space per individual pedestrian so the number pedestrian per unit time and unit length is highly affected. Traffic parameters may include composition of traffic such as percentage of heavy vehicle, percentage of two-wheeler, percentage of intermediate public transit etc. Traffic parameters affect directly as well as indirectly. More number of two-wheelers can disturb the pedestrian flow on the sidewalk. On street pedestrian movement is highly affected by the two-wheeler movement. Similarly heavy vehicle create a feeling of insecurity in the mind of pedestrians. IPTs may attract some of the pedestrians towards them so that the pedestrian movement gets altered. In addition to these some other factors also can be taken into consideration such as vendor encroachment on sidewalk, live-stocks interruption etc. These factors disturb pedestrian movement significantly.

2.2 Pedestrian Facilities

2.2.1 Uninterrupted-flow Pedestrian Facilities

Both exclusive and shared pedestrian paths (both indoor and outdoor) are included in uninterrupted pedestrian facilities. Pedestrians do not feel that much disturbance on this type of facilities. Pedestrians face disruption only at interaction with other pedestrians and on shared paths with other non-motorized modes of transportation. Pedestrian walking speed, pedestrian start-up time, and pedestrian space requirements are used in this procedure.

Walkways and Sidewalks

Walkways and sidewalks are exclusively provided for pedestrian where no motorized or non-motorized vehicles are allowed. These types of facilities can be found often on city streets, at airports, in subways and at bus terminals. Geometrically these are straight always and include straight sections such as sidewalk, terminals, stairs and cross-flow areas where streams of pedestrian cross. Walkways and sidewalks always accommodate the highest volume of pedestrians among the three uninterrupted types of facility. Best level of service is also experienced on these walkways and sidewalks as pedestrians do not share the facilities with other modes.

Cross Flows

Cross flows represent the transverse flow manner as it is approximately perpendicular to the traditional pedestrian stream. When two pedestrian flow cross each other then normally the smaller one is called as cross-flow condition.

Queuing Areas

These are the areas on the sidewalks where pedestrian stands temporarily or waits to be served for some time. This type of condition arises when the crowd is dense and pedestrians get very little room for movement. In this condition average space available for pedestrian is very less so possible circulation is limited for a certain period of time.

Pedestrian Platoons

Unregulated pedestrian flow some short-term fluctuations as pedestrians arrive randomly at certain time intervals. Sometimes because of the traffic signal fluctuations are exaggerated and interruption in flow takes place. This leads to queuing near the intersection points. Contribution of transit facilities to platoon flow can’t be ignored as sometimes it releases large group of pedestrians to the urban street in very short time interval followed by intervals during which no flow occurs. Till dispersion pedestrian in these types of groups move in a platoon. In certain case impedance also leads to platoon flow as passing is restricted due to insufficient space which makes the faster pedestrian slow behind the slow walkers.

2.2.2 Interrupted-flow Pedestrian Facilities

In case of interrupted flow impact of motorized vehicles on pedestrian movement is taken into consideration.

Signalized Intersection

Behavior of pedestrian crossing a signalized intersection is a very tedious affair. It is comparatively more complicated to analyze that a midblock crossing. Pedestrian movement on signalized intersection includes sidewalk flows as well as crossing the street. It also includes the queuing behavior which changes according to the change of signal. Pedestrian delay factor should also be considered in this aspect.

Un-signalized Intersection

To calculate the LOS for an un-signalized intersection mainly pedestrian crossing against a free-flowing traffic stream or an approach not controlled by a stop sign are to be considered. In case of a zebra strip crossing pedestrians get a right of way to cross the street. In this case approach should be different to estimate the LOS.

Pedestrian Sidewalks on Urban Streets

In case of interrupted flow sidewalk movement is highly affected non-motorized vehicles. Motorized vehicles also affect significantly pedestrian movement in case of sidewalk for interrupted flow condition. Pedestrian average speed and space per person is highly affected by vehicular activities.

This study includes pedestrian flow on both interrupted sidewalks and un-interrupted sidewalks and the methodology to estimate level of service is described below.

Chapter-3

Review of Literature

3.1 General

Level of service concept appeared first time in 1965 HCM and it provided a convenient way to describe the service quality, operational quality and quality of some facilities provided for traffic movement. In HCM 2000 LOS concept was divided in to two different segments that is un-interrupted pedestrian facilities and interrupted pedestrian facilities. In HCM 2010 LOS service was estimated using two major parameters such as pedestrian flow rate and sidewalk space. Pedestrian flow rate is associated with speed, density and volume and is equivalent to vehicular flow. According to the HCM "As volume and density increase, pedestrian speed declines. As density increases and pedestrian space decreases, the degree of mobility afforded to the individual pedestrian declines, as does the average speed of the pedestrian stream."

Ullman & Ullman (2010) discussed the idea of using proper signs for pedestrian, which can convey the actual message to the pedestrians without any bias or ambiguity and also how to restrict the misinterpretation of these signs by drivers. Survey was conducted by using different types of signs to a number of road users and asking a few questions. The response from the users helped in developing innovative signs which can increase the safety standards of the pedestrians.

Aultman-Hall et al (2009) gave the idea about the variation of pedestrian traffic volumes with weather and season. A study was done by analysing the pedestrian volume along with the weather data such as temperature, relative humidity, precipitation, and wind to determine the factors affecting count variability. Results indicate consistent patterns in relative volumes by hour of the day and month of the year that show that good adjustment factors can be developed to use with time-limited counts to estimate usage and pedestrian exposure to accidents.

Miller et al (2000) developed some concepts of calibrating the pedestrian level of service. Different parameters such as walkway width, median openings, and signalization parameters, or user perceptions, such as continuity and convenience were defined for the calibration of level of service for pedestrian. Level of service always differs according to perception like it is different for pedestrian and a driver. To overcome this a scaling system was developed for pedestrian LOS and calibrated using visualization (computer-aided modelling techniques consisting of still shots and animations).

Hubbard et al (2008) gave the concept of assessing the Real-Time pedestrian Performance measures incorporated with existing infrastructure of traffic signal system. During the research real time performance measures were indulged in order to enable better operations. Pedestrian service was compared at different location or at same location in different condition. The proposed pedestrian performance measures were used in conjunction with existing vehicle performance measures, resulting in an integrated approach to assessing the level of service for vehicles and pedestrians under different conditions and for different signal timing plans.

Chen et al (2008) studied the walking behaviour of pedestrians under different types of walking facility i.e. one-way passageway, two-way passageway, ascending stairway, and descending stairway. Data collected are based on pedestrian flow parameters such as pedestrian flow, density, and speed. Pedestrian flow–density–speed relationships for each kind of walking facility were developed. Combined with the investigation of walking behaviour, pedestrian flow characteristics on various walking facilities are compared with each other, particularly for the flow–density and speed–density relationships.

Muraleetharan and Hagiwara (2007) enhanced the idea of over-all level of service of the urban working environment and its influence on pedestrian route choice behaviour. In this research they tried to assess the level of service from the utility value. Level of service in this research is directly related to operational and geometrical characteristics of the sidewalk and crosswalk. Characteristics of the routes followed by pedestrian were analysed by geographic information system (GIS). It was found that pedestrian change the route not only for the distance but also for the overall level of service. Researchers developed a multinomial logit model to express quantitatively the route choice behaviour of pedestrians.

Landis et al (2001) tried to quantify the pedestrians' perception of safety and comfort in the road side environment. This quantification, or mathematical relationship, would provide a measure of how well roadways accommodate pedestrian travel. This can lead to roadway cross-sectional design and also help evaluate and prioritize the needs of existing roadways for sidewalk retrofit construction. The measure can be used to evaluate traffic calming strategies and streetscape designs for their effectiveness in improving the pedestrian environment. The Model was developed through a stepwise multi-variable regression analysis of 1250 observations from an event that placed 75 people walking on a roadway course in the Pensacola metropolitan area in Florida. The Pedestrian LOS Model incorporates the statistically significant roadway and traffic variables that describe pedestrians' perception of safety or comfort in the roadway environment between intersections.

Muraleetharan and Hagiwara (2007) worked on overall level of service of the Urban Walking Environment and Its Influence on Pedestrian Route Choice Behavior. A methodology was developed for estimating the overall LOS of pedestrian walkways and crosswalks based on the concept of total utility value.

Kim et al (2006) worked on walking of pedestrian in Waikiki, Hawaii and tried to measure Pedestrian Level of Service in an Urban Resort District. a series of 15-min pedestrian counts was conducted to establish overall sidewalk volumes and flows. All the potential parameters affecting level of service were measured. In addition to the width of the sidewalk, there are also movable and immovable objects, street furniture, plantings, and other activities that affect access and use of sidewalks. To test and refine the approach, the impacts of street performers who occupied the sidewalks in the area were analyzed in terms of the effects on pedestrian flow and LOS.

Jaskiewicz (2000) gave some statement regarding walking that careful attention should be paid for the pedestrian safety and comfort if walking needs to be encouraged as a viable alternate form of transportation.

Petrisch et al. (2005) tried to deal with perceived comfort and safety (i.e., perceived exposure and conflicts) and operations (i.e., delay and signalization) and developed a model which reflects pedestrian perspective on the goodness of intersection's geometric and operational characteristics.

Kim et al. (2006) gave a view that street performer put impact in a negative way on pedestrian LOS by creating congestion, access limitation and interference on pedestrian flows.

Jianhong et al. (2008) studied the flow characteristics of pedestrian on the aspect of one-way passageways, two-way passageways, descending stairways, and ascending stairways in

Shanghai metro stations and came out with some consistent rules for traffic flow, density, and speed which can be applied for both vehicle as well as pedestrian flow.

Schneider et al. (2009) tried to integrate the pedestrian volume in a routine pattern into transportation safety and planning objects and tried to figure out some method to explorate total weekly pedestrian intersection crossing counts from manual counts using the data obtained from automated counters.

Marshall and Garrick (2012) described the significance of influence of three major fundamental parameters such as street network-street connectivity, street network density, and street patterns. These parameters influence choice to drive, walk, bike or take transit.

Bian et al (2009) developed a model to estimate level of service for sidewalks from the perspective of the pedestrian's pedestrian of comfort and safety for Chinese roadside environment. The model was based on the data collected from questionnaire survey, traffic flow characteristics and geometric data.

3.2 Level of Service Analysis for Pedestrian Facilities

3.2.1 Sidewalk

Dandan et al. (2007) put forwarded the concepts of assessing the pedestrian level of service for sidewalk using different methods. Researchers discussed about various factors which affect the level of service for pedestrians such as Road transect form, Pedestrian flow characteristics, Vehicle and bicycle flow characteristics, Obstructions on the sidewalk and the frequency of driveway access. Questionnaire survey data were collected and analysed to determine the level of service. Different variables such as the bicycle flow volume, the pedestrian flow volume, the vehicle flow volume, the driveway access frequency, the distance between sidewalk and vehicle lane were taken to develop the pedestrian level of service model.

Petritsch et al. (2005) enhanced the Level-of-Service Model for Urban Arterial Facilities with Sidewalks. The model represented perceptions of how well urban arterials with sidewalks (a combination of roadway segments and intersections) meet their needs. Study participants represented a cross section of age, gender, walking experience, and residency. The research was designed to elicit responses from participants walking individually, not in pairs or groups. A Regression model can be developed to Represent Mathematically Pedestrians' Perceptions of How Well an Urban Arterial Facility Accommodates Pedestrians' Needs.

Landis et al (2006) developed a model for pedestrian level of service for urban arterial facilities with sidewalks. Developed model was based on how efficient the urban arterials with sidewalks (a combination of roadway segments and intersections) are in satisfying the users. This model incorporates traffic volumes on the adjacent roadway and exposure (i.e. crossing widths) at conflict points with intersections and driveways. Data were collected from an innovative "Walk for Science" field data collection event. The proposed level of service model is based on Pearson correlation analyses and stepwise regression modeling of approximately 500 combined real-time perceptions (observations) from pedestrians walking a course along a typical U.S. metropolitan urban area's streets. The study reveals that traffic volumes on the adjacent roadway and the density of conflict points along the facility are the primary factors in the LOS model for pedestrians traveling along urban arterials with sidewalks.

3.2.2 Crosswalk

Lee et al (2005) discussed about new level of service standard for Signalized Crosswalks with Bi-Directional Pedestrian Flows. Key point of this study is bidirectional flow of pedestrian was taken into account. Interview survey technique was adopted for this purpose. The researchers defined explicitly the LOS boundaries for different levels of bi-directional flow regarding area occupancy, pedestrian flow, and walking speed. Level of service estimation was based on area occupancy, pedestrian flow, and walking speed.

3.2.3 Intersection

Marisamynathan & Vedagiri (2013) tried to develop a delay model for pedestrian at signalized intersection. Some notable facts were observed from the videographic survey conducted such as pedestrians adjust their crossing speed based on the traffic condition at that particular time, pedestrian non uniform arrival pattern, and some of the pedestrians were crossing the crosswalk during flashing red signal phase and red phase. Researchers developed a new delay model for Indian condition considering three factors such as waiting time delay, crossing time delay and pedestrian vehicular interaction delay. Waiting time delay is based on signal red timing for pedestrians in waiting area, crossing time delay is based on pedestrian walking speed, and vehicular interaction delay is based on acceptable gap and walking speed.

Bian et al (2009) attempted to develop a pedestrian level of service model at signalized intersection. Researchers considered three main factors affecting level of service i.e. traffic conflicts, crossing facilities and delay. They tried to determine how well intersections accommodate pedestrians by evaluating their perceptions of safety and comfort when crossing signalized intersections.

Muraleetharan et al (2005) tried to identify the factors affecting pedestrian level of service at intersection and to propose a method of evaluation of level of service. Researchers tried to get response from a significant number of pedestrians from different location and followed a stepwise regression model to develop a model to achieve level of service. A field survey was conducted to collect geometric, operational and traffic characteristics of crosswalks. A number of primary independent variables influencing pedestrian LOS was identified and tested in the stepwise regression analysis. The factors such as space at corner, crossing facilities, turning vehicles, delay at signals, and pedestrian-bicycle interaction were identified as the primary factors affecting pedestrian LOS at intersections.

3.3 Modeling and Simulation

Miller et al developed some concepts of calibrating the pedestrian level of service. Different parameters such as walkway width, median openings, and signalization parameters, or user perceptions, such as continuity and convenience were defined for the calibration of level of service for pedestrian. Level of service always differs according to perception like it is different for pedestrian and a driver. To overcome this a scaling system was developed for pedestrian LOS and calibrated using visualization (computer-aided modelling techniques consisting of still shots and animations).

Petritsch et al (2008) put forwarded the idea of assessing level of service from a provider-based measure to a user-based measure. Data for the model were obtained from participants in video simulation laboratories. The density LOS is computed according to the methods provided in the Highway Capacity Manual. The non-density LOS is a function of the pedestrian LOS of roadway segments, the pedestrian LOS of intersections, and the roadway crossing difficulty factor.

Muraleetharan and Hagiwara (2007) enhanced the idea of over-all level of service of the urban working environment and its influence on pedestrian route choice behaviour. In this research they tried to assess the level of service from the utility value. Level of service in this research is directly related to operational and geometrical characteristics of the sidewalk and crosswalk. Characteristics of the routes followed by pedestrian were analysed by geographic information system (GIS). It was found that pedestrian change the route not only for the distance but also for the overall level of service. Researchers developed a multinomial logit model to express quantitatively the route choice behaviour of pedestrians.

Sisiopiku et al. (2007) tried to apply the pedestrian level of service methods for the evaluation of operation at pedestrian facilities. Generally level of service methods utilize principles of vehicular traffic to evaluate pedestrian traffic operations or deal with the facility design and walking environment than the actual pedestrian flows. Researchers compared some of the more common and widely accepted methods for determining pedestrian LOS at sidewalks. These include the Highway Capacity Manual 2000 method, the Australian method, the Trip Quality Method, the Landis model, and the Conjoint Analysis approach. After describing the methods and their associated measured criteria, a total of 13 sidewalks are evaluated at two study sites. The comparison provides useful information on the consistency of outcomes from the various methodologies, and identifies needs for modifications and improvements. Data used in this study were geometric and traffic control data such as sidewalk width, distance between recognizable features (such as pavement joints), width of street furniture and their distance from curbs, and related sidewalk features along with the video graphic data for determining vehicular and pedestrian activity.

Christopoulou and Pitsiava (2012) developed a new level of service model for different conditions found in Greece. Research was mainly based on questionnaire survey. The developed model was compared with other eleven existing model. They found that level of service 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.

Jensen (2007) tried to develop methods for objectively quantifying pedestrian and bicyclist stated satisfaction with road sections between intersections. The result gave how efficiently the urban and rural road accommodates pedestrians. Videos of 56 segments were taken by a walking pedestrian and a bicyclist which was shown to 407 number of people and responds were recorded. This resulted in 7,724 pedestrian ratings and 7,596 bicyclist ratings. Roadway segments and video clips were described by 150 variables. Pedestrian and bicyclist satisfaction models were developed by cumulative logit regression of the ratings and the variables. Variables that significantly influenced the level of satisfaction were motorized traffic volume and speed; urban land uses; rural landscapes; the types and widths of pedestrian and bicycle facilities; the numbers and widths of the drive lanes; the volumes of pedestrians, bicyclists, and parked cars; and the presence of median, trees, and bus stops.

3.4 Summary

Literature review related to LOS is discussed in detail in this chapter along with different method and simulation model followed by different researchers. From extensive review the parameters affecting PLOS were found out and used for this study. Different analysis techniques were studied for development of model were also studied. From literature review it is clear that many more research can be done on the current PLOS methodology described in different literatures. Data collection through videography is found to be an efficient and accurate technique.

Chapter – 4

METHODOLOGY and MODEL DEVELOPMENT

4.1. General

Now-a-days so many techniques and software are used for empirical modeling. Regression analysis is used as the modeling tool for the modeling purpose in this study. SPSS software is used for the regression analysis. Several types of regression techniques are available such as linear regression, binomial regression, multiple regression hierarchical regression etc. Multiple regression is used for this research work.

4.2. Regression Analysis

In statistics, regression examination is a measurement methodology for evaluating the connections among variables. It incorporates numerous procedures for demonstrating and dissecting a few variables, when the attention is on the relationship between an indigent variable and one or more free variables. All the more particularly, regression analysis helps one to see how the common estimation of the needy variable (or 'standard variable') changes when any of the autonomous variables is changed, while the other free variables are held settled. Most usually, regression analysis appraises the conditional expectations of the dependent variable given the independent variables that is, the normal estimation of the indigent variable when the free variables are settled. Less ordinarily, the attention is on a quantile, or other area parameter of the contingent appropriation of the indigent variable given the autonomous variables. In all cases, the estimation, target is a component of the independent variables called the regression function. In regression analysis, it is additionally of enthusiasm to portray the variety of the dependent variable around the regression function which can be depicted by a likelihood circulation.

Regression analysis is generally utilized to forecast and determining, where its utilization has significant cover with the field of machine learning. Regression analysis is likewise used to comprehend which, among the independent variables are identified with the dependent variable, and to investigate the types of these connections. In confined circumstances, regression analysis can be utilized to establish causal connections between the independent and dependent variables. However, this can prompt illusions or false connections, so alert is advisable.

Numerous strategies for completing regression analysis have been created. Commonplace routines, for example, direct regression and normal least squares regression are parametric, in that the regression function is characterized regarding a limited number of finite parameters that are evaluated from the information. Nonparametric regression refers to systems that permit the regression function to lie in a predetermined arrangement of functions, which may be infinite-dimensional.

The execution of regression analysis routines relies upon the manifestation of the information creating methodology, and how it identifies with the regression methodology being utilized. Since the genuine manifestation of the information creating methodology is for the most part not known, regression investigation regularly depends to some degree on making approximation about this procedure. These approximations are in some cases testable if an adequate amount of information is accessible. Regression models for expectation are regularly valuable notwithstanding, when the suspicions are reasonably abused, despite the fact that they may not perform ideally. In any case, in numerous applications, particularly with little impacts or inquiries of causality in view of observational information, regression routines can give misdirecting result.

From the extensive literature study and field observations some vital parameters were found which affect significantly pedestrian level of service. In addition to those two factors were introduced such as disturbance factor (D_f) and vehicle factor (V_f).

Overall framework of the methodology:

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Disturbance factor (D_f) :

Multiple linear regression was used to find out this parameter. The parameters used to determine this factor interrupts pedestrian movement in so many ways. They mostly interfere in the pedestrian movement and cause a reduction in pedestrian level of service. For performing the regression average of sum of scores of the following questions was taken as Y-coordinate.

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- Very bad
- Bad
- Do not affect

For calculation of scores in the first question "Always" is assigned with score 5. Similarly 4 for "Very often", 3 for "often", 2 for "Sometimes" and 1 for "Not at all" were assigned. For second and third questions 5,4,3,2,1 were assigned for "Acute", "Severe", "Very bad", "Bad" and "Do not affect" respectively.

Above mentioned questions were asked to several people and the average of sum of their scores were noted and taken as Y-coordinate. For X-coordinate 3 parameters were chosen such as number of median cutting and access roads (N_{mc} + N_{ar}), percentage of vendor encroachment (*%Ve*) and number of stray animals found in 5 minutes (*L*). Geometric data and videography data were used to determine the value of these parameters.

By performing the regression following equation was found out.

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Above equation was used to calculate the D_f value for all the links.

Vehicle factor (V_f) :

This factor was also developed by multiple regression. Composition of motorized vehicle is generally taken into consideration for determination of this factor. This represents how different types of vehicles affect pedestrian activity in different manner. For performing the regression average of sum of scores of the following questions was taken as Y-coordinate.

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For calculation of scores 1 to 5 were assigned to the options in a similar manner as defined for D_f.

For X-coordinate parameters like percentage composition of heavy vehicle (*%HV*), percentage composition of two-wheeler (*%TW*), and percentage composition of intermediate public transit (%IPT) were taken into consideration. Video data were used to determine the value of these parameters.

By performing the regression following equation was found out.

Table 4.2: Multiple Regression for Defining Vehicle Factor (V_f)

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Above equation was used to calculate the V_f value for all the links.

Pedestrian Level of service (PLOS) :

Above mentioned D_f and V_f were used in this step to find out the final equation for pedestrian level of service by multiple regression. All the parameters which affect pedestrian movement directly or indirectly in Indian condition are taken into consideration for the determination of

PLOS. One single question was used to determine the Y-coordinate for the regression analysis which is

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To calculate the score option “Excellent”, “Good”, “Average”, “Inferior”, “Poor” and “Terrible” are given marks 1,2,3,4,5 and 6 respectively.

All the parameters including Df and Vf were taken as X-coordinate parameters. The parameters are

- ✓ Width of landscape strip width and width of non-motorized lane ($W_{ls}+W_n$)
- ✓ Buffer width (W_b)
- ✓ Sidewalk width (W_s)
- ✓ 5 minutes motorized vehicle volume (Vol_{m5})
- ✓ 5 minutes non-motorized vehicle volume (Vol_{n5})
- ✓ 5 minutes pedestrian volume (Vol_{p5})
- ✓ Number of obstructions (*Ob*)
- ✓ Disturbance factor (D_f)
- ✓ Vehicle factor (V_f)

The following equation was found after performing the regression.

Table 4.3: Multiple Regression for Defining PLOS

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4.3. Summary:

This chapter gives a brief idea about the procedures followed for the development of PLOS model. Techniques used for modeling and software used in the modeling are also discussed in this chapter. This chapter also gives idea how the perception data are quantified and used in the model development.

Chapter 5

Study Area and Data Collection

5.1 General

This particular chapter deals with study area, map preparation and data collection. Bhubaneswar and Rourkela city of Odisha state, India are taken as the study area for the research work. Data for the study were taken using a video camera. In this chapter type and timing of data collection, data smoothening and data compilation are also discussed in detail. Characteristics of the pedestrian and their walking speed were observed through videography. A pedestrian database was built using the data from the survey conducted. The database was helpful in understanding the relationship between pedestrian characteristics. Pedestrian data were recorded on the sidewalk at various locations in 15-minute segments using digital video camera. Pedestrian walking behavior, including pedestrian interactions with street furniture or with other pedestrians were observed thoroughly from the video clips. Number of pedestrian passing through a particular section was counted and their walking speeds along with other relevant characteristics were recorded. These data were used to build a pedestrian database, which is the core data source for this study. The database helped in finding out the pedestrian behavior and how they are affected by different factors on sidewalk environment for both on street and off street condition.

5.2 Study Corridors

5.2.1 Map preparation

Using Google map a detailed roadway map is prepared for both the cities which helped in the preparation of plan for collection of data by videography of different road segments.

5.2.2 Study Corridors

New millennium has brought revolution to the industrialization which has made India as the fourth rapid growing country. According to census 2011 out of 121crores of people 37.7crores live in urban areas. Growth of urban population is 9.1crores within last 10 years. However urbanization is not that significant in Odisha state. It is much less than the national average. According to census 2011 population of Odisha is 4.2crores. 16.69% of the total population of Odisha lives in urban region.

Bhubaneswar and Rourkela are two important cities of Odisha which were chosen for collection of data. Bhubaneswar, the capital of Odisha is known as the temple city. It has good connectivity with the other growing nearby cities of Odisha. Improvement in passenger transit options is much needed for better interaction. Bhubaneswar is well known for its excellent tourism. Bhubaneswar is one of the fastest growing cities of eastern India incorporating with trades and business. It gets its main revenue from the tourism industry as it attracts about 1.5 million tourists every year. It also possesses a large residential area and surrounded by a number of small industrial areas. In last two decades it is experienced that the economy of this city is majorly influenced by retail and small scale manufacturing. Capacity of the existing traffic and transportation network at intra urban level are the main drawbacks for its future growth. Increase in traffic demand cannot be accommodated comfortably with the current traffic facilities.

Rourkela, well known as the steel city is one of the major industrially developed city of Odisha. It is one of the largest cities of Odisha situated in the north-west region of the state. Site selection for the survey is an important job for the proper calculation of PLOS. It is not an easy task as site should be selected in such a manner that different sites should give different PLOS value. Selected sites give some key features like significant foot traffic, on-street and off-street pedestrian movement, interaction between pedestrians and public transits (subway, bus, train) etc. Selected sites show great variety of land uses such as commercial, residential, office and institutional (e.g., school, hospital). The following figures (Fig 5.1 (a) & Fig 5.1 (b)) show the various locations of Bhubaneswar and Rourkela city chosen for data collection.

Fig 5.1(a) Bhubaneswar North Region

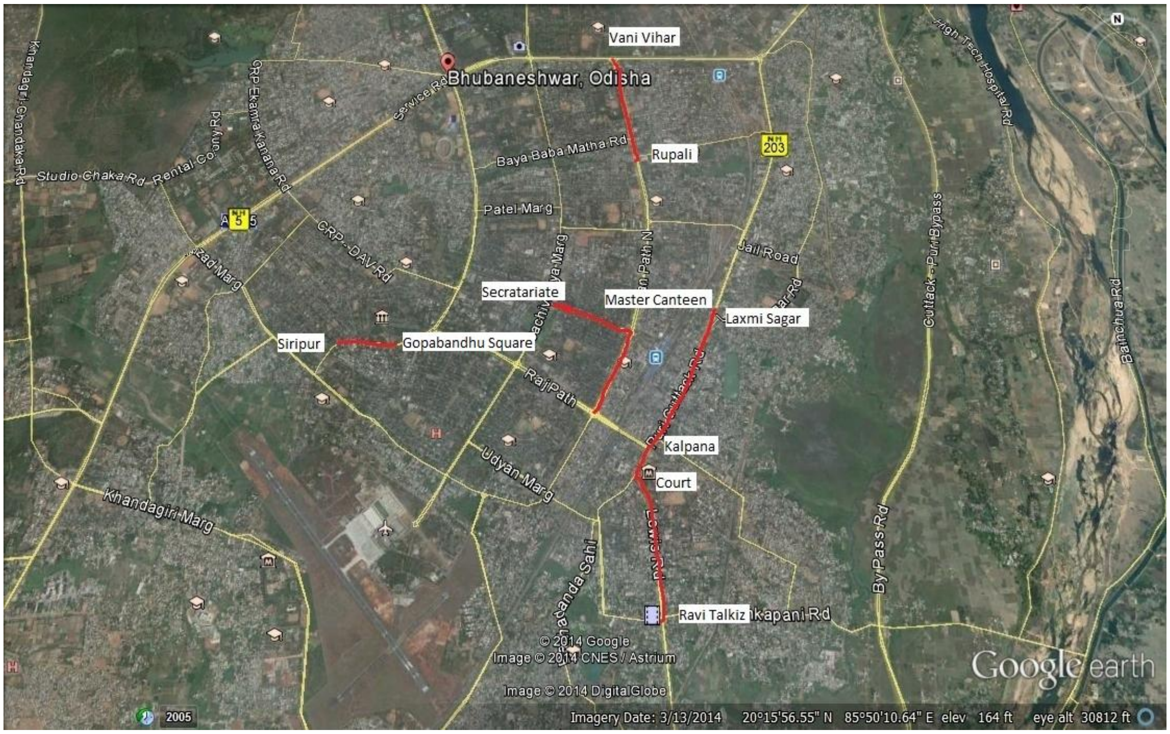


Fig 5.1(b) Bhubaneswar South Region

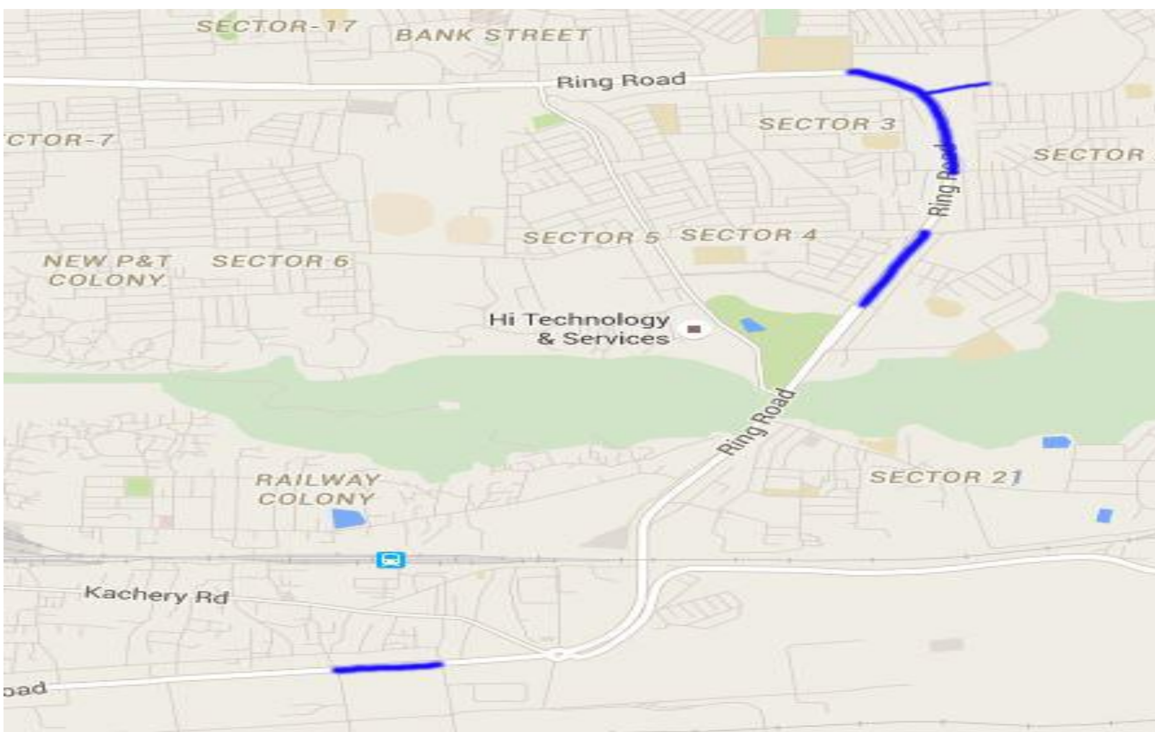


Fig 5.1 (c) Rourkela Corridor

The following figures Shows some typical images study locations.

Fig 5.2 Study Corridors

Most of the ancient cities of India have narrow and winding streets. Bhubaneswar and Rourkela are two modern cities having straight and wide streets. Adequate separation is present in most of the case between carriageway and sidewalks by means of small trees and curb. Streets are arranged in a grid, meeting at signalized/un-signalized intersections that are installed with pedestrian crosswalks. In the surveyed area, some streets have sidewalks on both sides or one side and some streets do not have sidewalks. Almost all streets have crosswalks at intersections.

5. 2.3. Data collection

From the extensive literature survey the parameters found out which are to be used in this survey can be divided into following parts.

Geometric Data

Geometric includes the following

Width of landscaped strip between motorized vehicle lane and non-motorized vehicle lane:

This is the space provided in between motorized and non-motorized vehicle lane. In most of the Indian road this space is not provided. In some cases this space is present. Presence of landscape strip width somehow affects the pedestrian activity.

Width of non-motorized vehicle lane:

This is the lane provided for the movement of non-motorized vehicle (bicycles). It is normally provided between sidewalk and carriageway. Width of such type of lane is in between 2.5m to 3.5m. Sometimes it is grade separated. Presence of non-motorized lane influences pedestrian activity in a positive manner. Width of this lane is measured by geometric means using measuring tape.

Segment length:

This is the length generally considered between two intersections. Long length generally discourages pedestrians. This is also measured by using measuring tape.

Number of obstructions on the sidewalk:

These are the objects presents on the street sides which creates obstacles to walking. Big size trees are normally considered as obstructions for walking. Obstructions normally change the walking trajectory. This is normally counted how many obstructions are present on a road segment.

Number of median cuttings:

These are the gaps on the traffic separator. Movement of heavy vehicles through these median cuttings affects walking on the street side. In case of heavy traffic movement through these median cuttings can create jam condition which affects adversely pedestrian activities. This parameter is collected by counting the numbers of median cutting present in the segment.

Number of Access roads:

These are the roads which connect the urban residential industrial and official areas with the main street. These roads interrupt the sidewalk movement. Vehicles moving through these access roads disturb the pedestrian movement significantly. This is also collected by counting the number of access roads present in the road segment.

Percentage of vendor encroachment:

In Indian road condition numbers of vendors are present on the street sides. They affect the walking adversely on the sidewalks. This is measured as the proportions of length of the sidewalk. This is normally represented by

$$\frac{Length\ of\ vendors\ present\ on\ the\ sidewalk}{Length\ of\ the\ sidewalk} * 100 \qquad (5.1)$$

Fig 5.3 Vendor Encroachment

Width of buffer area:

The space between the walkway and nearest path of moving vehicles is the walkway support. In case buffer area is not present sidewalk width provided should be more. A more extensive walkway permits a person on foot to stay away from the sprinkle zone (territory nearby an engine vehicle travel path into which water splash made by an engine vehicle going through water on the roadway enters) and gives more agreeable partition between moving vehicles and walkers.

Width of sidewalk:

Width of the sidewalk is measured geometrically using a measuring tape. More width gives pedestrian more space for walking hence increases the level of service and vice versa. Sidewalk encourages walking as it provides safety measures from moving traffic.

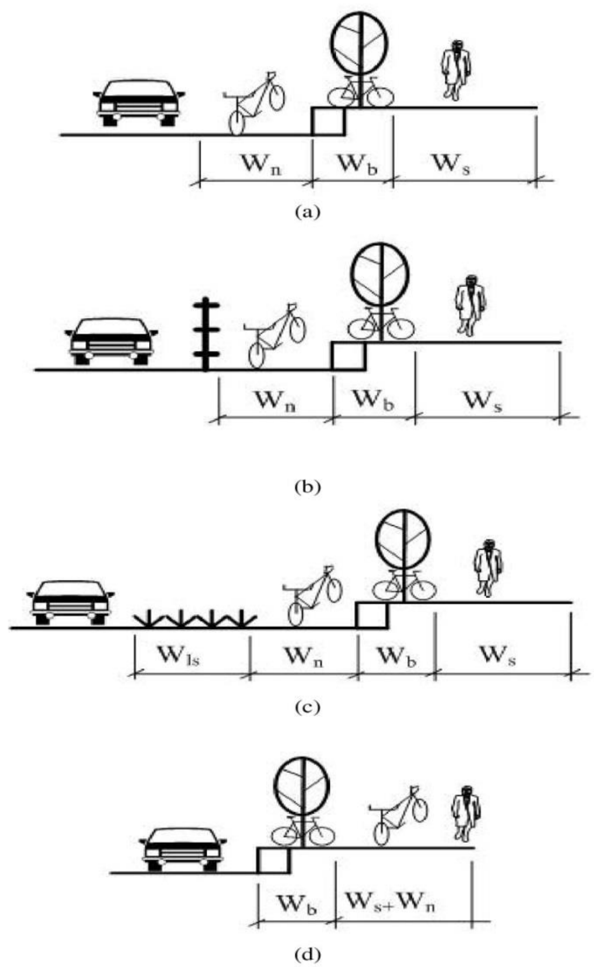


Fig 5.4 Geometric Parameters

Video Data

Video data includes the following

Average 5 minutes motor vehicle volume:

This is the number of motorized vehicles pass through a particular section of a segment in 15 minutes. Movement of motorized vehicles makes significant impact on pedestrian movement. More volume of motorized vehicle can create jam condition hence affects pedestrian activities in an adverse manner.

Average 5 minutes non-motorized vehicle volume:

Movement of non-motorized vehicle also affects the pedestrian movement as they sometimes share the path meant for pedestrians when non-motorized vehicle lane is not provided. Non-motorized vehicles have a tendency to move towards the sidewalk hence they affect the pedestrian movement significantly.

Average 5 minutes pedestrian volume on the sidewalk:

Number of pedestrian passing through a section in certain duration of time affects level of service significantly. Movement of large number of pedestrian leads to discomfort as space per pedestrian is decreased. This also decreases the speed of movement. Similarly very few number of pedestrians gives good space for walking which leads to free movement of pedestrians.

Percentage composition of heavy vehicle:

This is the percentage of heavy vehicles move in a particular traffic scenario. Movement and turning of heavy vehicle affects the pedestrian significantly. This parameter is found out by following equation

$$\frac{Number\ of\ heavy\ vehicles\ passes\ in\ 15\ minutes}{Total\ number\ of\ vehicles\ passes\ in\ 15\ minutes} * 100 \qquad (5.2)$$

Percentage composition of two-wheeler:

Two-wheelers have a tendency to move towards the side region of a street. They frequently use the median cuttings and access roads. So their role in disturbing the pedestrian is quite significant. This parameter can be found out by

$$\frac{Number\ of\ two\!-\!wheelers\ passes\ in\ 15\ minutes}{Total\ number\ of\ vehicles\ passes\ in\ 15\ minutes} * 100 \qquad (5.3)$$

N.B: To take the videography data a camera is set on the side of a carriage way. The camera is set in such a way that it records the movement of pedestrian, non-motorized vehicles and motorized vehicles at a time from a transverse direction. A segment of 8m to 10m is chosen within which traffic movement is recorded.

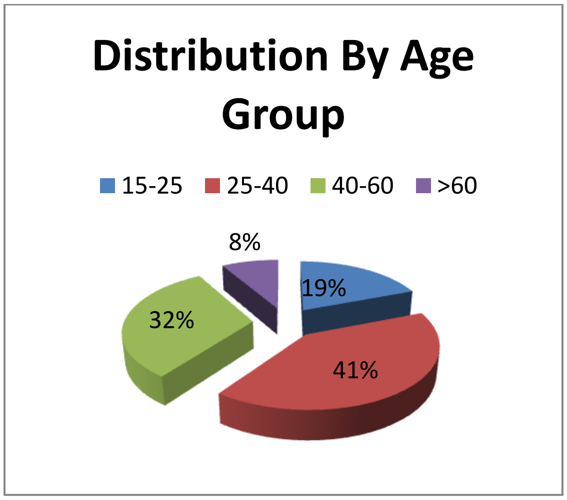
Live-stocks found in 5 minutes:

In Indian condition movements of live stocks on the street cannot be ignored. Mainly they move on the road sides and sidewalk. They can cause significant disturbance to the pedestrian movement.

Fig 5.5 Live-stocks Interruption

Perception 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 is given below.



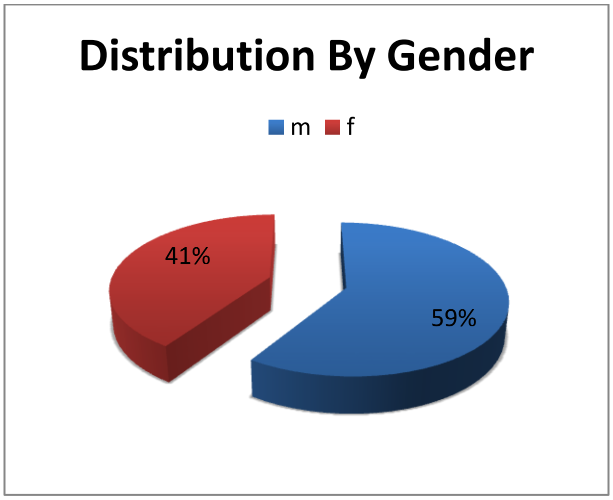


Fig 5.6 Distribution of perception data by age and gender

5.3 Summary:

This chapter gives a brief idea of the process involved in data collection such as map preparation, selection of study corridor etc. The details of all the parameters, how they are collected are discussed in this chapter. This chapter also discusses the basic features of the two cities used for data collection.

Chapter 6

Result and Analysis

6.1 General

Result of regression analysis is discussed in this chapter. Mainly multiple regression analysis is used in this study. This chapter gives the basic idea about the parameters used for the analysis. Development of the PLOS model is discussed briefly in this chapter. This chapter gives the brief idea how PLOS score is calculated from the developed model and PLOS score of different links of different cities are discussed in this chapter.

6.2 PLOS model, Validation and Comparison

After the extensive literature review parameters affecting PLOS for Indian condition were decided. Some new parameters were introduced from the site observations. Using those parameters a new PLOS model is developed for Indian condition. The developed model is given below.

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Where

W_{ls} = *Width of landscaped strip between non-motorized vehicle lane and motorized vehicle lanes(m)*

W_n = *Width of non-motorized vehicle lane (road with exclusive non-motorized vehicle lane, m) or width of shoulder (road without exclusive non-motorized vehicle lane, m)*

W_b = *Width of buffer area, the maximum of street trees strip width and non-motorized vehicle parking strip width*

Ws = Width of sidewalk (m)

Vol_{m5} = *Average 5 minutes motor vehicle volume on the adjacent roadway*

Vol_{n5} = *Average 5 minutes non-motorized vehicle volume on the adjacent non-motorized lane*

Vol_{p5} = *Average 5 minutes pedestrian volume on the sidewalk*

Ob = Number of obstructions present in the link

D_f =*Disturbance Factor*

V_f =*Vehicle factor*

$\%V_e$= *% of vendor encroachment*

N_{mc}= *Number of median cutting*

N_{ar}= *Number of Assess road*

L = Number of live-stocks found in 5 minutes

%HV= % composition of heavy vehicle

%TW= %composition of two wheeler

%IPT %composition of intermediate public transit

Model Validation

Almost 70% data were used for model development. Rest 30% data were used to validate the model. A graph was plotted between observed value and estimated value. Observed values are taken in Y-axis and estimated values are taken in X-axis. Best fitting line was drawn between these two data and the slope of the line was determined.

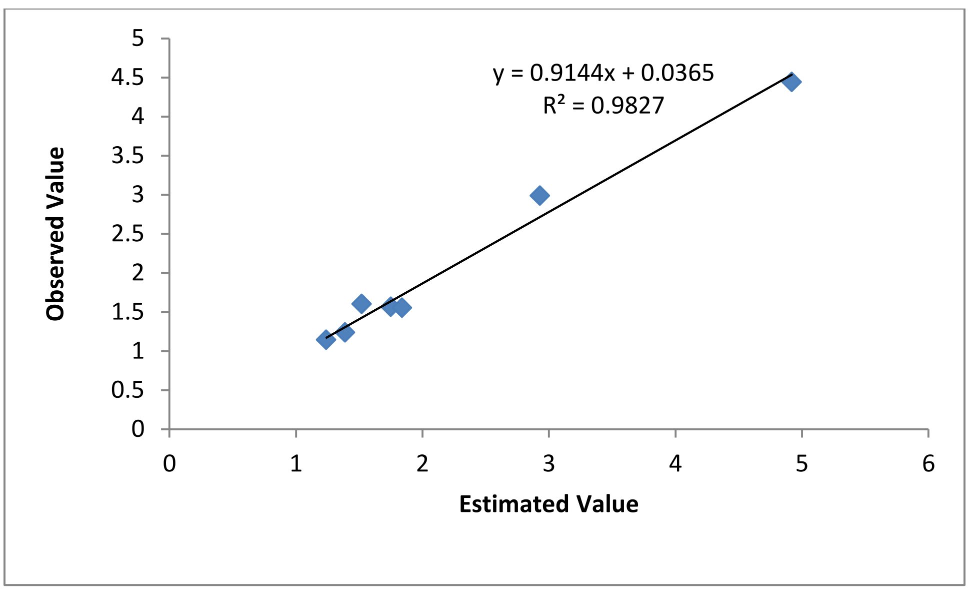

Fig 6.1 Chart showing Validation

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.

Model Comparison

Results obtained from the model developed for different links was compared with the results obtained from the Yang Bian model for those links. Yang bian model does not give the suitable values for the Indian conditions as the values obtained from this model are beyond the range. The newly developed model gives appropriate values for Indian conditions. Following table shows the comparison between the values obtained from the above mentioned two models.

Table 6.1: Comparison of PLOS score obtained by two models

Site id	PLOS Bian et. al. model	Plos new model
Big Bazar to KIIT	6.509	2.924
Court to Ravi Talkiz	40.2255	2.045
CTTC Lane	7.1342	1.653
Gopabandhu Square to Siripur	8.906	2.408
Kalpana to Court	7.262	4.21
KIIT to Big Bazar	6.759	3.054
Laxmisagar to Kalpana	10.7802	5.043
Master Canteen to Rajmahal	10.148	2.537
Master Canteen to Secratariate	9.303	3.5
Ravi Talkiz to Court	27.8786	2.909
Rupali to Vani Vihar	7.21903	2.384
Siripur to Gopabandhu Square	10.0992	2.456
Vani Vihar to Rupali	12.677	2.463
kalpana to Laxmisagar	14.4678152	4.867

6.3 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 3 and 3.5 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

PLOS Score for Bhubaneswar city:

Using the developed model PLOS score of different links of Bhubaneswar city was calculated. Details of PLOS score of the city is given below

Table 6.2: PLOS score and Level of service of Bhubaneswar city using new model

Site Id.	PLOS Score	LOS
Big Bazar to Court	2.92	C
Court to Ravi Talkiz	2.04	B
CTTC Lane	1.65	B
Gopabandhu Square to Siripur	2.41	B
Kalpana to court	4.21	D
KIIT to Big Bazar	3.65	D
Laxmisagar to Kalpana	5.04	E
Mastercanteen to Rajmahal	2.54	C
Mastercanteen to Secratariate	3.5	C
Ravi Talkiz to court	2.9	C
Rupali to Vanivihar	2.38	B
Siripur to Gopabandhu square	2.45	B
Vanivihar to Rupali	2.46	B
Kalpana to Laxmisagar	4.87	E
Damana to Shailashree Vihar	2.98	C
Lingaraj Temple road	4.44	D

Above table shows that PLOS score of most of the links lies between 1.5 and 2. That indicates they fall under level of service category ‘B’ and ‘C’. Those links experience medium traffic and moderate facilities (sidewalk, buffer width etc.) for pedestrians. The segments like “Kalpana to court”, “KIIT to Big-bazar” and “Kalpana to Laxmisagar” have PLOS score in between 3.5 and5. This indicates level of service ‘D’. Those areas experience high volume of traffic and large number of pedestrians. Facilities provided for pedestrians are also not efficient. So those area operates at a poor level of service condition. The link “Laxmisagar to Kalpana” gives level of service more than 5, which means it operates at a condition of level of service ‘E’. This area experiences high rate of congestion during the peak hours of traffic. Traffic comprises of a large number of heavy vehicles, two-wheelers and IPTs. So the space per pedestrian decreases. Random movement of vehicles interrupts pedestrian movements frequently. All these difficulties give rise to a level of service condition ‘E’ for this segment.

PLOS Score for Rourkela city:

PLOS score for some of the links of Rourkela city using the newly developed model is given below.

Table 6.3: PLOS score and Level of service of Rourkela city using new model

Site Id	PLOS Score	Level of Service
Rourkela Club to ILS	1.56	B
Rourkela Club to Sector 3	1.6	B
Sail chow to Station Market	1.55	B
Sector 2 to Sector 4	1.14	A
Sector 20 onwards	1.23	A

Most of the links of Rourkela city operates at better level of service condition in comparison to Bhubaneswar city. Rourkela city experiences very less traffic than Bhubaneswar city. Facilities provided for pedestrian activities are efficient as very less number of pedestrian movements takes place in this city. Some of the links like "sector 2 to sector 4" and "Sector 20 to onwards" operate at level of service 'A'. These links are equipped with very good sidewalk, crosswalks. Movement of traffic is very less at these locations. Conditions are very favourable for pedestrian movement at these locations.

6.4 Summary

Data collected by videography, 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. Basing upon the score level of service of those links was determined.

Chapter 7

Summary, Conclusions and Future Scope

7.1 Summary

A detailed review on the existing methods on Pedestrian level of service is carried out in this study. The influencing variables and their contribution on the overall performance of the model is thoroughly investigated. It was found that the existing models though have strong application for the countries where originally developed but have significant limitation for applications in Indian cities. Also it has been observed that those models do not consider some additional factors which affect pedestrian movement under the influence of mixed traffic condition. The PLOS ranges defined through the PLOS scores deviate from the required PLOS scores of Indian cities. Considering the limitations of the existing models a new model is proposed in this study which considers all the variables that influence the pedestrian movement on urban stretches.

Several empirical model developing tools and techniques were tried to develop a suitable method for Indian context. Many of the previous model were developed using regression analysis. Therefore regression analysis was chosen for model development. Various types of regression were used such as linear regression, binomial regression, multiple regression, stepwise regression and hierarchical regression etc. Among all these types of regression multiple regression gives the best suited model for Indian context.

A number of modelling software are available in market for regression analysis. SPSS is one of them. This software is easy to use and user friendly. This software provides a number of tools which can be used for performing various kinds of regression analysis and gives results with higher degree of accuracy. So this software was used for this particular study.

7.2 Conclusion

PLOS methods have been developed in different ways since many years for different walking environment. It also has been substantially improving from time to time. This is an attempt to develop a model which will be fit for Indian scenario as there is no suitable model for Indian condition. IS code is also silent about this aspect so development of model is highly necessary for a country like India where traffic as well as pedestrians grow in a very rapid manner day by day.

The developed model gives six ranges of level of service such as ‘A’, ‘B’, ‘C’, ‘D’, ‘E’ and ‘F’. Level of service said to be ‘A’ and ‘B’ when PLOS score lies between ‘0 to 1.5’ and ‘1.5 to 2.5’ respectively. Level of service ‘A’ represents the best level of service. ‘B’ represents little less operating condition than ‘A’. These conditions are experienced when traffic is very less. Links are provided with good sidewalks. Vehicle-pedestrian interaction is very less. Adequate separation gap is provided between pedestrian and moving traffic. Pedestrians can travel very comfortably in this condition. Level of service ‘C’ and ‘D’ represent the PLOS score range ‘2.5 to 3.5’ and ‘3.5 to 4.5’ respectively. These level of services represent average conditions for pedestrian movement. Medium traffic is found in such type conditions. Most of the cases sidewalks are present on the road segment. Pedestrians face little difficulties to move but these conditions are still hostile for pedestrians. Level of services are called ‘E’ and ‘F’ when PLOS score ranges between ‘4.5 to 5.5’ and above 5.5 respectively. These are extremely poor conditions for pedestrian movement. There is no sidewalk present in these scenarios. Traffic is very high in these conditions. There is no protective separation between pedestrians and moving traffic. These types of level of services badly need development.

The developed model holds very good for medium size cities like Bhubaneswar and Rourkela. Somehow it fails for the traffic condition found in metro cities like Kolkata. Further development of model is required to assess the scenarios found in metro cities.

R^2 value in regression analysis signifies the accuracy of the model. It generally lies between 0 and 1. The more the R^2 value more accurate is the model. Three multiple regressions have been done in this study which are to find out Disturbance factor, Vehicle factor and PLOS score. R^2 values are 0.745, 0.77 and 0.89 for Disturbance factor, Vehicle factor and PLOS score respectively. All the values are above 0.5 which shows that the accuracy of the model is very high.

7.3 Applications

- **Operational Analysis**

Using this model level of service of the current facilities can be found for the future demand.

- **Periodization**

Pedestrian level of service evaluation of the infrastructures provided to the pedestrians helps in prioritizing the development activity with the limited resource available. Infrastructures can be developed to achieve a higher grade of level of service.

- **Traffic management**

Pedestrian shares a major percentage of local trips of urban mobility in India. To streamline pedestrian movement with the highly heterogeneous motorized vehicular movement realistic PLOS assessment helps in managing the traffic in the urban confinement.

- **Planning and Preliminary Engineering Analyses**

The parameters used for developing the model can be considered for development in order to increase the operational quality.

7.4 Limitations and Future Scope

These are some limitations in this study and opportunities lie in future studies to eliminate these limitation.

- This research was carried out by taking observations and data from Bhubaneswar and Rourkela city of Odisha state. Similar study can be done in other cities of India also as Indian cities are full of diversities.
- In this study only medium size cities are considered for modelling. The developed model fails when number of pedestrian and traffic is very large as found in metro cities. Further studies can be done on this aspect and separate model can be developed for metro cities also.
- For perception study only pedestrian perceptions are considered for model development. Other road users like drivers of motorized vehicle and users of non-motorized vehicles are not included in this study.

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